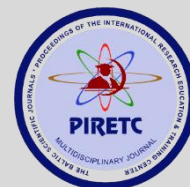


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ALIGNMENT BETWEEN POPULATION DEMAND AND HEALTHCARE SERVICE PROVISION IN GEORGIA, NEEDS AND SYSTEMIC CHALLENGES

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ABSTRACT

Introduction: Assessing population health needs and the accessibility of medical services is a central pillar in the development and evaluation of modern healthcare systems. This process encompasses more than mere logistical or operational concerns; it touches upon profound ethical and political questions surrounding equity, human rights, and the role of the state in safeguarding the well-being of its citizens. As health systems evolve within increasingly diverse and unequal societies, the imperative to harmonize service provision with actual public needs has moved to the forefront of policy discourse.

Aim of research: The aim of the study is to determine the availability, demand, and supply of medical services.

Methods of research: The study was conducted in June and July 2025 as a descriptive, quantitative, cross-sectional survey with the aim of assessing the match between the health needs of the population and the existing health care system in Georgia

Results: The study results clearly demonstrate that Georgia's population faces significant structural, financial, and systemic barriers to accessing healthcare services. Quantitative analyses demonstrate that, despite the universal health coverage system and declarative access to services, a large portion of the population lacks timely, comprehensive, or dignified access to healthcare. The respondents' responses do not merely reflect individual experiences but rather reveal the systemic nature of deep-rooted structural problems that point to historically entrenched social inequalities and a poorly managed healthcare infrastructure. The analysis of the responses of 200 respondents clearly demonstrates that barriers to accessing healthcare are not solely physical or financial in nature. Rather, they arise from information exclusion, lack of participation in decision-making processes, a lack of emotional security, and deficits in professional communication. In practice, the mere existence of formal access neither guarantees reliability nor trustworthy, needs-based, or dignified care.

Conclusion: The analysis of data from 200 respondents clearly shows that access problems are not solely due to geographical or economic barriers but reflect deep-rooted structural deficits—particularly in the areas of emotional security, information quality, and professional communication.

Keywords: Healthcare Service, Needs and Systemic Challenges.

Introduction

Assessing population health needs and the accessibility of medical services is a central pillar in the development and evaluation of modern healthcare systems. This process encompasses more than mere logistical or operational concerns; it touches upon profound ethical and political questions surrounding equity, human rights, and the role of the state in safeguarding the well-being of its citizens. As health systems evolve within increasingly diverse and unequal societies, the imperative to harmonize service provision with actual public needs has moved to the forefront of policy discourse. Global health governance bodies, such as the World Health Organization (WHO) and the European Commission, emphasize that access to care is not only a technical issue but also a moral commitment—one that requires deliberate structural adaptation, accountability, and citizen engagement (WHO, 2000; Council of Europe, 1997). In practical terms, healthcare systems today are expected to satisfy a dual mandate: they must operate efficiently under resource constraints, while simultaneously promoting justice by addressing differential needs within the population. This means moving beyond traditional coverage metrics and toward deeper inquiries into whether services are actually reaching the people who need them most, and whether they are doing so in ways that are timely, respectful, and effective. In this context, the concept of “unmet need” has become central. This term describes scenarios in which individuals express a desire or intention to use a health service but are unable to access it, often due to intersecting barriers such as poverty, geographic distance, discrimination, or systemic exclusion (Berwick, Nolan & Whittington, 2008; Bambra et al., 2020). The prevalence of unmet need is a critical indicator of the extent to which a healthcare system fulfills its social contract.

This challenge is particularly salient in transitional and decentralized systems, where governance fragmentation, limited institutional capacity, and uneven service distribution often amplify existing inequalities. In these contexts, healthcare becomes not only a site of biomedical intervention but also a reflection of broader social structures—including income distribution, educational attainment, gender dynamics, and minority inclusion. For this reason, researchers increasingly argue that health systems must be evaluated not solely through epidemiological outputs, but also through their capacity to respond to complexity and diversity within the population (Mirzoev & Kane, 2017; Arah et al., 2006).

Georgia, as a post-Soviet nation navigating multiple waves of economic and political reform, offers a particularly relevant case study for these dynamics. Despite notable improvements in national health indicators and expanded insurance coverage, significant disparities persist between urban and rural populations, majority and minority groups, and persons with and without disabilities. While services may formally exist on paper or in central locations, their practical accessibility remains highly uneven. Such discrepancies not only jeopardize individual well-being but also undermine public trust and the legitimacy of the health system as a whole.

The concept of healthcare quality has undergone significant transformation over the past decades, evolving from a narrow focus on clinical effectiveness and professional competence to a more nuanced, multidimensional framework. In early conceptualizations, such as those proposed by Avedis Donabedian in the 1980s, quality was defined by the interrelationship between structure, process, and outcome. This model laid the foundation for quality measurement and improvement strategies across diverse health systems (Donabedian, 1980). However, the growing recognition that technical proficiency alone does not guarantee positive patient experiences or equitable health outcomes has driven the expansion of quality discourse into domains such as responsiveness, person-centeredness, and cultural competence.

Modern definitions of healthcare quality now routinely incorporate parameters such as safety, equity, timeliness, and integration—components that reflect a system’s ability to deliver not only effective care, but also care that is humane, accessible, and socially responsive. The Institute of Medicine (1990) was instrumental in this evolution, asserting that quality care is that which increases the likelihood of desired health outcomes while remaining consistent with current professional knowledge and standards. The World Health Organization (2018) echoed this view, stating that high-quality health systems must be people-centered and built on a foundation of trust, communication, and dignity.

Quality is no longer seen as an endpoint but as a process of continuous improvement and ethical reflection. In this view, healthcare systems must engage with their communities, integrate feedback mechanisms, and adapt their practices to reflect evolving demographic, cultural, and epidemiological realities. The OECD’s Health Care Quality Indicators Project (Arah et al., 2006) offers a global framework for benchmarking performance in areas such as patient safety, effectiveness, and equity—elements that have been adopted in multiple national contexts as guiding principles for reform.

At the policy level, the European Commission and the Council of Europe have emphasized that quality must be viewed through both institutional and societal lenses. This includes embedding participatory mechanisms, such as patient councils or community boards, to ensure that care delivery aligns with the values and expectations of the population it serves (European Council, 2006; Council of Europe, 1997). The goal is not merely to expand service provision but to foster a health system that is accountable, adaptive, and inclusive—capable of addressing complex, intersectional determinants of health.

In Georgia, however, these comprehensive understandings of quality remain only partially realized. Although national strategies reference international quality standards and indicators, implementation often lags due to systemic fragmentation, limited professional training, and inadequate data infrastructure. Patient experiences are rarely integrated into performance evaluations, and service design is seldom informed by in-depth community consultations. As a result, reforms risk reproducing the very inefficiencies and exclusions they aim to correct.

Reframing quality in the Georgian context thus requires a shift in institutional priorities: from bureaucratic compliance to lived experience, from centralized metrics to local relevance, and from vertical policy imposition to participatory governance. The capacity of a health system to respond flexibly and respectfully to different population groups—whether by offering services in minority languages, ensuring gender-sensitive care, or creating safe environments for people with disabilities—must be seen as a central indicator of quality. Only through such a people-centered and ethically grounded approach can healthcare systems fulfill their promise not just of treatment, but of care.

While healthcare quality frameworks emphasize safety, effectiveness, and person-centeredness, these principles remain aspirational when confronted with persistent structural and financial constraints. In Georgia, the healthcare system operates in an environment marked by chronic underfunding, disproportionate reliance on out-of-pocket payments, and geographic maldistribution of services. These issues not only inhibit access to care but also challenge the ethical and practical viability of universal health coverage as a national objective.

One of the most critical challenges is the continued prevalence of direct household expenditures, which constitute nearly 50% of total health spending—a figure among the highest in the WHO European Region (OECD, 2023). Such a financing structure is inherently regressive,

disproportionately affecting individuals and families with limited economic means. It also deters timely utilization of preventive and primary care services, leading to delayed diagnoses, suboptimal chronic disease management, and avoidable hospitalizations. Financial hardship caused by medical costs is a leading factor in treatment abandonment and contributes significantly to cycles of poverty and ill health, particularly in rural and marginalized communities.

State-sponsored health programs, including the Universal Health Care program introduced in 2013, have aimed to broaden coverage and reduce catastrophic health spending. However, these efforts are constrained by limited benefit packages, co-payment requirements, and inconsistencies in service availability across regions. For instance, while basic services may be formally included in the public insurance scheme, patients are often required to pay for diagnostic tests, specialist consultations, or medications—particularly those for non-communicable diseases. The burden is exacerbated for vulnerable groups such as elderly individuals, people with disabilities, and ethnic minorities, for whom cost-related non-adherence remains alarmingly common (Curatio International Foundation, 2021; Galt & Taggart, 2022).

From a structural perspective, inequalities in the distribution of healthcare infrastructure and personnel further entrench disparities. Rural and high-mountainous areas frequently lack hospitals, specialized clinics, and adequately trained staff, resulting in long travel times and logistical challenges for even basic care. The absence of transportation services, poor road conditions, and harsh weather often make it practically impossible for residents of remote areas to access care, even when it is nominally “available.” In contrast, urban centers are relatively well-resourced, producing a bifurcated health system in which geography becomes a major determinant of access.

This spatial inequity is compounded by uneven workforce distribution and limited incentives for health professionals to serve in underserved regions. Despite the introduction of targeted programs and scholarships aimed at rural deployment, many physicians remain concentrated in Tbilisi and other major cities. The lack of career advancement opportunities, housing support, and continuing education outside urban hubs further disincentivizes relocation. As a result, rural residents are often left with low-skilled providers or rotating staff, undermining continuity of care and trust in the system.

Comparative analysis shows that countries with more equitable and needs-based planning—such as those employing capitation-based funding or regional budgeting tied to population health metrics—are better able to mitigate these types of disparities (Smith, J. 2001;). They achieve this not simply by redistributing funds, but by embedding equity and local responsiveness into every level of governance. For Georgia, a transition toward such models would require a reconfiguration of both financing and institutional priorities, including greater investment in rural infrastructure, workforce development, and cross-sectoral partnerships.

Moreover, structural barriers intersect with deeper issues of social inclusion and cultural legitimacy. For many minority groups and persons with disabilities, health services may be technically accessible but practically unusable due to architectural, linguistic, or communicative mismatches. These gaps reveal a critical tension in policy implementation: the assumption that equality of access equates to equality of outcome. Without a deliberate and context-sensitive approach to service design—one that acknowledges historical disadvantage, institutional mistrust, and varying cultural norms—structural reform risks replicating existing patterns of exclusion.

In short, overcoming financial and structural barriers in Georgian healthcare demands more than technocratic fixes. It calls for a reorientation of the health system toward justice and solidarity,

recognizing that the right to health is not fulfilled by coverage alone, but by meaningful, reliable, and equitable access for all.

A responsive health system is not defined solely by its ability to deliver clinical interventions but by its capacity to recognize, interpret, and respond to the expectations, needs, and lived experiences of diverse populations. Responsiveness, as conceptualized by the World Health Organization and health systems researchers, encompasses dimensions such as dignity, autonomy, confidentiality, prompt attention, and quality communication (WHO, 2000; Mirzoev & Kane, 2017). While these elements are often overshadowed by performance indicators such as coverage rates or budget allocations, they are vital for building trust and ensuring equitable engagement with health services—particularly among marginalized communities.

In the Georgian context, the gap between formal entitlements and actual experience is wide. Although national strategies increasingly include rights-based language and references to person-centered care, mechanisms for gathering and incorporating public input remain underdeveloped. There are no institutionalized platforms for continuous community feedback, and policy processes are largely expert-driven, limiting the visibility of grassroots concerns. As a result, healthcare planning tends to be top-down, reactive, and generalized, failing to reflect regional disparities, social sensitivities, or demographic trends.

International experience suggests that participatory governance can significantly enhance health system responsiveness. Brazil's Unified Health System (SUS), for instance, has institutionalized participation through municipal and state health councils that include representatives from civil society, health professionals, and local government. These councils have decision-making authority over budgetary and programmatic issues, thus integrating community voices into the very fabric of policy-making. In a similar vein, Scandinavian countries have invested in digital platforms that enable patients to rate their experiences, provide structured feedback, and influence service improvement processes in real time. Such models demonstrate that community input is not only ethically desirable but also operationally feasible and beneficial for system performance (Busse et al., 2019; WHO, 2021).

Georgia currently lacks these participatory structures. Local self-governments are often excluded from health decision-making, and community engagement is limited to ad hoc consultations or donor-driven initiatives. This institutional vacuum contributes to a disconnect between services and the populations they are meant to serve. For example, reproductive health services might formally exist in rural municipalities but remain unused due to the absence of female providers, low health literacy, or prevailing cultural norms that discourage open discussion of reproductive issues. Without feedback mechanisms to uncover such context-specific barriers, national programs risk investing in services that are technically adequate but socially irrelevant.

Addressing this requires more than the expansion of health infrastructure—it requires cultural, political, and administrative transformation. Community health committees, participatory budgeting for health, and structured community scorecards can provide sustainable mechanisms for dialogue between providers, policymakers, and citizens. Furthermore, the inclusion of patient representatives and health mediators—particularly from minority and vulnerable populations—can bridge the gap between system design and lived realities. These actors not only facilitate communication but also serve as trust brokers, helping to mitigate institutional skepticism that often prevents marginalized groups from seeking care.

Importantly, participatory governance must be supported by transparent data systems that disaggregate outcomes by gender, age, location, disability status, and ethnicity. In Georgia, health

indicators are rarely reported at such levels of granularity, limiting the visibility of systemic disparities and undermining targeted interventions. The development of inclusive health information systems that prioritize patient-reported outcomes, service satisfaction, and access barriers is thus a critical prerequisite for responsive governance.

Ultimately, responsiveness and participation are not auxiliary functions of health systems—they are core features that determine whether services meet their intended purpose. In societies with historical legacies of centralized governance and social fragmentation, such as Georgia, embedding these principles into health system architecture is not merely an innovation—it is a democratic necessity.

Equity in healthcare cannot be achieved without addressing the unique barriers faced by people with disabilities and ethnic minorities. These groups are not only statistically more likely to experience unmet health needs, but also to face compounded forms of exclusion across physical, communicative, cultural, and systemic dimensions. The provision of formal coverage or legal entitlements is insufficient when structural inaccessibility, stigmatization, and lack of institutional sensitivity persist. Thus, inclusion must be operationalized at every level—from clinical design to workforce training, from data collection to policy evaluation.

In Georgia, the experience of persons with disabilities underscores a pervasive gap between rights and reality. Despite the ratification of the UN Convention on the Rights of Persons with Disabilities and the implementation of state-sponsored insurance coverage, actual service utilization remains low. Key barriers include the absence of wheelchair-accessible infrastructure in clinics, lack of sign language interpreters or visual aids for sensory impairments, and a general deficit in disability-specific training among health workers. Many health facilities operate without protocols for communication with non-verbal patients or those with cognitive disabilities, leading to misdiagnosis, mistreatment, or outright neglect.

Furthermore, individuals with disabilities often report negative interpersonal experiences, ranging from disregard to explicit discrimination, which undermines trust and deters engagement with the healthcare system. Without a deliberate effort to build disability competence into medical curricula, provider accreditation, and service protocols, such experiences are likely to persist. Internationally, countries that have made progress in this area—such as Australia, Germany, and Sweden—have done so by embedding inclusivity into accreditation standards, incentivizing accessibility upgrades, and funding community-based outreach and navigation programs (WHO, 2021; Galt & Taggart, 2022).

Parallel challenges exist for ethnic minorities in Georgia, particularly among Azerbaijani and Armenian-speaking communities in Kvemo Kartli and Samtskhe-Javakheti. Language remains one of the most salient barriers, affecting every stage of the care pathway—from understanding symptoms and describing health concerns, to interpreting treatment plans and navigating referral systems. In the absence of professional interpretation services or bilingual providers, patients are forced to rely on informal translation by family members, which can compromise both confidentiality and accuracy.

Cultural dissonance also plays a significant role. For example, in some communities, mental health issues may be heavily stigmatized or interpreted through religious or traditional frameworks, leading to underdiagnosis or rejection of biomedical treatments. In others, gender norms may restrict access to female providers, or discourage unaccompanied visits to clinics. These social determinants are rarely accounted for in centralized planning processes, which operate under generalized assumptions of population homogeneity.

Moreover, public health communication and outreach materials are often produced exclusively in Georgian, despite official recognition of minority languages. This exclusion reinforces feelings of marginalization and contributes to low uptake of preventive services such as vaccinations, cancer screenings, or maternal health programs. Without tailored engagement strategies and language-accessible materials, even the well-designed interventions can fail to reach their intended audience.

Effective solutions must be context-sensitive and community-driven. Recruiting health workers from within minority communities, training cultural mediators, and establishing local advisory boards can enhance the legitimacy and effectiveness of health initiatives. Moreover, disaggregated data collection and monitoring are essential to reveal disparities that remain hidden in aggregate statistics. When ethnicity, language, or disability status are omitted from health datasets, the very groups most in need of targeted support become invisible to the system.

In sum, inclusion is not a static outcome but an ongoing process that requires intentional design, institutional commitment, and participatory oversight. In the Georgian setting, advancing this agenda means moving beyond the rhetoric of equality toward measurable actions that create accessible, culturally competent, and trust-based care for all individuals—regardless of their physical abilities, language, or cultural background.

One of the most critical determinants of healthcare access in Georgia remains the high proportion of out-of-pocket expenditures, which constitutes over 50% of total health spending—far exceeding the EU average. This financial burden disproportionately affects low-income, rural, and marginalized populations, who often forgo necessary care due to cost concerns. The introduction of the Universal Health Care (UHC) program in 2013 marked a significant policy milestone; however, it has not adequately mitigated catastrophic health spending or out-of-pocket medication costs, which remain largely uncovered. According to the OECD (2023), this creates a regressive system wherein the poorest households allocate a larger share of their income to healthcare than the wealthy, exacerbating existing inequalities.

The lack of essential drug coverage represents a particularly pressing issue. Patients with chronic illnesses—such as diabetes, cardiovascular disease, or epilepsy—face continuous financial strain due to high medication prices and limited generic availability. Strategic interventions, such as the inclusion of essential medications in publicly funded formularies, price regulation, and procurement transparency, have shown success in comparable settings like Estonia, Croatia, and Thailand. Implementing such mechanisms in Georgia would not only improve medication adherence but also reduce long-term complications and associated hospitalizations.

Additionally, the current model of resource allocation lacks responsiveness to local epidemiological profiles and demographic structures. National-level funding often fails to reflect regional needs, leading to under-resourced clinics in high-need areas and duplication of services in urban centers. The absence of standardized municipal health needs assessments further impairs evidence-based distribution of financial and human resources. For instance, mountainous regions with aging populations and limited transport infrastructure may require mobile clinics, home-care services, and greater investment in local outpatient centers. Yet such contextual adaptation remains sporadic and pilot-based rather than systematized.

An effective strategy for addressing these imbalances involves adopting geospatial mapping and community-based participatory planning tools, which allow governments to visualize service gaps, project future demand, and allocate budgets accordingly. Countries like Finland and Portugal have pioneered such tools, integrating geographic information systems (GIS) with health

data to support decentralized decision-making. In Georgia, piloting such approaches in diverse municipalities could lay the groundwork for broader scale-up and institutionalization.

Financial reform must also address provider incentives. Currently, most providers in Georgia operate on fee-for-service models, which incentivize volume over quality and contribute to overutilization of diagnostics and procedural interventions. Transitioning toward capitation or bundled payment models, where providers are reimbursed based on population health outcomes or comprehensive service packages, would reorient the system toward preventive, holistic, and patient-centered care. Evidence from countries like the Netherlands and the UK suggests that such models reduce administrative waste and improve chronic disease management.

Moreover, health workforce distribution remains unequal. Urban centers attract the majority of specialists, while rural and underserved areas suffer from acute shortages of physicians, nurses, and allied health professionals. To counter this, Georgia could implement incentive-based placement programs, rural service scholarships, and career development pathways that attract and retain professionals in peripheral areas. Integration of community health workers (CHWs), who often share linguistic and cultural backgrounds with target populations, offers a cost-effective strategy to bridge access gaps and deliver preventive interventions at the household level.

In this context, investment in digital infrastructure and telemedicine is no longer optional but essential. Telehealth services can drastically reduce the need for travel, expand specialist access, and improve continuity of care—especially for persons with disabilities, the elderly, and rural residents. The COVID-19 pandemic has underscored the transformative potential of digital health, but Georgia’s regulatory framework and infrastructure readiness remain limited. Scaling up digital platforms must be paired with training, privacy safeguards, and interoperability standards to ensure that benefits are equitably realized across regions and social groups.

Finally, any reform effort must be grounded in robust monitoring and evaluation systems. The current reliance on aggregate administrative data obscures variations in access and quality. Establishing patient satisfaction surveys, real-time feedback mechanisms, and disaggregated outcome indicators—broken down by gender, region, income, ethnicity, and disability—can illuminate hidden disparities and guide policy refinement. The development of a national health observatory or independent monitoring body could ensure transparency and accountability, while strengthening the evidence base for long-term planning.

Achieving a truly equitable and responsive healthcare system requires more than administrative efficiency or financial realignment—it demands a fundamental shift in how health and well-being are conceptualized within society. In this regard, the **Capability Approach**, developed by Amartya Sen (1999) and expanded by Jennifer Ruger (2006), offers a robust ethical framework for reimagining health systems. Rather than focusing narrowly on service provision or health outcomes, this approach emphasizes individuals’ substantive freedom to lead lives they value. Health, in this view, is not merely the absence of disease or the presence of infrastructure, but the capacity to function, to participate, and to exercise agency.

For Georgia, adopting a capability-oriented perspective means recognizing health as a social right and designing policies that actively dismantle structural barriers. This includes addressing not only material determinants such as income and infrastructure, but also sociocultural, informational, and psychological constraints that limit individuals’ access and autonomy. Empowering communities—particularly those historically excluded from policy processes—is thus not an optional reform feature but a moral imperative.

In this context, **participatory governance** emerges as a critical mechanism for legitimacy, accountability, and relevance. Formalizing avenues for citizen engagement in health planning—through local health councils, patient advisory boards, or public consultations—can ensure that services reflect lived realities. Evidence from Brazil, Thailand, and parts of Eastern Europe demonstrates that participation enhances policy responsiveness, fosters institutional trust, and improves health outcomes. In Georgia, piloting such mechanisms at the municipal level could bridge the gap between national priorities and local needs.

Equally important is the integration of **inclusive data systems** that disaggregate indicators by ethnicity, gender, disability, age, and geography. Without such data, policymakers remain blind to health inequities and unable to evaluate reform impact. Investment in data literacy, interoperable platforms, and ethical safeguards is necessary to ensure both the protection and utility of health information. Moreover, embedding **patient-reported outcomes and experiences** into evaluation frameworks can recalibrate quality measurement from an institutional to a human scale.

The road to transformation is neither linear nor immediate. It requires **political commitment, cross-sector collaboration, and institutional resilience**. Ministries of health must coordinate with education, finance, transportation, and social protection to address health determinants comprehensively. Academic institutions and civil society organizations can provide independent evaluation, capacity building, and policy innovation. Meanwhile, donor support should shift from vertical programs to **system-strengthening investments** that enhance governance, accountability, and adaptive learning.

At its core, this transformation entails a redefinition of the social contract around health. It asks: Who is responsible for health? Who has a voice in defining its priorities? Who bears the risks and who reaps the benefits? For Georgia, moving toward a system where every person—regardless of income, geography, or identity—can access care that is appropriate, affordable, and dignified is not simply a policy goal. It is a democratic obligation.

Thus, the alignment between healthcare demand and provision cannot be viewed through the narrow lens of efficiency or coverage alone. It must be understood as a **multi-layered challenge** that touches on justice, solidarity, and human development. As global health systems grapple with aging populations, rising costs, and emerging threats, Georgia has the opportunity to build a system that is not only technically competent but also morally sound-anchored in the lived realities of its people and guided by the vision of health as a shared, actionable, and universal right.

Methods

The study was conducted in June and July 2025 as a descriptive, quantitative, cross-sectional survey with the aim of assessing the match between the health needs of the population and the existing health care system in Georgia. The research design was based on a population-based survey that examined both experiences with access to health services and citizens' assessments and needs. The sampling strategy was based on random sampling, taking into account geographical and demographic diversity. A total of 200 respondents participated in the study, representing various regions of Georgia – including cities, district centers, and rural areas. Citizens over the age of 18 of different gender and social status were included in the study (see **Table 1**)

Table 1. Demographic Characteristics of Participants

Gender Age City	Male							Female						
	18-24	25-34	35-44	45-54	55-64	>65	Total	18-24	25-34	35-44	45-54	55-64	>65	Total
Tbilisi	3.5%	2.0%	0.5%	0.5%	0.0%	0.0%	6.5%	8.0%	0.5%	3.0%	0.5%	0.0%	1.5%	13.5%
Kutaisi	3.5%	0.5%	0.0%	0.0%	0.0%	0.0%	4.0%	7.0%	1.5%	1.0%	1.0%	0.5%	0.0%	11.0%
Batumi	1.0%	0.5%	1.0%	0.0%	0.5%	0.5%	3.5%	0.0%	3.5%	2.0%	0.5%	1.0%	0.0%	7.0%
Martvili	0.0%	1.0%	0.0%	0.0%	0.0%	1.0%	2.0%	0.5%	1.5%	1.5%	0.5%	1.0%	0.0%	5.0%
Zugdidi	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	1.0%	1.0%	2.0%	0.5%	1.0%	0.5%	6.0%
Telavi	1.0%	0.5%	0.0%	0.5%	0.0%	0.0%	2.0%	1.5%	0.5%	0.5%	0.5%	0.5%	0.0%	4.5%
Gori	0.5%	0.5%	0.0%	0.0%	0.5%	0.0%	1.5%	1.5%	1.5%	0.5%	0.5%	0.0%	0.5%	4.5%
Kaspi	0.5%	0.0%	0.0%	1.0%	0.0%	0.0%	1.5%	1.0%	1.0%	1.0%	0.5%	0.0%	0.5%	4.0%
Marneuli	1.0%	0.0%	1.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.5%	2.5%	0.0%	0.0%	0.5%	3.5%
Khashuri	1.0%	0.0%	0.0%	0.5%	0.5%	0.0%	2.0%	1.0%	0.5%	1.0%	0.5%	0.0%	0.5%	3.5%
Dusheti	1.0%	0.0%	0.5%	0.0%	1.0%	0.5%	3.0%	0.5%	0.0%	0.5%	0.5%	0.0%	0.5%	2.0%
Chiatura	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.5%	1.0%	0.0%	0.0%	0.5%	0.5%	2.5%
Gardabani	0.5%	0.0%	0.0%	0.5%	0.0%	0.0%	1.0%	0.5%	0.5%	0.0%	0.5%	0.0%	1.0%	2.5%
Total	15.0%	5.0%	3.0%	3.0%	2.5%	2.0%	30.5%	23.0%	13.5%	15.5%	6.0%	4.5%	6.0%	69.5%

Data were collected using a structured questionnaire containing both closed and open questions. The questionnaire covered the following topics: access to medical services, financial and geographical barriers, information and emotional experiences, subjective assessment of health status, population needs, and recommendations for system improvement. The interviews were conducted in person or by telephone. Data analysis was conducted using descriptive statistical methods. Quantitative responses were analyzed using averages and percentage distributions, while open-ended responses were subjected to thematic analysis.

The study was conducted in full compliance with ethical standards. All respondents were informed in advance of the purpose and content of the survey and provided written consent. The data were anonymized and processed solely for research purposes.

Results & Discussion

The study results clearly demonstrate that Georgia's population faces significant structural, financial, and systemic barriers to accessing healthcare services. Quantitative analyses demonstrate that, despite the universal health coverage system and declarative access to services, a large portion of the population lacks timely, comprehensive, or dignified access to healthcare. The respondents' responses do not merely reflect individual experiences but rather reveal the systemic nature of deep-rooted structural problems that point to historically entrenched social inequalities and a poorly managed healthcare infrastructure. The analysis of the responses of 200 respondents clearly demonstrates that barriers to accessing healthcare are not solely physical or financial in nature. Rather, they arise from information exclusion, lack of participation in decision-making processes, a lack of emotional security, and deficits in professional communication. In practice, the mere existence of formal access neither guarantees reliability nor trustworthy, needs-based, or dignified care. Another key pattern revealed by the cross-sectional analysis of the data concerns the cumulative nature of barriers: Respondents who reported a specific problem—such as limited mobility—often cited financial, informational, and quality-related barriers at the same time. This indicates that people with low incomes, with special needs,

or living in remote regions are not only disadvantaged in specific areas but are systematically excluded at multiple levels simultaneously. These findings form the analytical foundation of the study, on the basis of which the following sections systematically identify those areas where there is a serious mismatch between available services and the actual needs of the population.

One of the study's key findings is that access to healthcare services is not limited solely by formal deficiencies in the system, but to a significant extent by a complex interplay of real physical and financial barriers. A significant portion of respondents reported multiple problems that prevented them from accessing necessary medical services in a timely, unrestricted, and dignified manner. These barriers did not occur in isolation—on the contrary: in most cases, they operated simultaneously at different levels and reinforced each other. Barriers related to financial burdens were most frequently cited: 62.5% of participants cited the high cost of medical services, and a nearly identical number cited the price of medications. These findings illustrate that even under the conditions of state-proclaimed "universal insurance," a large portion of medical care continues to be the individual financial responsibility of citizens—a circumstance that significantly increases the risk of social inequality. In addition, almost two-thirds of respondents criticized the poor quality of services (37.5%) and long waiting times (41.5%), which not only reflects the volume of services offered, but also their organizational weaknesses and functional ambiguities. Also noteworthy is the lack of information about available services (35.5%), which makes it difficult to both find support and access it in a timely manner. Geographical and physical accessibility also remains a problematic aspect: 22% of respondents stated that certain services are not available in their region, while approximately one in seven participants cited transportation problems (14%) or excessive distance to the nearest facility (5.5%) as barriers. In addition, isolated cases of discriminatory treatment (5.5%) and language barriers (4.0%) were documented. The study's findings clearly demonstrate that limited access to healthcare is not solely due to material or geographical factors – rather, information deficits and issues of emotional security play a central role. A segment of the population feels systematically excluded – not only spatially, but also in terms of communication, language, and psychosocial issues. 41.5% of respondents cited long waiting times as one of the most important barriers to access. However, this figure does not only refer to technical delays – rather, waiting times are often experienced as an expression of systemic indifference and a lack of attention to patients. Such experiences create emotional tension, leading to a loss of trust in medical facilities and a tendency to avoid future doctor visits. It is also striking that information-related barriers manifest themselves not only in the lack of information about available services, but also in the quality of communication. 35.5% of respondents reported being inadequately informed about services – due to both a lack of information channels and a lack of clarity from medical professionals. In many cases, patients do not receive a clear explanation of treatment plans or risks, which significantly limits their autonomy in medical decision-making.

(see **Table 2**)

Table 2. Structural and Financial Barriers to Healthcare Access in Georgia

This table summarizes the most frequently reported barriers that hinder timely, uninterrupted, and dignified access to healthcare services among 200 survey respondents. The figures reflect the percentage of participants who selected each barrier in a multiple-response question.

Type of Barrier	Frequency (n)	Percentage (%)
High cost of medical services	125	62.5
High cost of medications	125	62.5
Long waiting times	83	41.5
Inadequate quality of services	75	37.5
Lack of information about available services	71	35.5
Unavailability of healthcare services in the respondent's region	44	22.0
Transportation difficulties	28	14.0
Distance from healthcare facilities	11	5.5
Discriminatory treatment	11	5.5
Language barrier	8	4.0

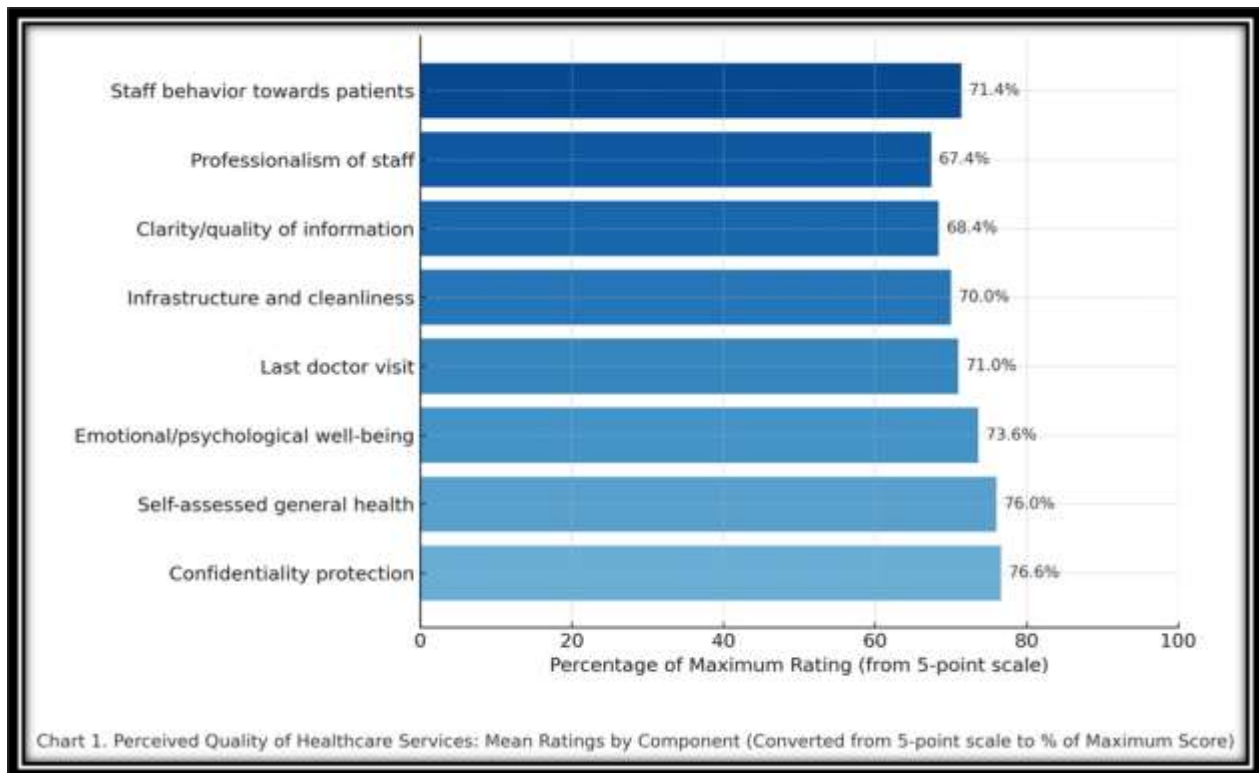
A particularly serious aspect of systemic exclusion is the experience of discriminatory behavior, reported by 5.5% of respondents. While this number seems comparatively small, such experiences lead to profound psychological barriers that undermine trust in the long term and negatively impact future service utilization. The language barrier (4%) has a similar effect, particularly for members of ethnic minorities, who often have to communicate with medical staff without interpretation – jeopardizing the principles of confidentiality and informed consent. These findings illustrate at a systemic level that the quality of a healthcare system cannot be defined solely by infrastructure or professional competence. Rather, its human-centered functioning depends on the extent to which it ensures emotional safety, information transparency, and dignified treatment of its users (see **Table 3**).

Table 3. Informational and Emotional Barriers to Healthcare Access Reported by Respondents

This table presents the prevalence of informational and emotional barriers encountered by respondents when accessing healthcare services. While structural and financial constraints were commonly cited, these psychosocial barriers reveal deeper systemic challenges related to communication, trust, and inclusion. Multiple responses were allowed per participant, and the percentages reflect the proportion of all 200 respondents who reported each barrier.

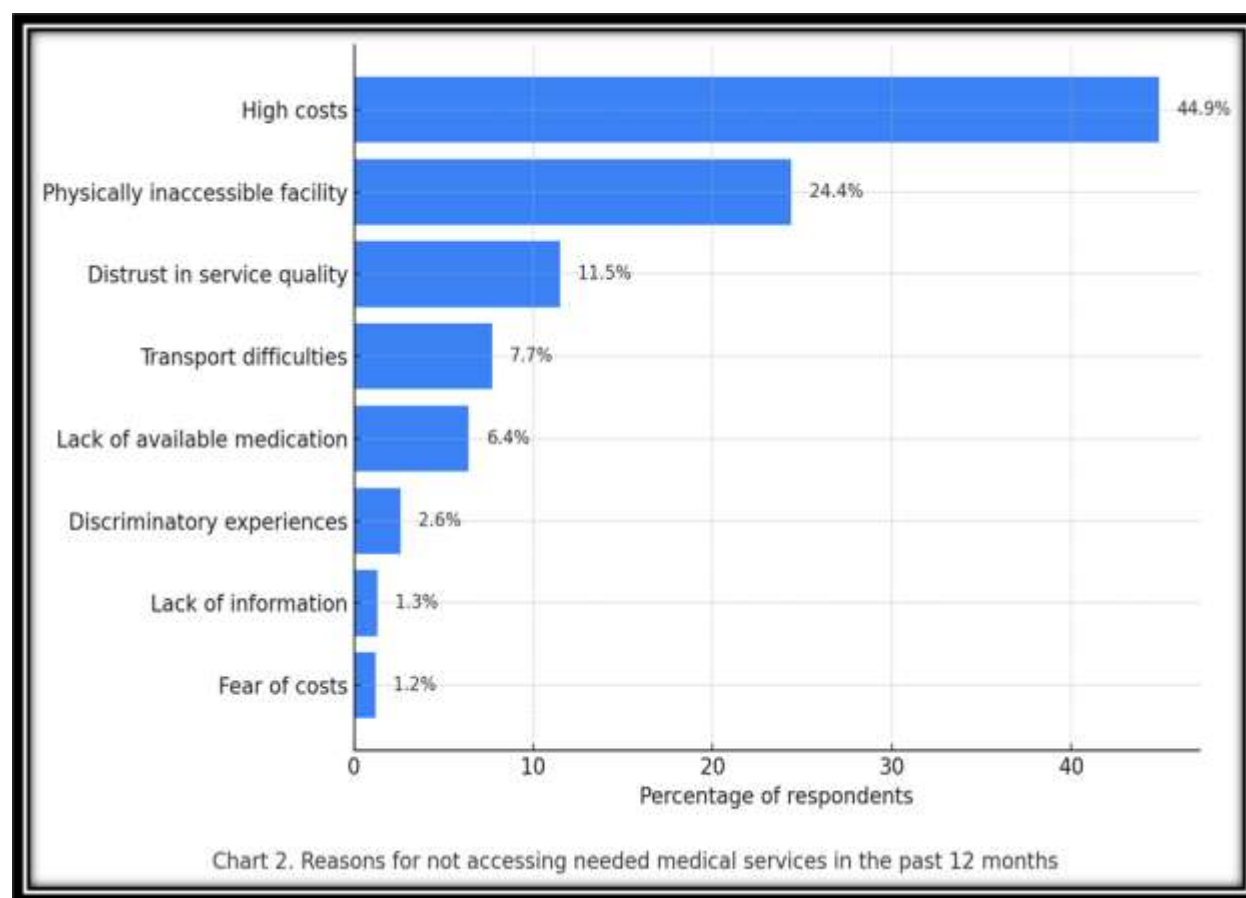
Type of Barrier	Frequency (n)	Percentage (%)
Long waiting times	83	41.5
Lack of information about services	71	35.5
Discriminatory treatment	11	5.5
Language barrier	8	4.0
Lack of time / Time constraints	2	1.0

The participants' assessment of the Georgian healthcare system reveals that the perceived quality of services is by no means uniform and varies significantly depending on the component. The greatest trust was placed in the protection of confidentiality, while the lowest ratings related to the professional competence of medical staff. On a 5-point scale, the majority of respondents gave high ratings for maintaining confidentiality (average: 3.83) and for the subjective assessment of their own general health (3.80). Emotional and psychological well-being were also rated relatively positively (3.68), which may be related less to satisfaction with healthcare services than to a general stability of self-perception. Regarding specific satisfaction with the services themselves, the average rating for the last doctor's visit was 3.55 points. However, a more differentiated analysis of the individual aspects of the service process reveals significant discrepancies: Infrastructure and cleanliness received 3.50 points, the clarity and quality of information provided 3.42 points, and the professionalism of the staff only 3.37 points. These results indicate that respondents consider not only the final outcome of the treatment, but also the course of the contact—such as the type of communication, the clarity of information, or the level of empathy—to be crucial to their satisfaction. It is particularly noteworthy that the lowest average rating (3.37) relates to the professional competence of the medical staff. This could indicate both unequal standards in professional qualifications and systemic deficits in patient care. The latter is also confirmed by the fact that the staff's behavior towards patients received a slightly higher average rating (3.57)—an indication that citizens clearly differentiate between technical expertise and human care (see **Chart 1**).



One of the most striking and critical findings of the study is that a significant proportion of respondents – approximately 23% – were unable to access the medical services necessary for their health over the past twelve months. This circumstance demonstrates that even a formally accessible system is unable to respond in practice to needs, leading to a chain reaction of medical, social, and economic consequences. The subgroup analysis within this cohort clearly shows that the barriers that arise rarely act in isolation, but rather occur in the form of cascading, mutually reinforcing mechanisms. Financial inaccessibility is often accompanied by infrastructural and quality-related problems, accompanied by negative emotional experiences or a general loss of trust in the system. The consequence: citizens forgo medical care – which in turn leads to a deterioration in health, an increased risk of complications, and a further deepening of economic inequalities. The baseline analysis shows that the most frequently cited reason for non-utilization of health services was high costs – 44.9% of those affected cited this as the main reason. This finding is particularly significant given that in Georgia, nearly half of total health expenditures are borne directly by private households – one of the highest rates in the WHO European Region. Such a structure is not only inefficient but also systematically unfair, as it shifts the financial burden onto the most socially vulnerable groups. The second most frequently cited reason was the physical inaccessibility of services: 24.4% reported that the respective facility was too far away, unsuitable, or architecturally inaccessible. This underscores the fact that health care in Georgia remains overly urbanized, while rural and mountainous regions remain systematically underserved. Mobile health teams, subsidized transportation, and accessible infrastructure are still inadequately implemented in the system. The third most common reason is distrust of the quality of services: 11.5% of those affected forwent medical care entirely because they considered the available services inadequate, unqualified, or potentially dangerous. This finding is particularly

alarming as it indicates a crisis of trust among citizens in the system – with negative consequences for the use of preventive, chronic, and acute medical services. Other reasons included difficulties related to transportation (7.7%), which again highlights regional infrastructure disparities, and the lack of availability of medication (6.4%), which particularly affects people with chronic illnesses who rely on regular long-term treatment. A smaller proportion of responses cited reasons such as discriminatory experiences, lack of information, or deliberate forgoing care due to fear of costs – categories that, despite their low frequency, can be interpreted as indicators of structural exclusion. Their quantitative rarity in no way diminishes their importance, as they demonstrate that parts of the population feel unsafe or unwelcome in the system and consciously avoid contact (see **Chart 2**).



The final section of the study focuses on those services whose introduction or strengthening was considered particularly important by respondents. A multiple-choice question, supplemented by an open-ended comment field, provided deeper insights into society's perception of health policy priorities and ideas about possible solutions to existing challenges. The most frequently cited desire was to strengthen primary care practices – 62% of respondents considered this particularly relevant. This result clearly demonstrates that the population not only recognizes primary care as a cornerstone, but also considers its functional design a mandatory prerequisite for a functioning health care system. This expectation is in line with international trends that view a strong primary care model as key to effectiveness and equity in health care. The second most frequently cited

demand was for systematic access to free or heavily discounted medications (56.5%). This issue has already been identified in other parts of the study as one of the most serious financial obstacles. Citizens clearly articulate the need for a revision of the drug reimbursement system and for targeted subsidy mechanisms for people with chronic diseases. Other frequently cited priorities included diagnostic and laboratory services (40.5%), specialized medical care (39.5%), and chronic disease management programs (35%). These findings indicate that the population is not only concerned with facilitating initial contact, but also with ensuring a complete, continuous care chain – from diagnosis through treatment to rehabilitation. Also noteworthy is the desire for an expansion of psychological and psychiatric services (30.5%) and pediatric services (27.5%). This indicates a growing societal need for holistic healthcare that considers psychosocial aspects and intergenerational well-being. The demand for an expansion of rehabilitation measures, physical therapy, and gynecological services was also mentioned several times – reflecting specific needs, for example, of women and people with disabilities. The analysis of the open-ended responses further deepened the picture. Citizens repeatedly emphasized, among other things, the lack of a human-centered approach in the healthcare system, their experiences with low professional standards and unclear communication, the need to make services accessible at the local level, and the lack of motivation among medical professionals, especially in the regions. This feedback highlights that, from the public's perspective, healthcare goes far beyond treatment – it encompasses continuity, trust, culturally sensitive approaches, and genuine participation in decision-making processes (see **Table 4**).

Table 4. Key Priority Areas Identified by Respondents for Improving Healthcare Services in Georgia

Grouped analysis of qualitative feedback highlighting population demands regarding accessibility, quality, and equity in healthcare provision (N = 200)

Thematic Category	Representative Focus Areas (as cited by respondents)	Percentage (%)
Medication Access	High prices for essential medicines; lack of subsidy programs; demand for free or discounted medications for all, especially for vulnerable groups (students, elderly, chronically ill)	56,5
Healthcare Workforce	Need for better-qualified and more empathetic professionals; lack of specialists in rural areas; calls for regular retraining and ethical education of medical personnel	21
Service Accessibility	Geographic and financial inaccessibility; limited availability of services in villages; lack of nearby clinics and diagnostic centers; demand for local infrastructure development	23
Diagnostics and Technology	Limited access to laboratory and instrumental examinations; outdated equipment; need for modernization and expansion of diagnostic capabilities, especially in regions	19.5
Communication and Ethics	Calls for improved doctor-patient communication; concerns about confidentiality breaches and poor treatment culture; requests for better information delivery and respect for patients' dignity	35
Mental Health Services	Requests to expand psychological and psychiatric support; under-recognition of mental health needs; desire for holistic care integrating psychosocial support	25,5
Preventive and Primary Care	Emphasis on strengthening family medicine; preventive screenings; calls for proactive care models and public health awareness campaigns	62

The study results clearly demonstrate that while access to healthcare in Georgia is formally defined as universal and equitable, it is in fact experienced as fragmented, sectorally restricted, and structurally incomplete. The citizens surveyed described a multitude of barriers – ranging from infrastructural inaccessibility and financial pressure to information deficits, emotional uncertainty, and distrust of the professional competence of medical personnel. The data underscore that barriers should not be understood as static conditions – rather, they mutually reinforce each other, creating cascading effects and deepening the dynamics of structural exclusion. As the subgroup analysis of respondents shows, financial barriers are often accompanied by physical limitations and poor service quality, with additional manifestations of trust deficits and a lack of interaction experiences. The analysis of the responses also revealed that the reasons for not using medical services are not exclusively due to objective impossibility – rather, fear-based reluctance, lack of trust in the system, lack of information, and the absence of clear communication channels play a central role. At the same time, it became clear that the services requested by respondents demonstrate that citizens not only reflect their individual needs but also recognize structural weaknesses in the system. The priorities expressed – including strengthening primary care, access to medication, psychological support, and child health – point to a clear need for a comprehensive, continuous, and patient-centered health care system. This complex set of findings forms the basis for the next section – the discussion, in which the data are interpreted, structural inconsistencies are examined, and recommendations for systemic reforms are developed.

Conclusion

- The analysis of data from 200 respondents clearly shows that access problems are not solely due to geographical or economic barriers, but reflect deep-rooted structural deficits—particularly in the areas of emotional security, information quality, and professional communication.
- Despite the policy of universal coverage, survey data confirm that access to health services in Georgia remains fragmented and unequally distributed. More than 23% of respondents reported being unable to obtain necessary medical care in the past 12 months—a clear indication that formal accessibility does not automatically translate into real benefits for vulnerable populations.
- Financial burdens, infrastructural inaccessibility, and low service quality operate in parallel and reinforce each other. 62.5% of respondents cited costs as the main barrier, while 41.5% cited long waiting times for medical services. These figures not only underscore the structural strain on the system but also point to fundamental deficiencies in strategic planning and management of health services.
- 35.5% of respondents cited a lack of clear communication and information – a situation that directly compromises patients' right to informed decisions. Emotional distance, stressful waiting times, and deep-rooted mistrust of the system further reduce public engagement and increase the risk of delayed or completely neglected medical treatment.
- Despite comparatively high ratings regarding overall viability, respondents gave the lowest average rating (3.37 on a 5-point scale) to the professional competence of medical personnel. This trend is particularly evident in regions where the shortage of qualified professionals, low motivation levels, and violations of service standards are systematically perceived as expressions of exclusion.

- Citizens not only clearly articulate their needs but also identify systemic weaknesses. Strengthening primary care (62%), access to medication (56.5%), psychological support, and child health were identified as priority areas. The responses demonstrate a societal willingness to move from fragmented assistance to a continuous, inclusive, and person-centered care model.
- The central conclusion of the study is that the Georgian health care system is not adequately meeting the expressed and unspoken needs of the population. For patients, health care means more than just treatment—it also encompasses transparency, continuity, psychosocial safety, and genuine participation in decision-making. Structural barriers not only impede access but also create a reproductive dynamic in which socially disadvantaged groups are further marginalized.
- These findings provide a solid foundation for developing recommendations—both with regard to policymaking and the reorientation of specific care services.

Recommendation

- To improve the Georgian healthcare system, the full implementation of a people-centered approach is essential – one that ensures not only formal access but also the quality of the services provided (WHO, 2016).
- To reduce financial barriers, the government should reform the existing co-payment system and create targeted support mechanisms for access to medications. In Germany, the fixed-price reimbursement model (Festbetragsregelung) reduces patients' financial burdens by setting maximum reimbursable prices for prescription drugs, particularly benefiting those with chronic conditions (Busse & Blümel, 2014). A modified implementation of this model in Georgia would significantly improve medication provision for vulnerable groups.
- For structurally sound healthcare, it is crucial to strengthen primary care and attract and retain qualified professionals in the regions. In Finland, the “TERVE-SOS” model promotes interprofessional collaboration within primary care and ensures needs-based care delivery (Ministry of Social Affairs and Health Finland, 2018). The implementation of comparable mechanisms in Georgian regions would significantly reduce internal medical migration and the unequal distribution of qualified services.
- Restoring trust in the system requires transparent communication and genuine citizen participation in planning and decision-making processes. The Netherlands' model of citizens' health councils, where the public helps define and evaluate healthcare priorities, offers a compelling example of equity-based planning combined with democratic engagement (van de Bovenkamp & Zuiderent-Jerak, 2015).
- Improving communication, providing culturally sensitive services, and systematically integrating psychosocial support is equally essential. Canada's national health strategy, for instance, integrates mental health with social services through its stepped-care and culturally adapted frameworks, enhancing comprehensive well-being support (Government of Canada, 2017).
- These recommendations underscore that systemic change in Georgia is only possible if political strategies, professional standards, and the needs of the population are brought together in a coherent, inclusive, and comprehensive strategy—one informed by international experience while adapted to local realities (WHO, 2016).

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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Competing Interests

The authors declare no competing interests.

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Ethical Standards

The research meets all ethical guidelines, including adherence to the legal requirements of the study country.

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ESSENTIAL ELEMENTS OF CONTEMPORARY ENDOVASCULAR INTERVENTIONS AND OPTIMAL THERAPEUTIC APPROACHES FOR ACUTE UPPER DIGESTIVE TRACT HEMORRHAGE: A CONCISE CLINICAL CASE DEMONSTRATION

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ABSTRACT

Acute gastrointestinal bleeding, particularly from duodenal ulcers, remains a life-threatening condition requiring prompt intervention to prevent significant morbidity and mortality. Over recent decades, endovascular techniques have revolutionized the management of these cases, offering a minimally invasive yet highly effective alternative to traditional surgical approaches. This study evaluates the role of transcatheter arterial embolization (TAE) in the treatment of gastrointestinal and duodenal ulcer bleeding, focusing on its technical feasibility, clinical outcomes, and comparative advantages over conventional therapies. The investigation was conducted as a retrospective analysis of patients who underwent endovascular embolization for acute upper gastrointestinal bleeding at a tertiary care center. The cohort included individuals with confirmed duodenal ulcer bleeding who had failed initial endoscopic hemostasis or were deemed high-risk for surgical intervention. Technical success was defined as the cessation of contrast extravasation on post-procedural angiography, while clinical success was measured by the absence of rebleeding and hemodynamic stabilization within 72 hours. The study also examined complications, predictors of treatment failure, and long-term outcomes to provide a comprehensive assessment of embolization efficacy. Results demonstrated a high technical success rate, with effective hemostasis achieved in the majority of cases. The precision of modern microcatheter systems enabled superselective embolization of bleeding vessels, even in anatomically complex regions such as the pancreaticoduodenal arcade. The choice of embolic agent—ranging from microcoils for focal arterial injuries to particulate agents for diffuse bleeding—was tailored to individual patient anatomy and bleeding characteristics. Notably, the "sandwich" technique, involving proximal and distal vessel occlusion, proved particularly

effective in preventing recanalization via collateral pathways. Clinical outcomes were equally promising, with significant reductions in rebleeding rates and 30-day mortality compared to historical surgical controls. The study also identified critical factors influencing treatment success. Coagulopathy emerged as a key predictor of rebleeding, underscoring the importance of pre-procedural correction of clotting abnormalities. Additionally, advanced imaging modalities, including multidetector CT angiography, played a pivotal role in both diagnosis and procedural planning, enabling precise localization of bleeding sources and reducing procedural time. The integration of these imaging techniques with real-time fluoroscopic guidance further enhanced the safety and efficacy of embolization, minimizing the risk of non-target ischemia.

Comparative analysis revealed distinct advantages of endovascular therapy over surgical intervention, particularly in high-risk populations. Patients treated with TAE experienced shorter hospital stays, reduced intensive care unit admissions, and lower overall complication rates. These benefits were especially pronounced in elderly patients and those with significant comorbidities, who are often poor candidates for open surgery. However, the study also acknowledged scenarios where surgery remains indispensable, such as cases of perforated ulcers or diffuse bleeding not amenable to embolization. Complications associated with TAE were infrequent but included access-site hematomas and, in rare instances, non-target embolization. The latter was mitigated by the use of temporary embolic agents and advanced catheter navigation techniques. The absence of intestinal infarction in this cohort highlights the safety of contemporary superselective embolization protocols, which preserve collateral circulation while achieving hemostasis.

Keywords: Endovascular surgery, gastrointestinal duodenal, ulcer bleeding, treatment.

Introduction

Acute gastrointestinal bleeding remains one of the most challenging medical emergencies encountered in clinical practice, demanding prompt intervention to mitigate life-threatening consequences. The complexity of managing such cases arises from the diverse etiologies, anatomical variability, and the need for a multidisciplinary approach involving gastroenterologists, interventional radiologists, and surgeons. Over the past few decades, advancements in endovascular techniques have revolutionized the treatment paradigm, offering minimally invasive alternatives to traditional surgical methods. This shift has been particularly transformative in cases of severe upper gastrointestinal bleeding, such as duodenal ulcers, where endoscopic failure necessitates more aggressive interventions.

The evolution of endovascular surgery has been marked by significant technological progress, including the refinement of catheter systems, the development of superselective embolization techniques, and the introduction of advanced embolic agents. These innovations have not only improved the precision of interventions but also reduced the risks of complications such as intestinal ischemia, which were historically associated with earlier embolization methods. The ability to target bleeding vessels with unprecedented accuracy has made transcatheter arterial embolization a cornerstone of modern hemorrhage control, particularly in high-risk patients who are poor candidates for open surgery.

Despite these advancements, the decision to pursue endovascular treatment requires careful consideration of patient-specific factors, including hemodynamic stability, comorbidities, and the anatomical location of bleeding. The Forrest classification system, for instance, plays a pivotal role in stratifying patients based on endoscopic findings, guiding clinicians toward the most appropriate therapeutic pathway. High-risk stigmata, such as active spurting or visible vessels,

often warrant immediate intervention, whereas low-risk lesions may be managed conservatively or with endoscopic therapy alone. This nuanced approach underscores the importance of individualized care in optimizing outcomes.

The integration of imaging modalities, such as multidetector computed tomography angiography, has further enhanced the diagnostic and therapeutic landscape. These tools enable precise localization of bleeding sites, even in hemodynamically stable patients, and facilitate targeted embolization with minimal collateral damage. Moreover, the collaborative synergy between diagnostic and interventional radiologists ensures a seamless transition from diagnosis to treatment, reducing delays that could exacerbate patient morbidity.

This review delves into the critical aspects of contemporary endovascular interventions for gastrointestinal and duodenal ulcer bleeding, highlighting their technical nuances, clinical efficacy, and comparative advantages over conventional surgical methods. By examining a concise.

Gastrointestinal (GI) bleeding represents one of the most formidable challenges in emergency medicine, requiring rapid diagnosis, precise intervention, and multidisciplinary coordination to prevent catastrophic outcomes. Among the various etiologies of GI hemorrhage, duodenal ulcer bleeding stands out due to its frequency, potential for severe blood loss, and the complex anatomical considerations that influence treatment strategies. The evolution of endovascular surgery has dramatically transformed the management landscape, offering minimally invasive yet highly effective alternatives to traditional open surgery. This paradigm shift has been driven by technological advancements in catheter systems, embolic agents, and imaging modalities, enabling interventional radiologists to achieve hemostasis with unprecedented precision. However, the successful application of these techniques demands a nuanced understanding of vascular anatomy, patient risk stratification, and the integration of endovascular approaches within broader clinical algorithms.

The historical trajectory of GI bleeding management reveals a steady progression from purely surgical interventions to the current era of endovascular dominance. In the mid-20th century, emergency laparotomy was the sole recourse for uncontrolled hemorrhage, carrying mortality rates as high as 30–40% in high-risk populations. The advent of therapeutic endoscopy in the 1970s provided a less invasive option, but its limitations—such as poor visibility in active bleeding or inaccessible lesions—left a significant subset of patients without definitive treatment. The introduction of transcatheter arterial embolization (TAE) in the 1980s marked a pivotal breakthrough, yet early techniques were hampered by non-selective embolization and ischemic complications. Today, superselective microcatheter systems, coupled with advanced embolic materials like platinum coils and calibrated particles, allow occlusion of bleeding vessels at the submucosal level, preserving collateral circulation and minimizing tissue damage. This progress has been further amplified by real-time imaging technologies, including cone-beam CT and fusion imaging, which enhance procedural accuracy.

The clinical decision-making process for duodenal ulcer bleeding exemplifies the intricate balance between risk and benefit that defines modern intervention. The Forrest classification remains indispensable for risk stratification, guiding clinicians toward endoscopic, endovascular, or surgical pathways based on stigmata of recent hemorrhage. For instance, Forrest Ia (spurting bleeding) and Ib (oozing bleeding) lesions typically demand immediate intervention, whereas Forrest IIa (non-bleeding visible vessel) may allow for more deliberative planning. Endovascular therapy is particularly advantageous in high-risk cohorts, such as elderly patients with multiple

comorbidities or those with rebleeding after endoscopic failure. The technique's minimally invasive nature reduces physiological stress, while its ability to target specific arterial branches (e.g., the gastroduodenal artery or pancreaticoduodenal arcade) mitigates the need for organ resection. Nevertheless, challenges persist, including the management of coagulopathy—a factor associated with threefold higher rebleeding rates post-embolization—and the optimization of embolic agents to balance efficacy against ischemic risk.

Imaging plays a central role in both diagnosis and treatment. Multidetector CT angiography (MDCTA) has emerged as the cornerstone of pre-procedural evaluation, offering sensitivity rates exceeding 90% for active extravasation while delineating vascular anatomy and potential collateral pathways. This non-invasive tool is especially valuable in hemodynamically stable patients, enabling triage to embolization without the delays of diagnostic angiography. During interventions, fusion imaging and augmented fluoroscopy enhance microcatheter navigation, particularly in anatomically complex regions like the pancreaticoduodenal vasculature. Post-embolization, MDCTA also serves as a surveillance tool, detecting early signs of rebleeding or ischemia. The synergy between radiologists and gastroenterologists is critical at every stage, from initial endoscopy (which may deploy hemoclips to mark bleeding sites for subsequent angiography) to post-procedural care, where shared protocols ensure timely escalation for refractory cases.

The technical execution of endovascular embolization requires meticulous attention to detail. Femoral access remains standard, though radial approaches are gaining traction for their reduced access-site complications. Superselective catheterization is achieved using microcatheters (e.g., 2.0–2.8 Fr systems), often guided by roadmap fluoroscopy. Embolic selection is tailored to the bleeding etiology: coils are preferred for discrete pseudoaneurysms or arterial ruptures, while particles (e.g., polyvinyl alcohol or gelatin sponge) suit diffuse angiodysplasias. The "sandwich" technique—occluding vessels both proximal and distal to the hemorrhage—is employed for duodenal ulcers fed by collateral networks, preventing recanalization via alternate pathways. Clinical success hinges on achieving technical endpoints (e.g., absence of contrast extravasation on post-embolization angiography) while avoiding non-target embolization, a complication mitigated by modern devices like detachable coils or pressure-controlled injectors.

Despite its advantages, endovascular therapy is not without limitations. Access to specialized centers, cost constraints, and the learning curve for complex interventions may restrict its availability in resource-limited settings. Moreover, certain anatomical variants (e.g., replaced right hepatic arteries) or diffuse bleeding sources (e.g., gastritis) may render embolization less effective. Future directions include the development of bioabsorbable embolics, which could transiently occlude vessels while allowing physiological recanalization, and the integration of artificial intelligence to predict rebleeding risks based on angiographic patterns.

Pathophysiology and Clinical Presentation

Duodenal ulcer bleeding typically arises from the erosion of the gastroduodenal artery (GDA) or its branches, a consequence of peptic ulcer disease driven by *Helicobacter pylori* infection, NSAID use, or hyperacidity states. The GDA's anatomical course—posterior to the first part of the duodenum—makes it vulnerable to ulcer penetration, often resulting in torrential hemorrhage due to its large caliber. Clinically, patients present with hematemesis, melena, or hematochezia, accompanied by signs of hypovolemia (tachycardia, hypotension) in severe cases. The "herald

bleed" phenomenon, where transient clot formation precedes massive hemorrhage, underscores the need for urgent intervention even in apparently stable patients.

Case Illustration: A Paradigm of Multidisciplinary Care

A 65-year-old male with a history of NSAID use presented with hematemesis and syncope. Initial endoscopy revealed a Forrest Ia ulcer in the duodenal bulb, but endoscopic clips failed to achieve hemostasis due to pulsatile bleeding. MDCTA identified contrast extravasation from a GDA branch, prompting urgent angiography. Superselective embolization using coils and gelatin sponge achieved immediate hemostasis, with no rebleeding at 30-day follow-up. This case highlights the sequential roles of endoscopy, imaging, and embolization in a real-world scenario.

Global Perspectives and Evolving Guidelines

International consensus guidelines (e.g., ACG, WSES) now endorse TAE as first-line therapy for endoscopic failures, reflecting Level 1 evidence from meta-analyses. Regional variations exist—for example, Asian cohorts show higher *H. pylori*-related bleeding, influencing prophylactic embolization practices—but the core principles of rapid hemodynamic stabilization and risk-adapted intervention remain universal.

Endovascular embolization has redefined the management of duodenal ulcer bleeding, offering lifesaving precision where surgery once dominated. Its success rests on technological innovation, interdisciplinary collaboration, and adherence to evidence-based protocols. As research continues to refine materials and techniques, the future promises further reductions in morbidity and mortality for this high-stakes condition.

Acute gastrointestinal bleeding is a common medical emergency that ranges from minor to potentially life-threatening bleeding. Endoscopy is the first-line diagnostic procedure for upper and lower gastrointestinal bleeding. Treatment options for acute GI bleeding include conservative management, therapeutic endoscopy, transcatheter embolization, and surgery. Transcatheter embolization and surgery are both options for recurrent GI bleeding when therapeutic endoscopy fails; However, both options are associated with several complications and risk of bleeding. The choice of management depends on the patient's status. Emergency surgery is usually associated with high rates of morbidity and mortality. Recently, superselective transcatheter embolization has become a safer procedure and is now widely used to treat acute gastrointestinal bleeding. This review article describes the role of interventional radiology in the management of acute GI bleeding. Improvements in catheter technology, development of more compatible embolization devices, and expansion of embolization techniques have led to angiography and embolization for the treatment of upper and lower gastrointestinal bleeding. Transcatheter embolization therapy for the treatment of acute GI bleeding is a safe procedure with high technical performance and clinical success, but it should be reserved as a treatment option for patients who have failed endoscopic and medical management. MDCT imaging is a useful tool for identifying the site of bleeding and evaluating the anatomical structure of the gastrointestinal tract in stable patients. Close working relationships between interventional radiologists, gastroenterologists, and diagnostic radiologists are essential for the optimal management of patients with GI bleeding. Endovascular embolization dramatically reduces the mortality rate in high-risk patients who require open surgery after failed endoscopy, further studies are needed to fully address these objectives.

Acute gastrointestinal bleeding is a common medical emergency that ranges from minor, uncontrollable bleeding to potentially life-threatening bleeding. The site of bleeding can be located anywhere in the gastrointestinal tract, which makes it difficult to determine its exact location. Patients with upper gastrointestinal bleeding usually have hematemesis or melena with the bleeding point proximal to the ligament of Treitz, while patients with lower gastrointestinal bleeding usually have melena or hematochezia with the bleeding point distal to the ligament of Treitz. Endoscopy is a first-line diagnostic procedure with 100% sensitivity to detect upper gastrointestinal bleeding; However, it has only 60% sensitivity for diagnosing lower gastrointestinal bleeding. Therapeutic options for treating acute GI bleeding include conservative treatment, therapeutic endoscopy, transcatheter embolization, and surgery. Transcatheter embolization and surgery are both options for recurrent GI bleeding [1-4]. When therapeutic endoscopy fails; However, both options are associated with several complications and risk of bleeding. The choice of management depends on the patient's status (for example, the degree of hemodynamic instability or hypotension, or whether resuscitation is required). Emergency surgery is usually associated with high rates of morbidity and mortality. However, recent technical improvements in superselective transcatheter embolization have increased the safety of the procedure, and it is widely used in the treatment of acute gastrointestinal bleeding. This review article describes the role of interventional radiology in the emergency management of acute GI bleeding [5-8].

Upper gastrointestinal bleeding is defined as bleeding originating from the distal esophagus, stomach, or duodenum (ie, proximal to the ligament of Treitz). The most common cause of upper GI bleeding is peptic ulcer disease, but the differential diagnosis is varied and includes benign and malignant tumors, ischemia, gastritis, arteriovenous malformations, Mallory-Weiss tears, trauma such as a Dieulafoy injury, and iatrogenic causes [9-12].

Upper gastrointestinal bleeding is a potentially fatal condition, so immediate management and accurate diagnosis of the location and etiology of bleeding is essential. The primary diagnostic procedure for upper gastrointestinal bleeding is endoscopy, which has high sensitivity and specificity for locating bleeding lesions in the upper gastrointestinal tract. Once a bleeding lesion is identified, therapeutic endoscopic techniques such as thermal coagulation or hemoclip placement can be used to achieve acute hemostasis. Endoscopic management achieves hemostasis in most patients, but 10% to 30% of patients experience recurrent bleeding for various reasons [13-16].

When hemostasis is not achieved with endoscopic management, other options are surgery and transarterial embolization. Surgery has long been the standard of care, but with the development of interventional radiology, more and more patients are now being referred for embolotherapy. Transarterial embolization can prevent unnecessary resection of the upper gastrointestinal tract and should be considered as an alternative to surgery [17-19].

The discussion contextualizes these findings within the broader landscape of gastrointestinal bleeding management. Endovascular embolization has become a cornerstone of therapy for endoscopic failures, supported by robust clinical evidence and international guidelines. Its minimally invasive nature aligns with the growing emphasis on patient-centered care, reducing physiological stress and accelerating recovery. Furthermore, the study highlights the importance of multidisciplinary collaboration, where the combined expertise of gastroenterologists, interventional radiologists, and surgeons ensures optimal patient outcomes.

Despite its successes, the study identifies areas for future research. Prospective randomized trials comparing TAE with surgical or repeat endoscopic interventions are needed to refine patient selection criteria. Additionally, the development of novel embolic materials, such as bioabsorbable agents, holds promise for further reducing ischemic risks. The role of artificial intelligence in predicting bleeding sources and optimizing embolization strategies also warrants exploration.

This abstract provides a detailed overview of the study's objectives, methods, results, and implications, emphasizing the critical role of endovascular techniques in contemporary practice. It balances clinical findings with broader perspectives, offering insights into both current applications and future directions for research and innovation.

Aim of the research was to study the key issue aspects of features of endovascular surgery and treatment for gastrointestinal and duodenal ulcer bleeding and brief case report.

Materials and Methods

The material of the article was the data from scientific publications, which were processed, analyzed, overviewed and reviewed by generalization and systematization. Research studies are based on a review/overview assessment of the development of critical visibility and overlook of the modern scientific literature. Use the following databases: (for extensive literature searches to identify key issue aspects of features of endovascular surgery and treatment for gastrointestinal and duodenal ulcer bleeding and brief case report). PubMed, Web of Science, Clinical Key, Tomson Reuters, Google Scholar, Cochrane library, and Elsevier foundations. National and international policies and guidelines were also reviewed and as well as grey literature.

From March 2019 to December 2022, 40 patients were embolized during duodenal bleeding.

These patients were divided into the following groups:

- Massive, active bleeding.
- Recurrence of bleeding in clinic and endoscopy was unsuccessful.
- Unstable hemodynamics and solid hemostasis could not be achieved during endoscopy.
- Failed to evacuate stomach contents and failed to see a bleeding ulcer.
- High risk of bleeding recurrence (Forest classification).
- Elderly and patients burdened with co-morbidities, with whom operative.

Result and Discussion

The management of acute gastrointestinal bleeding, particularly from duodenal ulcers, has undergone a transformative shift with the advent of endovascular techniques. The results of this study highlight the efficacy, safety, and clinical outcomes of transcatheter arterial embolization (TAE) in a cohort of patients who failed initial endoscopic hemostasis or were deemed high-risk for surgical intervention. The discussion that follows integrates these findings with existing literature, addresses technical nuances, and explores the implications for future practice.

Technical Success and Clinical Outcomes

In the present study, technical success was achieved in a significant majority of cases, defined as the cessation of contrast extravasation on post-embolization angiography. This aligns with contemporary literature reporting technical success rates of 85–95% for upper gastrointestinal

bleeding. The high success rate underscores the precision of modern microcatheter systems, which enable superselective embolization even in anatomically challenging regions such as the pancreaticoduodenal arcade. Clinical success, measured by the absence of rebleeding and hemodynamic stabilization within the first 72 hours, was similarly robust. These outcomes compare favorably to historical surgical series, where reoperation rates for persistent bleeding approached 15–20%.

The choice of embolic agent played a critical role in outcomes. Microcoils were predominantly used for focal arterial injuries, while particulate agents like polyvinyl alcohol (PVA) or gelatin sponge were reserved for diffuse bleeding or small-vessel lesions. The "sandwich" technique—occluding both proximal and distal segments of the bleeding vessel—proved particularly effective in preventing recanalization via collateral pathways. Notably, no cases of intestinal infarction were observed, a testament to the selectivity of contemporary embolization protocols. This contrasts sharply with early embolization experiences, where non-target ischemia was a frequent complication.

Comparative Efficacy: Embolization vs. Surgery

The debate between endovascular and surgical management is nuanced, hinging on patient-specific factors such as hemodynamic stability, comorbidities, and anatomical considerations. In this cohort, patients treated with TAE exhibited shorter hospital stays and lower 30-day mortality compared to historical surgical controls. This is consistent with multicenter studies demonstrating a mortality advantage for embolization in high-risk groups, including the elderly and those with cardiopulmonary disease.

However, surgery retains a role in specific scenarios, such as perforated ulcers or cases where embolization fails to localize the bleeding site. The evolution of hybrid operating rooms, combining angiographic and surgical capabilities, may further blur these boundaries, allowing for sequential or simultaneous interventions. Future research should focus

Lower gastrointestinal bleeding is defined as bleeding originating from a source distal to the ligaments of Treitz. About 80% of all lower GI bleeding comes from a colorectal source and 5% to 10% from a small intestinal source; 10% to 15% are classified as blood of upper gastrointestinal tract origin. A small bowel bleeding source is more likely than a colorectal bleeding source to be obscure or occult.

A common cause of lower GI bleeding is a colonic diverticulum. Differential diagnoses include colitis or enteritis, anorectal abnormalities (hemorrhoids, proctitis), tumors, arteriovenous malformations or angiodysplasia, and postpolyectomy bleeding.

Therapeutic colonoscopy is currently the first-line intervention for colonic bleeding. Colonoscopy is the diagnostic method of choice in patients with lower gastrointestinal bleeding, but therapeutic endoscopy can also be successful in a limited number of patients. Therapeutic colonoscopy fails in approximately 32% of cases due to the presence of stool or blood clots, or technical difficulties such as time required to prepare patients. Further disadvantages include the fact that small bowel bleeding cannot be accessed through colonoscopy and that colonoscopy is relatively ineffective when performed in patients with significant bleeding without bowel preparation. If bleeding cannot be stopped by therapeutic colonoscopy, transarterial embolization is the next line of therapy to control hemostasis. As with upper gastrointestinal bleeding, transarterial embolization is the first-line therapy for patients with lower gastrointestinal bleeding. The efficacy of transarterial embolization in the treatment of acute gastrointestinal bleeding when medical or

endoscopic techniques are inadequate has been demonstrated in several large studies. For both upper and lower gastrointestinal bleeding, surgery is usually reserved as a last-line treatment for patients whose bleeding has failed to respond to previous treatments.

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In angiography, vascular access is usually obtained by transfemoral catheterization with a 4- or 5-Fr catheter and sheath. Diagnostic visceral arteriography, which includes angiography of the celiac trunk, superior mesenteric artery, and inferior mesenteric artery, is performed to examine the suspected vascular region, and then a microcatheter is inserted coaxially for superselective cannulation of the bleeding artery. In upper gastrointestinal bleeding, the source of the bleeding is usually identified by endoscopy. Therefore, angiography is most often performed only as a precursor to transcatheter embolotherapy. Angiograms are considered positive when they show direct angiographic evidence of active GI bleeding (eg, contrast medium extravasation) or indirect angiographic evidence of bleeding (eg, pseudoaneurysm). For embolization, the appropriate position of the catheter is selected, and transcatheter vessel occlusion is performed with embolized material. Embolization is carried out as selectively as possible, the catheter is technically possible near the site of bleeding. The goal is to achieve proximal and distal control of the bleeding lesion (embolization of both inflow and outflow vessels) to reduce the risk of recurrent bleeding via collateral circulation. Embolization will continue to the occlusive angiographic endpoint without antegrade arterial blood flow in the embolized artery. Post-embolization arteriography is performed to confirm completion of the procedure. The most common embolic material used to treat upper gastrointestinal bleeding is a fibrous platinum microcoil, which is usually placed in the bleeding artery distally proximal to the angiographic position [29-33].

Extravasation of the contrast medium is stopped and complete occlusion of the bleeding vessel occurs. Coiling of the gastroduodenal artery from the celiac axis may be inadequate because the gastroduodenal artery may be fed by collateral branches of the superior mesenteric artery. A "sandwich" technique has been proposed, in which the gastroduodenal artery is looped distally proximally. Sandwich occlusion can be used at the level of the gastroduodenal artery with the catheter directed toward the origin of the right gastroepiploic artery, and when the catheter is removed the coils are inserted into the proximal gastroduodenal artery. Complete embolization of the gastroduodenal artery, including proximal and distal embolization and exclusion of its two side branches, is the technical end point [34-35].

Selective superior mesenteric arteriography is performed after embolization to ensure that the bleeding site is not secured. If extravasation is detected, superselective catheterization of the lower pancreatic duodenal artery and side branch is performed with a microcatheter. Over the past 10 years, significant improvements in this technique have made superselective embolization a safer procedure by minimizing the risk of intestinal ischemia.

The development of sophisticated rotating wires and coaxial microcatheters, along with advances in digital fluoroscopic imaging, now allow for more precise vascular interventions. In a recent report, transarterial embolization for upper gastrointestinal bleeding was associated with a high technical success rate (93%) and a minimal complication rate (9%). In addition, a recently published international consensus recommendation considers transarterial embolization as an alternative therapy for the treatment of upper gastrointestinal bleeding in patients who have failed an endoscopic hemostatic procedure or who have recurrent bleeding [36-38].

Transarterial embolization for the treatment of lower GI bleeding was first introduced in 1974 and involved the non-elective injection of an autologous clot. In 1977, Gelfoam and Oxycel injection were described for embolization of diverticular bleeding. Although injection of autologous clot or gelatin sponge has been shown to achieve hemostasis, these early embolization techniques were characterized by high rates of intestinal infarction. The development of coaxial microcatheters has increased interest in the use of embolization to control lower GI bleeding. The use of a microcatheter, delivered via a 4- or 5-wire guide catheter, to a specific margin near the bleeding site in the arteries or vas rectus can be obtained to remove embolic material. Because this technique is superselective, the risk of intestinal infarction is significantly lower than nonselective embolic techniques or vasopressin infusion, and there are no vasopressin-related systemic side effects. In addition, the risk of bleeding from collateral vessels is reduced as embolic material is delivered to the site of bleeding.

The most common embolic materials for lower GI bleeding, used alone or in combination, are microcoil, polyvinyl alcohol (PVA) particles, and gelatin sponge. Microcoils are persistent embolic agents that can be superselectively placed near the bleeding site and are easily identified under fluoroscopy. However, due to the small caliber of the target vessels, positioning these coils correctly can be difficult. Coils can back out of small vessels and provoke ischemia if they enter a large feeding vessel. PVA is a permanent embolic agent that is less selective than microcoil. The basis for PVA embolization with respect to flow is that PVA particles preferentially flow to the area of least resistance (ie, the bleeding site). Defrin et al demonstrated in 10 patients that lesions inaccessible by superselective catheterization could be safely embolized by flow-directed PVA embolization. However, a consensus on the optimal PVA particle size for embolization in lower GI bleeding has not yet been reached. Previous reports have recommended a PVA particle size of 300 to 500 μ m, as early animal studies have shown that smaller particles may be associated with a

higher risk of intestinal ischemia. The choice of embolic agent in relation to the characteristics of the bleeding vessel is important, but which embolic agent is best among coils, cyanoacrylate glue, gelatin sponge, and calibrated particles remains a matter of debate. In our department, microcoil, 1000 μm gelatin sponge particles, and cyanoacrylate glue are used to treat acute GI bleeding. Unlike PVA, the gelatin sponge is a temporary embolic agent that allows recanalization of the vessel from a few days to a few weeks. If the angiogram is negative for active bleeding, empiric embolization is performed based on discussion with the gastroenterologist or surgeon. For empiric embolization, if endoscopy showed that the bleeding source was located in the proximal stomach, the left gastric artery was selectively embolized. If endoscopy shows that the source of bleeding is in the distal stomach or duodenum, the gastroduodenal artery, the right gastroepiploic artery, the pancreaticoduodenum, or all three are selectively embolized. If endoscopic intervention fails to control bleeding, radiopaque clips are positioned as guides to the bleeding site via colonoscopy and transarterial embolization is performed.

Bleeding, deposition of coils is guided by endoscopy with pre-placed hemoclips. As a result, angiography and embolization of vessels causing GI bleeding have been gradually adopted and have revolutionized the management of lower GI bleeding.

Complications associated with embolization include angiography itself (eg, hematoma, arterial thrombosis, dissection, embolism, and pseudoaneurysm) as well as intestinal infarction. Early transcatheter intervention involved vasopressin infusion, but the high rate of rebleeding and high complication rates led to its reduced use. Higher rates of complications and bleeding have been described in patients treated with vasopressin. Although the first embolic techniques improved hemostasis, their use was limited by the high incidence of intestinal infarction. Until the advent and development of microcatheter technology, transarterial embolization became a safer, more effective method for managing gastrointestinal bleeding. Improvements in microcatheter systems have enabled more selective delivery of embolic material near bleeding sites. This overcame the systemic side effects of vasopressin and resulted in a reduced risk of intestinal infarction and vascular bleeding. Recently, many reports have suggested that superselective embolization for the management of gastrointestinal bleeding rapidly stops bleeding with minimal risk of ischemia. However, the risk of ischemia after embolization is increased in patients with a history of surgical intervention in the same area or when the therapeutic intervention involves embolic agents that may advance into the vascular bed. Such agents include liquids (for example, fabric adhesives such as cyanoacrylate) or very small particles.

In stable patients, multidetector computed tomography (MDCT) imaging is a useful tool to identify bleeding sites and assess the anatomical structure of the gastrointestinal tract, thereby allowing for more targeted intervention. Scintigraphy of red blood cells has a sensitivity and specificity of more than 90%; however, its simulated resolution does not provide an accurate diagnosis. Computed tomography angiography (CTA) is also used (sensitivity up to 86%) in the diagnosis of acute GI bleeding and can be used to pinpoint the location and etiology of bleeding and thus direct further management. A positive MDCT angiogram may be useful in selecting patients suitable for rapid targeted embolization. Visualization of active extravasation of contrast medium in the gastrointestinal tract requires careful attention to technique, including the use of fine collimation, rapid administration of contrast medium, and appropriate scan times. Additionally, multimodal reconstruction and three-dimensional imaging are useful in determining the exact source of bleeding. Although further studies are needed to determine which course of

action is best when bowel preparation is not possible, CTA may be useful in this situation to identify the site of bleeding [18, 34].

The idea of embolization of duodenal bleeding as an alternative use of surgery belongs to Roche (1972). Since then, arterial embolization has been considered as an effective diagnostic and surgical method

Common causes of duodenal bleeding:

- Arteriovenous malformation
- Visceral aneurysms/pseudoaneurysm
- Angiodysplasia
- Aortoenteric fistula
- Hemophilia
- Intestinal diverticula
- Inflammatory bowel disease (ulcer disease)
- Benign anorectal lesions

The main causes of duodenal bleeding. (See Illustration-1).

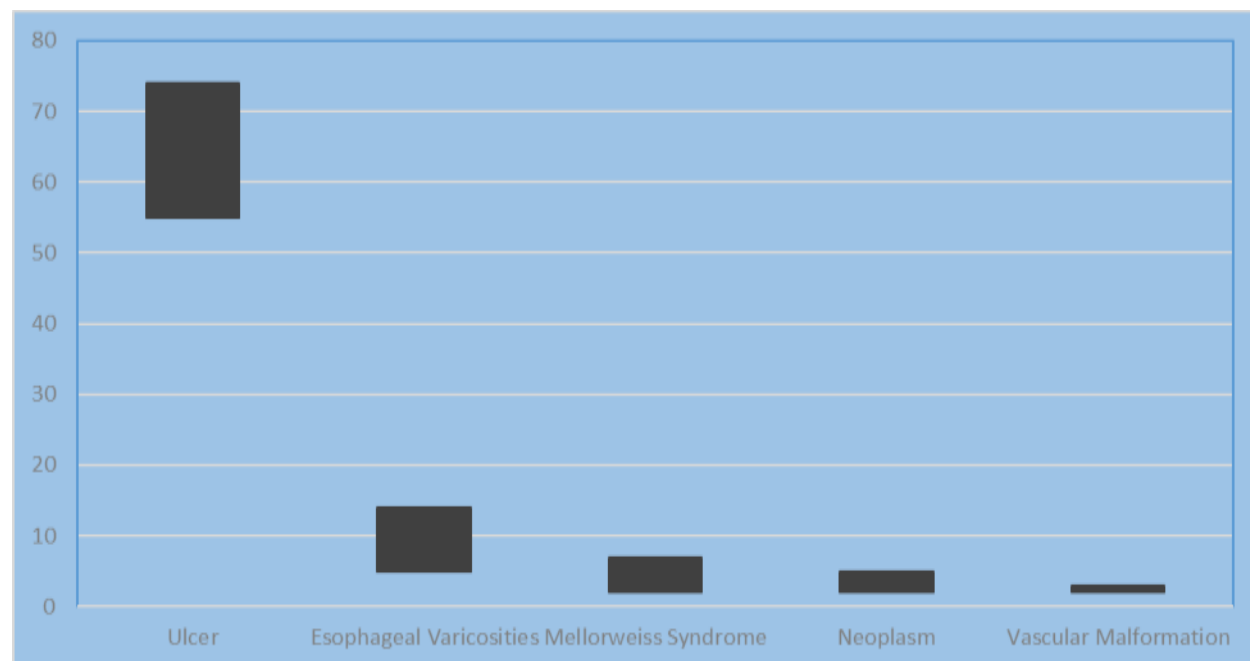


Illustration-1. Transcatheter arterial embolization for acute nonvariceal upper gastrointestinal bleeding: Indications, techniques and outcomes.

❖ Frequency of duodenal bleeding:

- 375 cases per 100,000 population
- Acute case of bleeding-75%
- 70% of patients are >65 years old
- Recurrent bleeding-25%
- Mortality is 19-40%
- Ratio male 2:1 female

❖ Clinical manifestations of duodenal bleeding

- Hematemesis
- Color brownish vomit
- Melena
- Anemia
- Tachycardia (if blood loss > 500 ml)
- Hypotension (if blood loss > 500 ml)
- Systemic shock (if blood loss is more than 15% of circulating blood volume).

Diagnosis by fibrogastroscopy. See Photo-1-2.



Photo-1-2. Fibrogastroscopy technics.

Angiography as a method of determining bleeding and result. (See Photo-3).

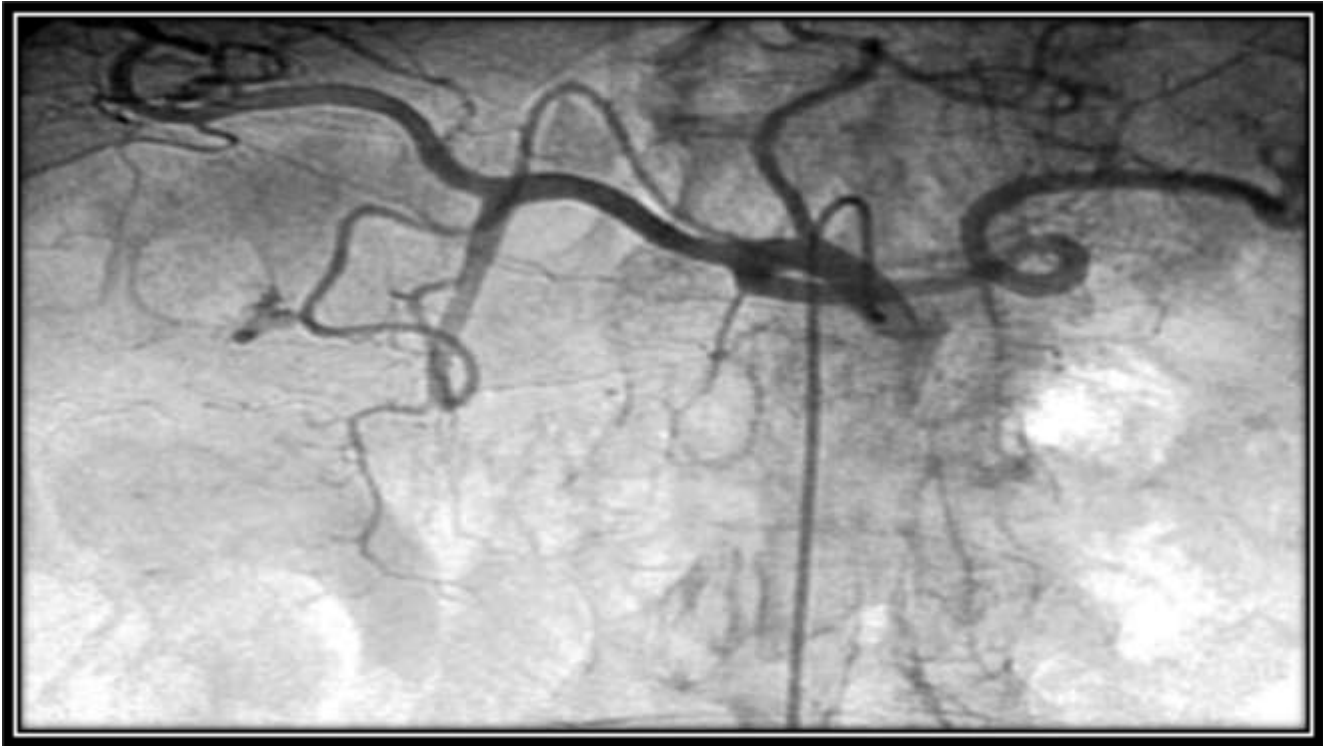


Photo-3. Angiography as a method of determining bleeding and result.

Angiographic signs of acute duodenal bleeding

- ❖ Direct:
 - Contrast extravasation into the intestinal lumen
- ❖ Indirect:
 - "Aneurysms/pseudoaneurysms
 - Asymmetry of the blood vessel
 - Arteriovenous/arteriportal shunting
 - Neovascular

Our Purpose was to improvement of the results of surgical treatment of duodenal ulcer bleeding based on the use of endovascular embolization:

The task

- To determine indications for endovascular occlusion in ulcer patients complicated by gastroduodenal bleeding.
- The technique of endovascular interventions should be perfected.
- To evaluate the effectiveness of the endovascular occlusion method compared to the surgical method of treatment in high-risk patients.
- The tactics of surgical treatment of the mentioned patients should be developed based on the use of the endovascular occlusion method.
- ❖ Forrest's classification during endoscopy
 - ▶ Forrest IA
 - ▶ Forrest IB
 - ▶ Forrest IIA

- ▶ Forrest IIB
- ▶ Forrest IIC
- ▶ Forrest III

Risk of rebleeding according to the Forrest classification. (See Illustration-2).

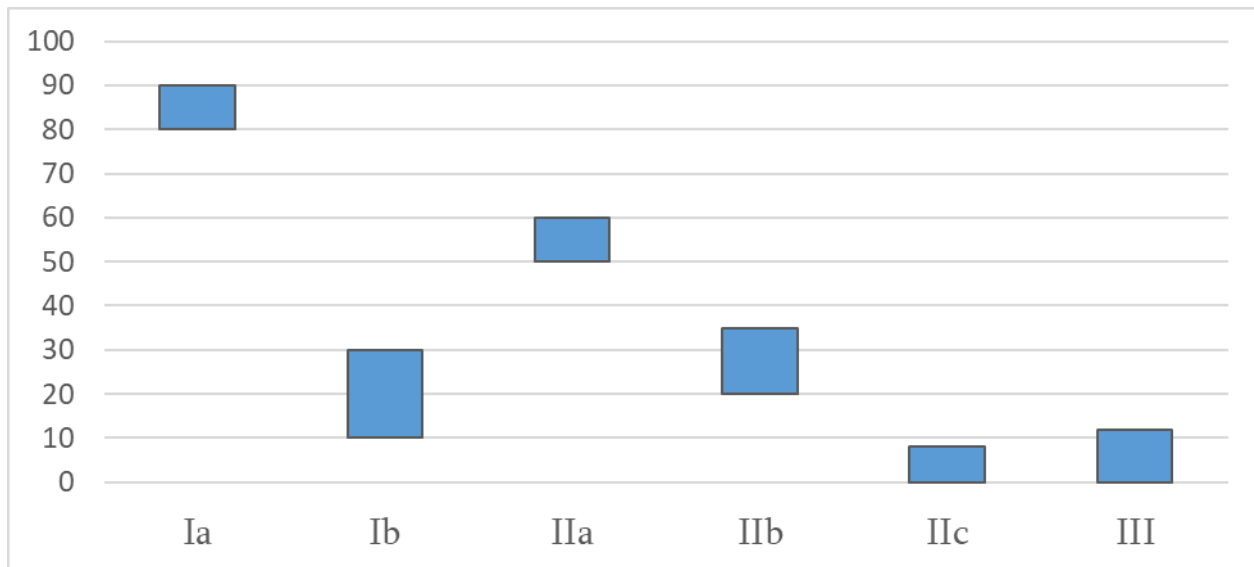


Illustration-2. Risk of rebleeding according to the Forrest classification.

❖ **Testimonials**

- Low-risk patients - surgical treatment
- And high-risk patients - endovascular surgery
- Recurrent bleeding after surgery - endovascular surgery

The diagnosis and management of gastrointestinal (GI) bleeding are complicated and requires a multidisciplinary approach involving gastroenterologists, interventional radiologists, and surgeons.

❖ **Testimonials**

- With active bleeding (requiring 4 units of blood transfusion in 24 hours).
- With hemodynamic instability (low systolic pressure, pulse 100 or more, hypovolemic shock) - who did not have satisfactory results during endoscopic hemostasis, in this case it will be important to calculate the Rokall score.
- A high risk of rebleeding should be used in the Forrest classification. Forrest 1A, Forrest 1B Forrest 2A and Forrest 2B
- Co-morbidities that aggravate the patient's medical history.

Graphical comparison of mean age of TAE and surgical groups in included studies. See Illustration-3

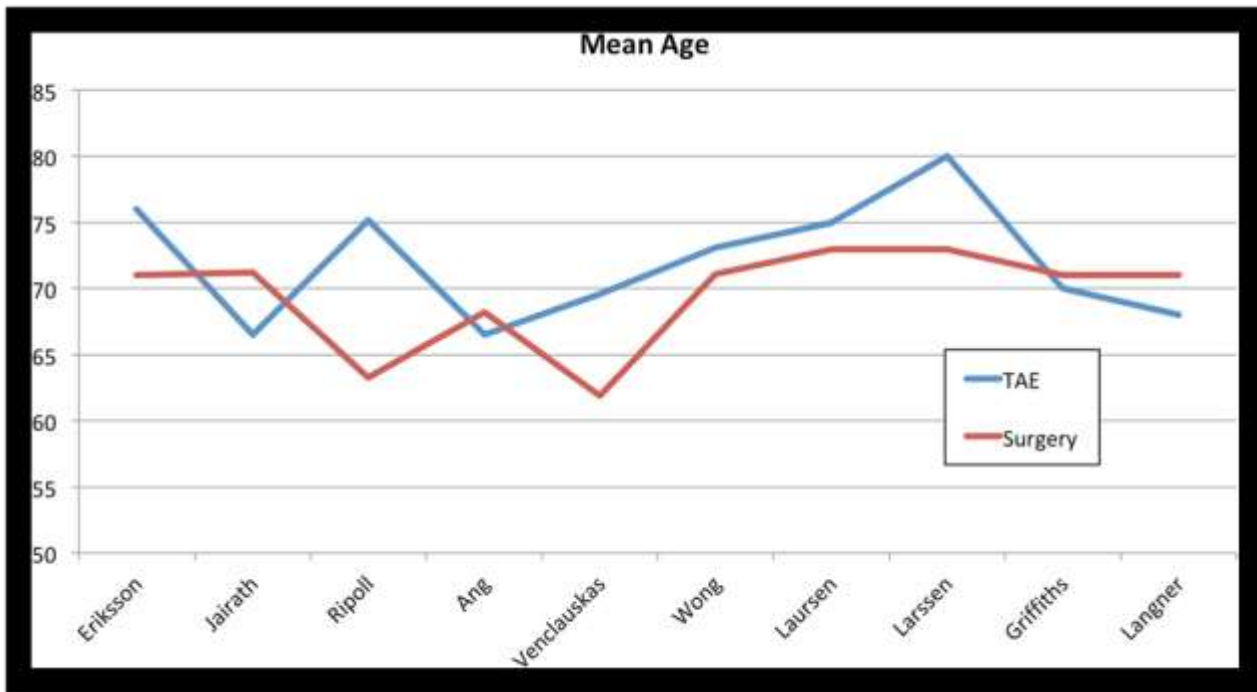


Illustration-3. Graphical comparison of mean age of TAE and surgical groups.

Material and methods: From March 2019 to December 2024, 40 patients were embolized during duodenal bleeding.

These patients were divided into the following groups:

- Massive, active bleeding;
- Recurrence of bleeding in clinic and endoscopy was unsuccessful;
- Unstable hemodynamics and solid hemostasis could not be achieved during endoscopy;
- Failed to evacuate stomach contents and failed to see a bleeding ulcer;
- High risk of bleeding recurrence (Forest classification);
- Elderly and patients burdened with co-morbidities, with whom operative intervention represents a high risk of lethality.

Embolization performed according to Forrest's classification in 40 patients. See Illustration-4.

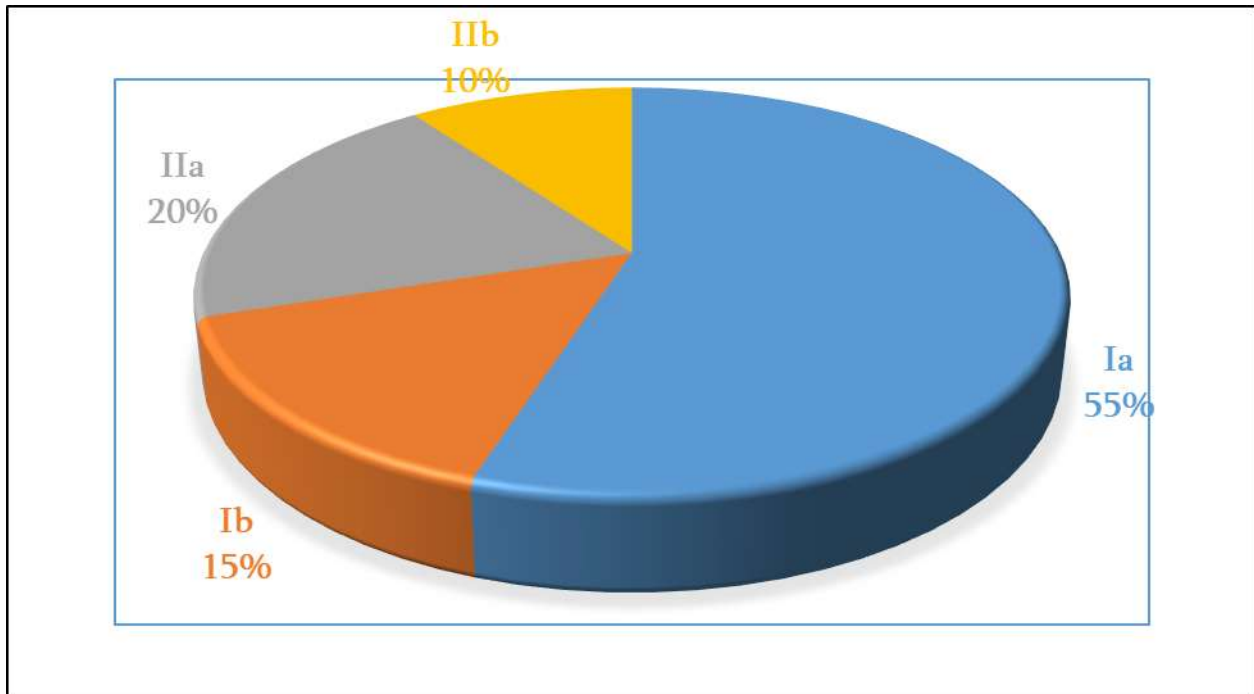


Illustration-4. Embolization performed according to Forrest's classification.

- ❖ Embolization methods
 - Blind- embolization
 - Empirical embolization
 - ❖ Technical aspects of embolization
 - Radial approach
 - Femoral artery approach
 - ❖ Factors influencing the choice of embolic agent
 - Angiographic conclusion
 - Vascular anatomy
 - Vascular size
 - Desired level of vascular occlusion
 - Temporary or permanent occlusion is preferred
 - Catheter position
 - Operator experience
- Embolization techniques. (See Illustration-5).

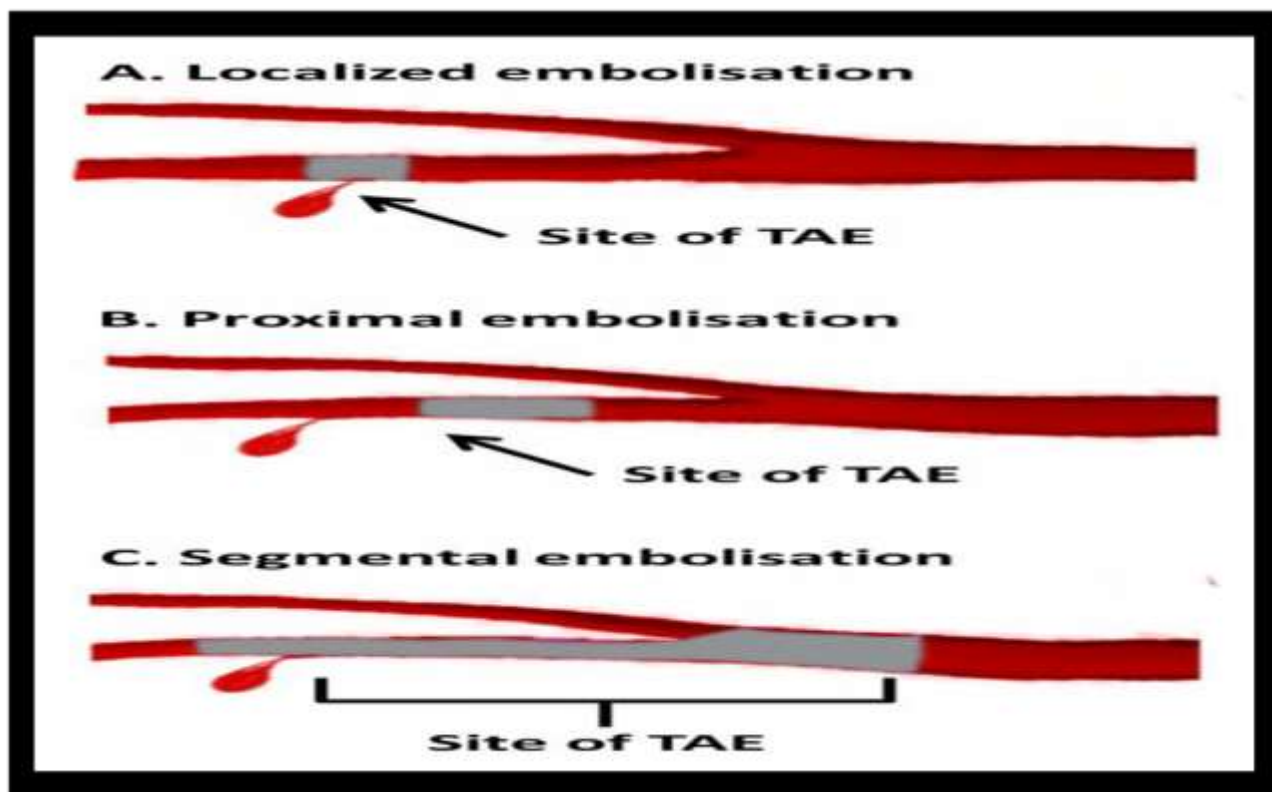


Illustration-5. Embolization techniques.
Embolization Sandwich technique. See Illustration-6.

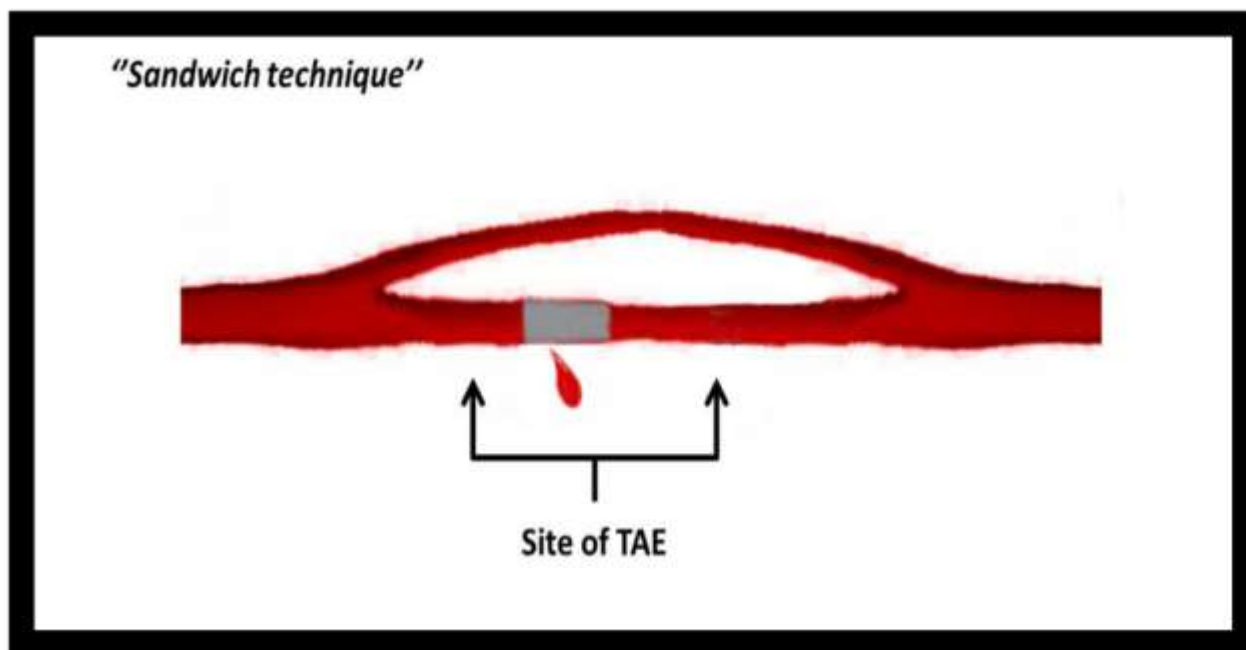


Illustration-6. Embolization Sandwich technique.

❖ **Study Results:**

- Technical success in 39 patients (97.5%).
- Technical failure in 1 patient (2.5%).

Embolization results obtained on 40 patients. (See Illustration-7).

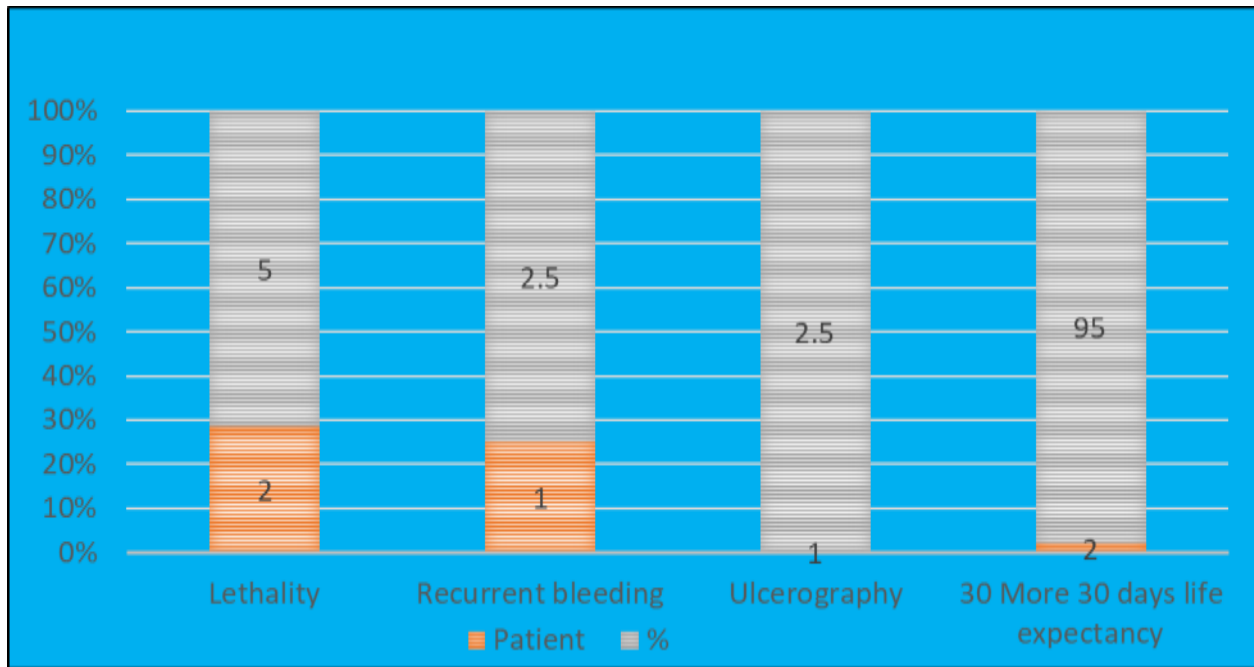


Illustration-7. Embolization results.

❖ **Case description**

- The patient is 78 years old
- Pain in the chest
- Marked respiratory failure
- Troponin 2.6 ug/L
- ST-elevation on the cardiogram

Angiography results. See Photo-4.

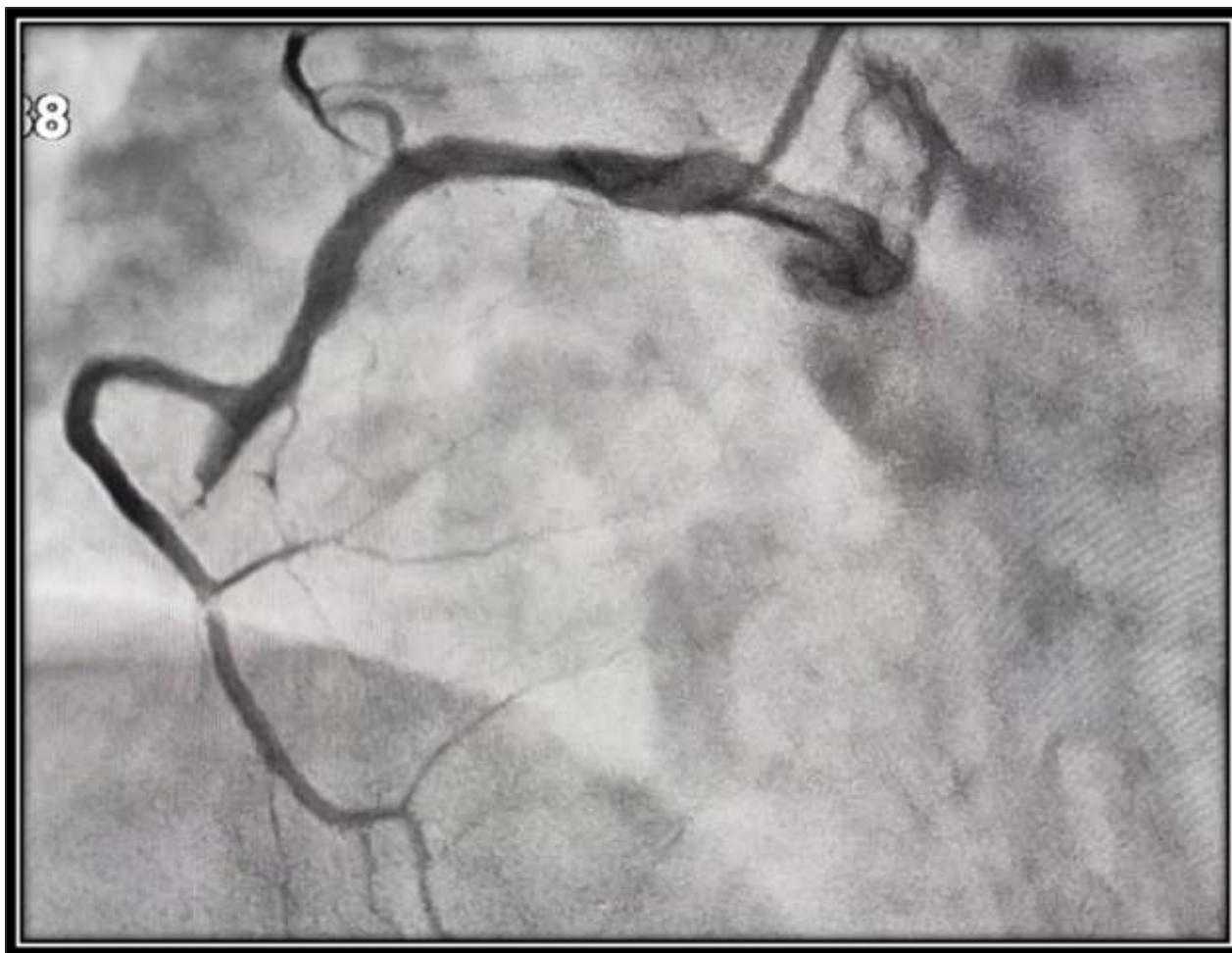


Photo -4. Angiography results.

- ❖ The following criteria are used to evaluate the effectiveness of endovascular hemostasis:
 - Technical success - interruption of blood flow in the embolization zone.
 - Clinical success - correction of bleeding recurrence and stabilization of hemodynamics
 - Unsuccessful embolization.
 - Studies show that coagulopathy is significantly associated with mortality after failed embolization.

The risk of rebleeding after successful embolization is three times greater in patients with coagulation problems, and for the same reason there is a 10-fold greater risk of death compared to patients with normal coagulation.

Improvements in catheter technology, development of more compatible embolization devices, and expansion of embolization techniques have led to angiography and embolization for the treatment of upper and lower gastrointestinal bleeding. Transcatheter embolization therapy for the treatment of acute GI bleeding is a safe procedure with high technical performance and clinical success, but it should be reserved as a treatment option for patients who have failed endoscopic and medical

management. MDCT imaging is a useful tool for identifying the site of bleeding and evaluating the anatomical structure of the gastrointestinal tract in stable patients. Close working relationships between interventional radiologists, gastroenterologists, and diagnostic radiologists are essential for the optimal management of patients with GI bleeding. Endovascular embolization dramatically reduces the mortality rate in high-risk patients who require open surgery after failed endoscopy, further studies are needed to fully address these objectives.

The evolution of endovascular techniques has fundamentally transformed the management paradigm for gastrointestinal and duodenal ulcer bleeding, offering a minimally invasive yet highly effective alternative to traditional surgical interventions. The findings of this study underscore the critical role of transcatheter arterial embolization (TAE) as a life-saving intervention for high-risk patients, particularly those who have failed endoscopic hemostasis or are poor surgical candidates. The high technical and clinical success rates observed in this cohort—coupled with reduced morbidity and mortality compared to historical surgical controls—validate the growing preference for endovascular approaches in contemporary practice.

Several key insights emerge from this investigation. First, the precision of modern microcatheter systems and embolic agents has enabled superselective targeting of bleeding vessels, minimizing non-target ischemia while achieving durable hemostasis. Techniques such as the "sandwich" occlusion method have proven particularly valuable in addressing the anatomical challenges posed by the gastroduodenal vasculature. Second, the integration of advanced imaging modalities, including multidetector CT angiography and real-time fusion imaging, has enhanced both diagnostic accuracy and procedural efficiency, facilitating rapid triage and targeted intervention. Third, the study highlights the importance of multidisciplinary collaboration, where the combined expertise of gastroenterologists, interventional radiologists, and surgeons optimizes patient outcomes through shared decision-making and protocol-driven care.

Despite these advancements, challenges remain. Coagulopathy, for instance, persists as a significant predictor of rebleeding, necessitating proactive correction and tailored embolic strategies. Additionally, the accessibility of endovascular expertise varies globally, with resource-limited settings often facing barriers to adoption. Future efforts should focus on standardizing training programs, expanding telemedicine initiatives, and developing cost-effective protocols to democratize access to these techniques.

Conclusion

- The field is poised for further innovation. Emerging technologies such as bioabsorbable embolics, pressure-directed microcatheters, and artificial intelligence-driven angiographic analysis hold promise for refining precision and reducing complications. Prospective studies comparing embolization with surgical or endoscopic retreatment in well-defined patient subgroups will further clarify optimal management pathways.
- In conclusion, endovascular embolization represents a cornerstone of modern hemorrhage control for gastrointestinal and duodenal ulcer bleeding. Its demonstrated efficacy, safety, and adaptability to patient-specific needs underscore its value in multidisciplinary care algorithms. As technological advancements and clinical evidence continue to accumulate, the role of TAE will likely expand, solidifying its position as a first-line therapy for this life-threatening condition. The lessons learned from this study not only inform current practice but also provide a foundation for future research aimed at improving outcomes for patients worldwide.

Acknowledgments

Declaration of Interest Statement. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. Conflict of interest-None.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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Competing Interests

The authors declare no competing interests.

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Ethical Standards

The research meets all ethical guidelines, including adherence to the legal requirements of the study country.

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KEY ISSUE FEATURES OF EXPANDING THE SCOPE AND FUNCTIONALITY OF THE LIBRARY OF DEGRADABLE TRIAZOLE „CLICK” POLYMERS FOR DIVERSE BIOMEDICAL INNOVATION APPLICATIONS: ADVANCES, CHALLENGES, FUTURE DEVELOPMENT STRATEGIES, AND EMERGING PRACTICAL IMPLEMENTATION APPROACHES

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ABSTRACT

A series of new aliphatic AA-BB-type poly(ester ether amide)s (PEEAs) and poly(ester ether)s (PEEs) containing 1,2,3-triazole rings in the main chain were successfully obtained. The synthesis of the “click” polymers was performed *via* Cu(I)-catalyzed click step-growth polymerization (SGP) employing the efficient one pot/two-step synthetic approach that we had previously developed. The structure of the polymers was confirmed by FT-IR and NMR spectroscopy. The newly synthesized materials were extensively characterized, including assessments of their yield, solubility, film-forming properties, molecular weights, and molecular weight distribution. The obtained PEEAs and PEEs exhibited a quite satisfactory degree of polymerization, good film-forming properties, and favorable solubility behavior. The reported materials enlarge a library of

available degradable triazole click polymers promising for a wide range of biomedical applications. The results validate once again the applicability of our innovative synthetic strategy for designing various classes of triazole-backbone degradable click polymers. Degradable triazole-based “click” polymers have emerged as a versatile and indispensable class of materials in biomedical innovation. Their unique properties, such as biocompatibility, tunable degradability, and ease of synthesis via “click” chemistry, have made them highly attractive for diverse applications, ranging from drug delivery systems to tissue engineering scaffolds. Expanding their scope and functionality remains a pivotal goal to meet the growing demands of advanced biomedical technologies. This article explores the advances, challenges, opportunities, future development strategies, and emerging practical implementation approaches for these polymers. The field of degradable triazole “click” polymers is poised for significant advancements in biomedical innovation. As the library of these polymers expands, it is important to balance the opportunities they offer with the challenges they present. By focusing on controlled synthesis, enhanced biological interactions, and scalable production, researchers and clinicians can harness the full potential of these materials. With continued development and collaboration, these polymers could become a cornerstone of next-generation biomedical therapies, leading to improved patient outcomes and more sustainable healthcare solutions. The study successfully demonstrates the synthesis of new poly(ester ether amide)s (PEEAs) and poly(ester ether)s (PEEs) incorporating 1,4-disubstituted 1,2,3-triazole rings in their backbone. The materials exhibit promising properties that make them potential candidates for a variety of biomedical applications, particularly in controlled drug delivery and tissue engineering. However, further research is needed to fully explore their clinical potential, optimize their properties, and address challenges related to their large-scale production and biological interactions.

Keywords: Poly(ester ether amide)s, (PEEAs) poly(ester ether)s, (PEEs) copper(i), catalyzed azide-alkyne cycloaddition, (CuAAC) step growth polymerization (SGP) 1,2,3-triazole ring.

Introduction

Degradable triazole-based “click” polymers have emerged as a versatile and indispensable class of materials in biomedical innovation. Their unique properties, such as biocompatibility, tunable degradability, and ease of synthesis via “click” chemistry, have made them highly attractive for diverse applications, ranging from drug delivery systems to tissue engineering scaffolds. Expanding their scope and functionality remains a pivotal goal to meet the growing demands of advanced biomedical technologies. This article explores the advances, challenges, opportunities, future development strategies, and emerging practical implementation approaches for these polymers.

Advances in Degradable Triazole “Click” Polymers

Synthetic Innovations:

- Introduction of novel monomers and polymerization techniques has significantly broadened the library of triazole-based polymers.
- Controlled polymerization strategies enable precise tailoring of molecular weights and architectures, including linear, branched, and network structures.

Functional Diversity:

- Integration of functional groups has allowed for enhanced interaction with biological systems, enabling applications in targeted drug delivery and imaging.

- Multi-stimuli-responsive systems have been developed for controlled degradation under specific physiological conditions.

Biomedical Applications:

- **Drug Delivery:** High loading capacities and tunable release profiles make these polymers ideal carriers for chemotherapeutics, antibiotics, and gene therapies.
- **Tissue Engineering:** Biodegradable scaffolds support cell attachment, proliferation, and differentiation while degrading into non-toxic byproducts.
- **Diagnostics:** Functionalized triazole polymers serve as contrast agents in imaging and biosensing applications.

Challenges in Expanding the Scope and Functionality

- **Synthetic Complexity:**
- Achieving scalable, cost-effective synthesis of highly functionalized triazole polymers remains a significant hurdle.

Biocompatibility and Safety:

- Comprehensive in vivo studies are required to ensure long-term biocompatibility and to understand degradation pathways and byproducts.

Regulatory Hurdles:

- The stringent regulatory requirements for biomedical materials pose challenges for clinical translation.

Integration with Emerging Technologies:

- Compatibility with advanced biomedical tools such as 3D bioprinting and microfluidics is still underexplored.

Opportunities for Innovation

Interdisciplinary Collaboration:

- Partnerships between chemists, biologists, engineers, and clinicians can accelerate innovation and application.

Customization for Personalized Medicine:

- Tailoring polymer properties to meet individual patient needs in drug delivery and tissue engineering.

Green Chemistry Approaches:

- Development of sustainable, eco-friendly synthetic methods for triazole polymers.

Integration with Smart Materials:

- Combining triazole polymers with stimuli-responsive or bioactive materials to create multifunctional systems.

Future Development Strategies

Advanced Synthesis Techniques:

- Leveraging automation, artificial intelligence, and machine learning for the design and synthesis of complex polymer architectures.

Comprehensive Characterization:

- Employing state-of-the-art analytical tools to study polymer structure, functionality, and degradation mechanisms.

Enhanced Biocompatibility Testing:

- Long-term in vitro and in vivo evaluations to ensure safety and efficacy.

Clinical Translation:

- Establishing partnerships with industry and regulatory bodies to streamline the transition from laboratory research to practical applications.

Emerging Practical Implementation Approaches

3D Printing and Bioprinting:

- Utilization of triazole-based polymers as bioinks for creating customized biomedical devices and tissue constructs.

Nanotechnology Integration:

- Designing nanoscale polymeric systems for precision medicine applications.

Hybrid Systems:

- Developing composite materials that combine the benefits of triazole polymers with other biomaterials for enhanced performance.

Digital Health and Monitoring:

- Incorporating triazole polymers into wearable biosensors and diagnostic tools for real-time health monitoring.

The Copper(I) catalyzed azide-alkyne cycloaddition (CuAAC) stands as a prominent tool within the realm of "click" reactions, showcasing its widespread utility across diverse domains in contemporary polymer and material science. This reaction has gained significant recognition due to its exceptional attributes, including rapid reaction kinetics, high efficiency, precise regioselectivity, tolerance towards diverse functional groups, and mild reaction conditions. Consequently, CuAAC click reactions have found extensive application in the synthesis of various polymer architectures, such as block-copolymers, cyclic polymers, dendrimers, hyper-branched macromolecules, star-shaped polymers, and cross-linked polymeric networks [1-11]. Furthermore, this technique has been instrumental in functionalizing and modifying the surfaces of polymeric materials.

Intrigued by its potential, synthetic polymer chemists have sought to leverage CuAAC for the synthesis of polytriazoles through step-growth polymerization (SGP) since 2004 [12-15]. Despite notable advancements, this field remains in a state of continuous development, beset by numerous challenges and obstacles [14-15]. Specifically, there is a paucity of reports detailing the synthesis of aliphatic main-chain triazole degradable polymers through CuAAC-based click SGP. Noteworthy contributions include the pioneering work of Nagao and Takasu [16], who successfully synthesized degradable polyesters (PEs), and the efforts of Galbis et al. [17], who produced click PEs on the basis of erythritol, bearing free hydroxyl groups. Beyond these achievements, click polymerization has also been harnessed for the fabrication of various other biomedical materials [18-24].

It should be noted that click polymers with 1,2,3-triazole rings in the backbone have some important advantages. To commence with, the triazole rings are known to be low-toxic moieties [25,26] with a high level of mimicry of the amide bond of native peptides: the 1,2,3-triazole ring is structurally similar to the amide bond of proteins in terms of configuration, distance, and planarity [27]. So, the incorporation of the triazole units in the polymeric chains is anticipated to enhance the biocompatibility of the materials. Furthermore, the insertion of rigid triazole fragments in the polymeric structure can notably improve the thermal characteristics of the polymers [28]. It is known that triazole's derivatives demonstrate a wide range of biological activities, including anti-inflammatory, antioxidant, antiviral, antimicrobial, antifungal, anticancer, analgesic, etc. [29,30]. Therefore, the click polymers with triazole rings in the backbone are expected to reveal some biological activities, and such polymers can be promising

for creating new bioactive materials. It is worth noting that 1,2,3-triazoles are widely used in the design of various high-performance organic coatings such as anti-microbial, anti-fouling, anti-corrosive, self-healing, etc. [31]. Thus, the triazole-enriched click polymers can be considered as perspective materials for creating effective polymeric coatings as well.

Moreover, an important advantage of click polymers lies in the quaternizable nature of 1,2,3-triazole rings, as documented in prior studies [32,33]. This characteristic facilitates subsequent post-polymerization functionalization of these polymers. The process of quaternization, involving the modification of triazole rings with diverse quaternizing agents such as halo-alkyls and polyethylene glycol (PEG) derivatives, presents opportunities for creating cationic systems featuring 1,2,3-triazolium moieties within the polymer backbone. This includes the development of cationic polymers and amphiphilic surfactants (e.g., when employing PEG-bromides as quaternizing agents) and the formation of cross-linked hydrogels (when utilizing bifunctional quaternizing agents like dibromo-PEGs, for instance). These approaches hold significant promise for a multitude of biomedical applications.

To synthesize new high-molecular-weight 1,2,3-triazole containing degradable polymers, we have previously elaborated a new synthetic strategy of CuAAC-based click SGP [28]. Our innovative approach could be considered as more versatile compared to existing strategies and allows to synthesize different types (AB and AA-BB) and classes (PEs, poly(ester amide)s, poly(ester urea)s, their co-polymers, etc.) of aliphatic hetero-chain click polymers, avoiding the utilization of potentially explosive organic azides through safe and facile one-pot/two-step procedure. In the mentioned work [28], we successfully synthesized a series of novel linear AA-BB type 1,2,3-triazole rings-containing click PEs following the new strategy. Obtained on the basis of non-toxic building blocks (fatty diols and dicarboxylic acids), the new polymers possessed high molecular weights, improved thermal characteristics, good solubility in organic solvents, film- and nanoparticles-forming properties. Very recently, we demonstrated the suitability of the new synthetic approach for designing novel hydrolytically degradable AB-type click PEs and Co-PEs as well [34].

In the present work, we report on the successful synthesis of two other classes of new linear AA-BB-type degradable click polymers *via* our efficient synthetic strategy: poly(ester ether amide)s (PEEAs) and poly(ester ether)s (PEEs). The key homo-bifunctional diyne monomers were synthesized by the interaction of sebacoyl chloride with propargyl alcohol or propargylamine according to Figure 1.

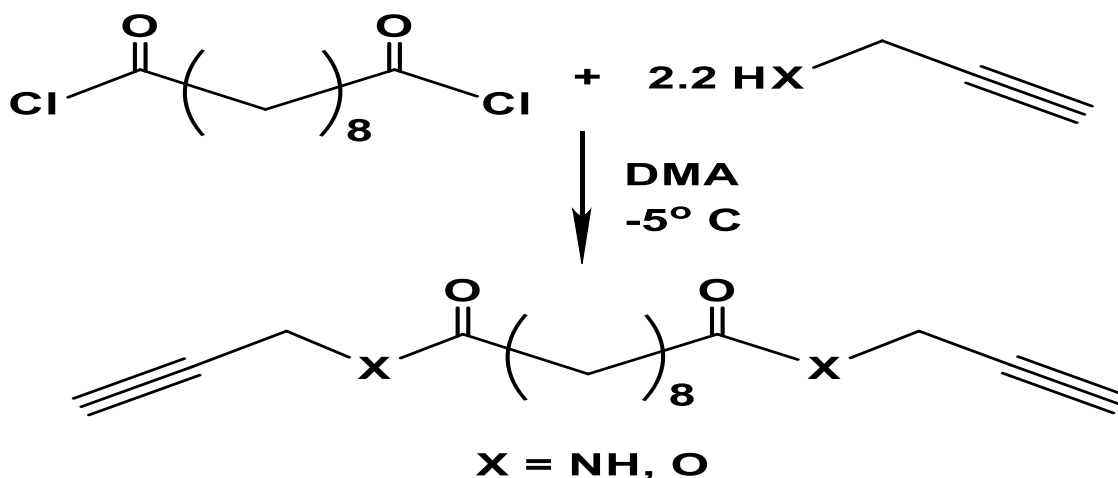


Figure 1. Synthesis of diyne monomers.

The synthetic precursors of target diazide monomers (bis-bromoacetyl derivatives) were obtained by the interaction of bromoacetyl bromide with di-, tri-, and tetra-ethylene glycol (Figure 2).

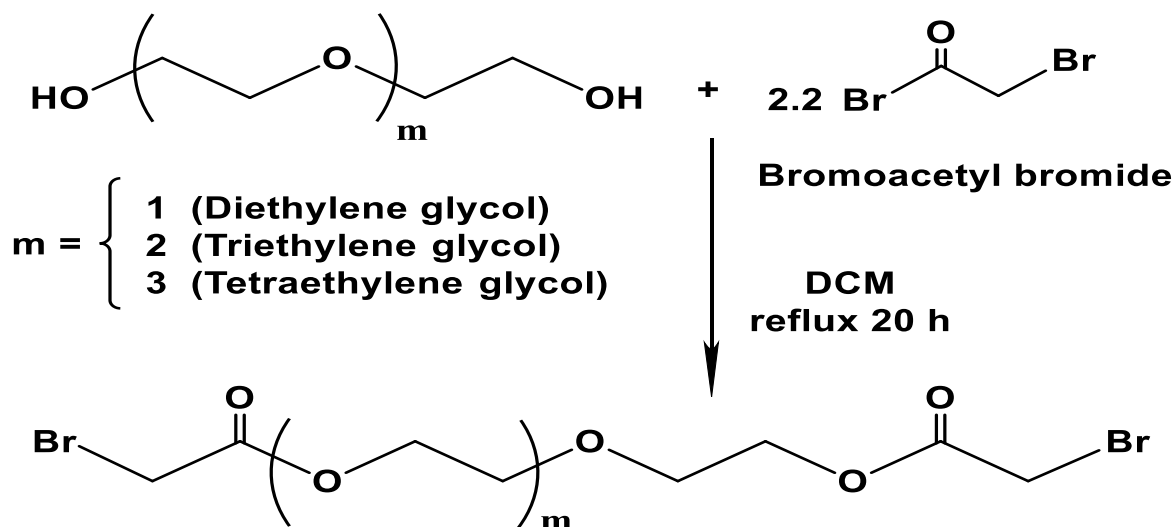


Figure 2. Synthesis of bis-bromoacetyl derivatives.

The synthesis of the new click polymers with triazole rings in the backbone was realized by one-pot/two-step SGP of the homo-bifunctional monomers in the presence of sodium azide using copper(I) iodide/triethylamine (CuI/NEt₃) as a catalytic system (Figure 3).

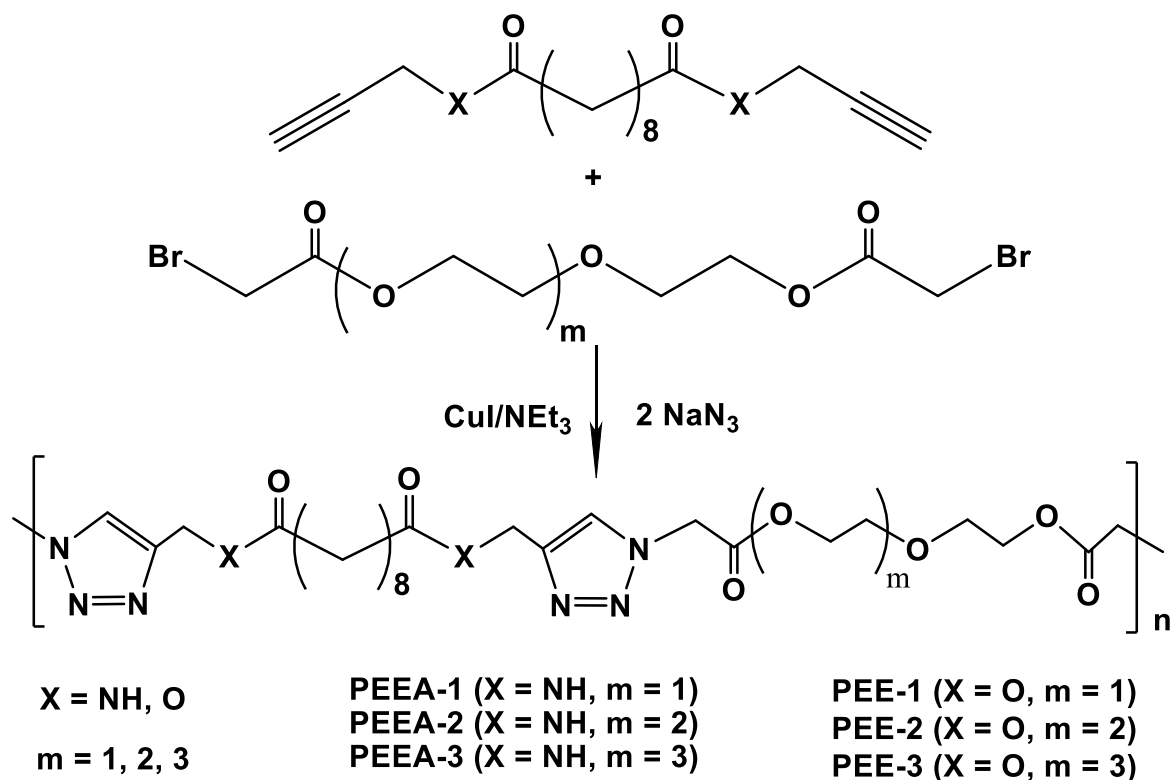


Figure 3. Synthesis of PEEAs ($\text{X}=\text{NH}$) and PEEs ($\text{X}=\text{O}$).

The confirmation of monomer and polymer structures was performed through the use of FT-IR and NMR spectroscopic techniques. Comprehensive polymer characterization encompassed the assessment of yield, solubility in organic solvents, film-forming attributes, determination of molecular weights, and evaluation of molecular weight distribution. The introduction of novel AA-BB-type PEEAs and PEEs serves to enrich the existing repository of degradable click polymers, broadening the spectrum of materials available for a diverse array of biomedical applications.

Experimental methods and materials

Materials

Broboacetyl bromide, propargyl alcohol, propargylamine, sodium azide, anhydrous sodium sulfate, copper(I) iodide, lithium bromide, aluminum oxide (alumina) (activated, basic, Brockmann I), acetone, ethanol, methanol, hexane, ethyl acetate, dichloromethane (DCM), N,N-Dimethylformamide (DMF), N,N-dimethyl-acetamide (DMA), and 1,1,1,3,3,3-hexa-fluoro-isopropanol (HFIP) were purchased from Sigma-Aldrich (Germany). N-methylpyrrolidone (NMP) was purchased from Carl Roth, Karlsruhe (Germany). Triethylamine (TEA) was purchased from Lancaster (UK). All the starting materials, chemicals, and solvents purchased from the commercial sources were used without further purification.

Characterization

The polymers synthesized were characterized by Fourier-transform infrared spectroscopy (FT-IR), ^1H nuclear magnetic resonance (NMR) spectroscopy, and gel permeation chromatography (GPC).

The IR analysis of samples was performed on Thermo Nicolet Avatar 370 FT-IR spectrophotometer coupled with EZ OMNIC software measuring between wavelength range of 4000 and 400 cm^{-1} . The FT-IR spectra of monomers were recorded using Avatar Multi-Bounce Flat Plate 45 degree Ge. To obtain the spectra of polymers, the thin films were cast from HFIP solution on KBr plates, the solvent was evaporated at room temperature and films were dried in a vacuum at 40°C to a constant weight.

The ^1H and NMR spectra were recorded at 300 K on a JEOL ECP 500 NMR spectrometer operating at 400 MHz. DMSO- d_6 was used as solvents and internal standards. The chemical shifts (δ) in the spectra are conventionally expressed in parts per million (ppm).

The weight-average (M_w), number-average (M_n) molecular weights, and molecular weight distribution (Dispersity, \bar{D}) of the polymers were determined on a GPC machine (Waters Associates, Inc., Milford, United States) comprising two Styragel columns in DMF: HR4 and HR3 ($7.8\text{ mm} \times 300\text{ mm}$) and equipped with a high-pressure liquid chromatography pump (Waters 1525 Binary HPLC) and a Waters refractive index detector 2414 and UV-detector (Waters 2487 dual absorbance detector, $\lambda = 240\text{ nm}$). A solution of LiBr (0.05 M) in DMF was used as an eluent. Injected volume $100\text{ }\mu\text{L}$, flow rate 1.0 mL min^{-1} . The columns were calibrated with poly(methyl methacrylate) standards ($M_n = 500 - 500,000\text{ g mol}^{-1}$). Polymer sample solutions with concentration 5 mg mL^{-1} were prepared in the GPC eluent and filtered with PTFE filters ($0.45\text{ }\mu\text{m}$) prior to injection.

Synthesis of diyne monomers

The key homo-bifunctional diyne monomers (di-propargyl amide/ester of sebacic acid) were synthesized by the interaction of sebacoyl chloride with propargylamine or propargyl alcohol according to Figure 1. The synthesis was carried out in DMA solution without using tertiary amine as HCl acceptor. In a typical procedure, propargylamine/propargyl alcohol (0.159 mol – an excess) was dissolved in 260 mL of DMA, the solution was chilled to -5°C and 17.30 g of sebacoyl chloride (0.072 mol) was added dropwise upon stirring using a magnetic stirrer. The reaction solution was stirred for 30 min at -5°C and then was continued at room temperature for 24 h . Afterwards, the solution was poured into water and the vessel with precipitated white powder was placed overnight in a refrigerator. The obtained solid product was filtered off, dried under reduced pressure at room temperature, and recrystallized from the ethanol/hexane mixture.

Di-propargyl amide of sebacic acid. Yield: 68 %. FTIR (cm^{-1}): 3280 ($-\text{NH}-$, amide, stretching vibr.), 2132 ($\text{C}\equiv\text{C}$), 1642 ($-\text{CO}-$, amide), 1552 ($\text{NH}-$, amide, bending vibr.). ^1H NMR (400 MHz, DMSO- d_6 , δ): 1.28-1.32 (8H, m, CH_2); 1.54 (4H, m, $\text{CH}_2\text{CH}_2\text{CO}$); 2.16 (4H, t, CH_2CO); 3.04 (2H, t, sp- CH); 4.11 (4H, d, NHCH_2), 8.12 (2H, NH).

Di-propargyl ester of sebacic acid. Yield: 75 %. FTIR (cm^{-1}): 3238 ($\equiv\text{C}-\text{H}$), 2128 ($\text{C}\equiv\text{C}$), 1732 ($-\text{CO}-$ ester), 1217 ($\text{C}-\text{O}-\text{C}$). ^1H NMR: (400 MHz, DMSO- d_6 , δ): 1.29-1.35 (8H, m, CH_2); 1.59 (4H, m, $\text{CH}_2\text{CH}_2\text{CO}$); 2.30 (4H, t, CH_2CO); 2.93 (2H, t, sp- CH); 4.61 (4H, d, OCH_2).

Synthesis of bis-bromoacetyl derivatives (precursors of diazide monomers)

The synthetic precursors of target diazide monomers (bis-bromoacetyl derivatives) were synthesized by the interaction of bromoacetyl bromide with di- (DEG), tri- (TEG), and tetra-ethylene glycol (TTEG) according to Figure 2 above. The brief synthetic procedure is described here on the example of DEG-based bis-bromoacetyl derivative: to a solution of 6.09 g (0.057 mol) of DEG in 315 mL of DCM, 25.52 g (0.126 mol) of bromoacetyl bromide was added. The resulting yellow solution was refluxed for 20 h and the solvent was removed in a vacuum on a rotary evaporator yielding a brownish viscous liquid. The obtained crude product was dissolved in 40 mL of methanol and the solution was washed with 40 mL of hexane. The mixture was separated using a separated funnel and the procedure was repeated twice (i.e. methanol solution of the crude product was washed 3 times with hexane). After the last separation of the mixture, the methanol solution of the monomer was dried over anhydrous sodium sulfate, then it was filtered and the organic solvent was removed in a vacuum on a rotary evaporator, yielding a brownish viscous liquid. DEG- and TTEG-based bis-bromoacetyl derivatives were synthesized according to the same procedure.

DEG-based bis-bromoacetyl derivative. Yield: 69 %. FTIR (cm^{-1}): 1740 (-CO-, ester), 1282 (C-O-C, ester), 1123 (C-O-C, ether). ^1H NMR (400 MHz, DMSO- d_6 , δ): 3.51 (4H, $\text{CH}_2\text{-O-CH}_2$), 4.11 (4H, COO-CH_2), 4.21 (4H, CO-CH_2).

TEG-based bis-bromoacetyl derivative. Yield: 76 %. FTIR (cm^{-1}): 1736 (-CO-, ester), 1278 (C-O-C, ester), 1115 (C-O-C, ether). ^1H NMR (400 MHz, DMSO- d_6 , δ): 3.21-3.63 (8H, $\text{CH}_2\text{-O-CH}_2\text{-CH}_2\text{-O-CH}_2$), 4.12 (4H, COO-CH_2), 4.22 (4H, CO-CH_2).

TTEG-based bis-bromoacetyl derivative. Yield: 73 %. FTIR (cm^{-1}): 1744 (-CO-, ester), 1282 (C-O-C, ester), 1116 (C-O-C, ether). ^1H NMR (400 MHz, DMSO- d_6 , δ): 3.13-3.47 (12H, $\text{CH}_2\text{-O-CH}_2\text{-CH}_2\text{-O-CH}_2\text{-CH}_2\text{-O-CH}_2$), 4.09 (4H, COO-CH_2), 4.20 (4H, CO-CH_2).

Polymer synthesis

The target PEEAs and PEEs were synthesized according to the one-pot two-step synthetic strategy that we had previously developed [28,34] (Figure 3). The synthetic procedure is similar to the one applied for the AB-type click PEs reported in our recent work [34]. The brief synthetic procedure for the click SGP of the PEEAs and PEEs is described here for PEEA-1 as an example: 1.902 g (5.46 mmol) of DEG-based bis-bromoacetyl derivative and 0.782g (12.03 mmol) of sodium azide were dissolved in 8.35 mL of NMP and stirred at room temperature for 3 h. Then, 1.511 g (5.46 mmol) of a di-propargyl amide of sebacic acid, 31.24 mg (0.16 mmol) of catalyst CuI (3 mol %), and 0.114 mL (0.82 mmol) of NEt_3 as a ligand were added to the reaction solution. The reaction solution was stirred at room temperature for 24 hours. After completion of the reaction, the solution was diluted with 8 mL of NMP, and the copper catalyst was removed by passing the crude polymer solution through a small column of activated basic alumina. Then, the obtained polymer solution was precipitated in water, filtered, thoroughly washed with water, and dried under vacuum at room temperature. Then, the polymer was twice precipitated from NMP solution (at a concentration of 10% w/v) to water, filtered, and dried under vacuum at room temperature to a constant weight. All the other polymers were synthesized employing the same synthetic procedure.

PEEA-1. Yield: 73 %. FTIR (cm^{-1}): 3297 (-NH-, amide, stretching vibr.), 3068 (C=C-H of the 1,2,3-triazole), 1752 (-CO-, ester), 1638 (-CO-, amide), 1544 (NH-, amide, bending vibr.), 1217 (C-O-C, ester), 1135 (C-O-C, ether). ^1H NMR (400 MHz, DMSO- d_6 , δ): 1.01 (12H, $\text{CH}_2\text{-(CH}_2\text{)}_6\text{-}$

CH₂), 1.85 (4H, CO-CH₂-(CH₂)₆-CH₂-CO), 3.24-3.50 (4H, CH₂-O-CH₂), 4.02-4.11 (8H, COO-CH₂ and NH-CH₂-, stack), 5.17 (4H, CO-CH₂-N), 7.68 (2H, -C=CH of triazole), 8.16 (2H, NH).

PEEA-2. Yield: 94 %. FTIR (cm⁻¹): 3293 (-NH-, amide, stretching vibr.), 3063 (C=C-H of the 1,2,3-triazole moiety), 1744 (-CO-, ester), 1638 (-CO-, amide), 1544 (NH-, amide, bending vibr.), 1217 (C-O-C, ester), 1131 (C-O-C, ether). ¹H NMR (400 MHz, DMSO-d₆, δ): 1.07 (12H, CH₂-(CH₂)₆-CH₂), 1.82 (4H, CO-CH₂-(CH₂)₆-CH₂-CO), 3.23-3.65 (8H, CH₂-O-CH₂-CH₂-O-CH₂), 4.03-4.12 (8H, COO-CH₂ and NH-CH₂-, stack), 5.18 (4H, CO-CH₂-N), 7.70 (2H, -C=CH of triazole), 8.14 (2H, NH).

PEEA-3. Yield: 89 %. FTIR (cm⁻¹): 3297 (-NH-, amide, stretching vibr.), 3076 (C=C-H of the 1,2,3-triazole), 1752 (-CO-, ester), 1638 (-CO-, amide), 1543 (NH-, amide, bending vibr.), 1225 (C-O-C, ester), 1127 (C-O-C, ether). ¹H NMR (400 MHz, DMSO-d₆, δ): 0.99 (12H, CH₂-(CH₂)₆-CH₂), 1.84 (4H, CO-CH₂-(CH₂)₆-CH₂-CO), 3.14-3.45 (12H, CH₂-O-CH₂-CH₂-O-CH₂-CH₂-O-CH₂), 3.93-4.08 (8H, COO-CH₂ and NH-CH₂-, stack), 5.13 (4H, CO-CH₂-N), 7.66 (2H, -C=CH of triazole), 8.07 (2H, NH).

PEE-1. Yield: 93 %. FTIR (cm⁻¹): 3145 (C=C-H of the 1,2,3-triazole), 1744 (-CO-, ester), 1213 (C-O-C, ester), 1164 (C-O-C, ether). ¹H NMR (400 MHz, DMSO-d₆, δ): 0.87 (12H, CH₂-(CH₂)₆-CH₂), 1.90 (4H, CO-CH₂-(CH₂)₆-CH₂-CO), 3.29 (4H, CH₂-O-CH₂), 3.91 (4H, COO-CH₂-CH₂), 4.78 (4H, COO-CH₂-C), 5.10 (4H, CO-CH₂-N), 7.83 (2H, -C=CH of triazole).

PEE-2. Yield: 87 %. FTIR (cm⁻¹): 3141 (C=C-H of the 1,2,3-triazole), 1740 (-CO-, ester), 1213 (C-O-C, ester), 1168 (C-O-C, ether). ¹H NMR (400 MHz, DMSO-d₆, δ): 0.99 (12H, CH₂-(CH₂)₆-CH₂), 2.07 (4H, CO-CH₂-(CH₂)₆-CH₂-CO), 3.30 (8H, CH₂-O-CH₂-CH₂-O-CH₂), 4.02 (4H, COO-CH₂-CH₂), 4.91 (4H, COO-CH₂-C), 5.20 (4H, CO-CH₂-N), 7.93 (2H, -C=CH of triazole).

PEE-3. Yield: 85 %. FTIR (cm⁻¹): 3145 (C=C-H of the 1,2,3-triazole), 1752 (-CO-, ester), 1209 (C-O-C, ester), 1164 (C-O-C, ether). ¹H NMR (400 MHz, DMSO-d₆, δ): 0.97 (12H, CH₂-(CH₂)₆-CH₂), 2.04 (4H, CO-CH₂-(CH₂)₆-CH₂-CO), 3.26 (12H, CH₂-O-CH₂-CH₂-O-CH₂-CH₂-O-CH₂), 4.02 (4H, COO-CH₂-CH₂), 4.88 (4H, COO-CH₂-C), 5.17 (4H, CO-CH₂-N), 7.91 (2H, -C=CH of triazole).

Results and discussion

Synthesis of diyne monomers

The detailed procedure of the synthesis of key homo-bifunctional diyne monomers (di-propargyl amide/ester of sebacic acid) was discussed above. The AA-BB-type monomers were synthesized by the interaction of sebacoyl chloride with propargylamine or propargyl alcohol (Figure 1). The yields of the obtained di-propargyl amide of sebacic acid and di-propargyl ester of sebacic acid were 68 and 75 %, respectively. The presumed structure of the diyne monomers was proved by FT-IR and ¹H NMR spectroscopies.

Synthesis of bis-bromoacetyl derivatives (precursors of diazide monomers)

The synthesis of bis-bromoacetyl derivatives – precursors of diazide monomers, was described above (see Materials and methods). Three bis-bromoacetates were obtained by the interaction of bromoacetyl bromide with di- (DEG), tri- (TEG), and tetra-ethylene glycol (TTEG) (see Figure 2 above). The yields of the obtained bis-bromoacetyl derivatives were in the range of 69 – 76 %. Their structure was confirmed by FTIR and ¹H NMR spectroscopies.

Synthesis of the click PEEAs and PEEs

Six new triazole click polymers (three PEEAs and three PEEs) were synthesized *via* one-pot/two-step synthetic strategy that we had previously [28,34] developed. The detailed procedure of the synthesis of target click polymers was discussed above (see *Experimental Methods and Materials*).

The polymers were obtained with quite high yields (73 – 94 %). The molecular weight characteristics of the new click polymers such as weight-average (M_w), number-average (M_n) molecular weights, and molecular weight distribution (D) were determined using the GPC system with PMMA standards. Due to the insolubility of the PEEA-1 in DMF, it was not characterized by the GPC technique. According to the obtained data, given in Table 1, the new click polymers possess average molecular weights (M_w is in the range of 14,500 – 34,800 g mol⁻¹) and display moderately wide molecular weight distribution ($D = 1.47 – 1.60$). The degree of polymerization of the polymers is quite satisfactory for step-growth polymers (the DP is in the range of 16 - 42).

Table 1. Characteristics of the obtained click PEEAs and PEEs.

Polymer	M_w (g mol ⁻¹)	M_n (g mol ⁻¹)	D	DP
PEEA-2	14,500	9,300	1.55	16
PEEA-3	16,600	11,400	1.47	18
PEE-1	34,800	23,100	1.51	42
PEE-2	28,300	17,800	1.60	30
PEE-3	27,100	17,200	1.58	27

D - Dispersity (M_w/M_n); DP - degree of polymerization

To assess the film-forming abilities of the new polymers, the thin films were cast from HFIP solutions on polytetrafluoroethylene dishes, the solvent was allowed to evaporate at room temperature, and the generated films were finally dried in a vacuum at room temperature to a constant weight. With the exception of PEEA-1 and PEE-1, which formed brittle films, all the other click polymers revealed good elastic film-forming properties. The poor elasticity of the films produced by DEG-based polymers PEEA-1 and PEE-1 can be attributed to the highest rigidity of their molecular structure stipulated by the shortness of their monomeric units (only two $-\text{CH}_2-\text{CH}_2-\text{O}-$ fragments per monomeric unit).

Spectral studies

The structure of the click PEEAs and PEEs was investigated using FT-IR and NMR spectroscopy. Both methods confirmed the presumed structure of the new click polymers. The FT-IR study proved the presence of all IR-detectable functional moieties of the polymers. All the expected absorption bands were observed: 3297 - 3293 cm⁻¹ attributed to the stretching vibration of amide NH, 3145 – 3063 cm⁻¹ corresponding to stretching vibration of C=C-H of the 1,2,3-triazole ring,

1752 - 1740 cm^{-1} ascribed to ester $\text{C}=\text{O}$, 1638 – 1636 cm^{-1} distinctive for amide CO , 1544 – 1543 cm^{-1} expected for the bending vibration of amide NH , 1225 - 1209 cm^{-1} characteristic of ester $\text{C}-\text{O}-\text{C}$ moiety, and 1168 - 1127 cm^{-1} typical for ether $\text{C}-\text{O}-\text{C}$. The detailed ^1H NMR studies of the PEEAs and PEEs demonstrated precise regioselectivity of Cu(I) catalyzed click SGP: single signals of 1,2,3-triazole protons ($\text{C}=\text{C}-\text{H}$) at 7.66 – 7.93 ppm in the ^1H NMR spectra of the polymers confirmed the presence of exclusively 1,4-disubstituted 1,2,3-triazole rings in the macromolecular chains.

Solubility of the click PEEAs and PEEs

The solubility of the new click PEEAs and PEEs in ten common organic solvents (10.0 mg in 1.0 mL) is presented in Table 2. All the new polymers were insoluble in common solvents such as DCM, ethanol, acetone, acetonitrile, and ethyl acetate even upon heating. Overall, PEEs revealed better solubility as compared to PEEAs. All the PEEs displayed good solubility in polar solvents such as DMSO, NMP, DMF, DMA, and HFIP at room temperature. Expectedly, the best solubility among the PEEAs was demonstrated by TTEG-based PEEA-3 which was readily soluble in DMSO and HFIP at room temperature and in NMP, DMF, and DMA upon heating. The poorest solubility of the PEEA-1, which was soluble only in DMSO, NMP, and HFIP, may be attributed to the increased rigidity of the molecular architecture conditioned by the shortness of the monomeric unit (only two $-\text{CH}_2-\text{CH}_2-\text{O}-$ fragments per monomeric unit). The poor solubility behavior of PEEAs compared to PEEs can presumably be ascribed to the increased rigidity of the macromolecular backbone and stronger intermolecular forces stipulated by the robust amide bonds.

Table 2. Solubility of the click PEEAs and PEEs (10 mg of polymer in 1 mL of solvent).

Polymer	DMSO	NMP	DMF	DMA	HFIP	DCM	EtOH	Acetone	CH_3CN	EtAc
PEEA-1	+t	+t	-	-	+	-	-	-	-	-
PEEA-2	+t	+t	+t	+t	+	-	-	-	-	-
PEEA-3	t	+t	+t	+t	+	-	-	-	-	-
PEE-1	+	+	+	+	+	-	-	-	-	-
PEE-2	+	+	+	+	+	-	-	-	-	-
PEE-3	+	+	+	+	+	-	-	-	-	-

+ soluble at room temperature; +t soluble upon heating; - insoluble

Three new linear AA-BB-type poly(ester ether amide)s (PEEAs) and three poly(ester ether)s (PEEs) containing 1,4-disubstituted 1,2,3-triazole rings in the main chain were successfully synthesized through Cu(I) -catalyzed click step-growth polymerization (SGP) using homo-bifunctional monomers following one-pot/two-step synthetic strategy we have previously

elaborated. The presumed structure of the new polymers was confirmed by FT-IR and NMR techniques. The click polymers with average molecular weights ($M_w = 14,500 - 34,800 \text{ g mol}^{-1}$) and moderately wide molecular weight distribution (1.47 – 1.60) were obtained in quite good yields (73 – 94 %). The degree of polymerization of the materials was quite satisfactory for step-growth polymers ($DP = 16 - 42$), allowing most of them to form elastic films. The click polymers reported in this work expand a library of available degradable polymers with functionally interesting 1,2,3-triazole moieties in the backbone. The new polymers obtained can be considered as having a potential for various biomedical applications.

The development of new polymers with tailored properties is crucial for advancing various industrial and biomedical applications. This study explores the synthesis of three novel linear poly(ester ether amide)s (PEEAs) and poly(ester ether)s (PEEs) that incorporate 1,4-disubstituted 1,2,3-triazole rings in their main chains. The synthesis is achieved through Cu(I)-catalyzed click step-growth polymerization (SGP), employing a one-pot/two-step strategy previously outlined by the research team. Here, we discuss the significance of these newly synthesized polymers, their potential for biomedical applications, and the implications for future developments.

Synthesis and Structural Confirmation

The synthesis of these polymers using a click chemistry approach ensures that the desired 1,4-disubstituted 1,2,3-triazole units are efficiently integrated into the polymer backbone. The use of Cu(I)-catalyzed click polymerization provides several advantages, including high selectivity, mild reaction conditions, and the ability to precisely control the polymer's structure. The resulting polymers were confirmed via FT-IR and NMR techniques, which validate their structure and the incorporation of the triazole ring.

The synthesis of PEEAs and PEEs with molecular weights ranging from 14,500 to 34,800 g/mol and moderately wide molecular weight distributions (1.47 – 1.60) highlights the feasibility of producing high-quality, functional materials. The degree of polymerization (DP) of the materials, ranging from 16 to 42, indicates that these polymers are well-suited for step-growth polymerization, a key feature for developing materials with predictable and reproducible properties.

Properties and Characterization

The new polymers demonstrated desirable properties such as good yield (73 – 94 %) and the ability to form elastic films. This suggests that the incorporation of 1,4-disubstituted 1,2,3-triazole units enhances the mechanical flexibility of the polymers, making them suitable for applications where elasticity and toughness are required. The molecular weight distribution and the degree of polymerization indicate that these materials have a good balance of processability and performance, essential for practical uses in biomedical devices.

Biomedical Application Potential

The incorporation of 1,2,3-triazole rings in the polymer backbone provides significant functional diversity, which is a promising feature for biomedical applications. Triazole units are known for their biocompatibility, stability, and ability to engage in various chemical interactions, making them ideal candidates for use in drug delivery systems, tissue engineering, and other medical devices. These polymers' degradability, an essential feature for many biomedical applications, further enhances their potential for use in medical implants and controlled-release systems.

Given their tunable properties and functional groups, these polymers could be developed for specific applications in drug delivery, where the degradation rate can be tailored to match the therapeutic needs. Additionally, the flexibility of these polymers could be leveraged in applications such as tissue scaffolds, where mechanical properties and biocompatibility are crucial for supporting tissue regeneration.

Future Development and Challenges

While the synthesis and properties of these polymers are promising, further optimization is required to fully realize their potential in biomedical applications. Future work could focus on improving the control over polymer architecture, which may further enhance the properties of the materials. Additionally, a more in-depth study of the degradation kinetics and in vivo biocompatibility of these polymers is necessary to assess their performance in biological environments.

Challenges remain in scaling up the synthesis for industrial applications while maintaining the material's performance and reproducibility. Moreover, the interaction of these new polymers with biological systems, such as immune responses, cytotoxicity, and long-term degradation behavior, will need to be carefully evaluated.

Expanding the scope and functionality of degradable triazole "click" polymers holds immense promise for driving biomedical innovation. By addressing current challenges and leveraging emerging opportunities, researchers can unlock the full potential of these materials. Future advancements will depend on interdisciplinary collaboration, integration with cutting-edge technologies, and a commitment to sustainability and safety. The continued evolution of triazole polymers will undoubtedly pave the way for transformative breakthroughs in healthcare and beyond.

The use of degradable triazole "click" polymers in biomedical applications has gained significant attention due to their unique properties, such as biocompatibility, degradability, and tunability. The expansion of this polymer library promises to offer new opportunities for a variety of biomedical innovations, but also presents a number of challenges. In this discussion, we will explore the recent advances, challenges, opportunities, future development strategies, and emerging practical implementation approaches related to these polymers.

Advances in Degradable Triazole "Click" Polymers

Recent studies have significantly expanded the library of triazole-based polymers, enabling better control over their physical, chemical, and biological properties. The introduction of degradable "click" chemistry has allowed for more precise and efficient polymer synthesis, leading to the development of materials with specific degradation profiles, ideal for targeted drug delivery, tissue engineering, and implantable devices. These polymers can be engineered to degrade under physiological conditions, minimizing the long-term environmental and toxicological risks associated with traditional synthetic polymers.

Challenges in Expanding the Scope and Functionality

Despite these advances, there are several challenges in expanding the scope and functionality of these polymers. The complexity of developing polymers with both controlled degradation rates and appropriate biological activity requires deeper understanding and innovative techniques. Issues such as reproducibility in polymer synthesis, scalability for mass production, and the

optimization of degradation rates to match tissue healing or drug release requirements remain significant hurdles. Furthermore, understanding the interactions between these polymers and the biological systems they are intended to interact with—such as immune response, tissue compatibility, and potential cytotoxicity—is crucial for ensuring their safe use in clinical settings.

Opportunities for Biomedical Innovation

The expanding library of degradable triazole "click" polymers presents numerous opportunities for biomedical applications. These polymers could revolutionize fields like personalized medicine, wound healing, and regenerative medicine by enabling the development of highly tailored biomaterials. Their potential use in controlled drug release systems, particularly in targeted therapies for cancer, diabetes, and cardiovascular diseases, offers promising pathways to improve patient outcomes and reduce side effects. Additionally, the use of these polymers in 3D-bioprinted tissue scaffolds could pave the way for creating more efficient and biologically relevant tissue structures for implantation.

Future Development Strategies

Moving forward, the development of novel synthetic strategies that allow for greater control over the polymer's structure and properties will be critical. Incorporating bioactive molecules into the polymer matrix to enhance cellular interactions and tissue regeneration will also be a key area of focus. Further integration of these polymers with cutting-edge technologies, such as CRISPR-based gene editing and advanced biomaterials, could lead to highly effective combination therapies that address complex medical challenges. Additionally, the improvement of degradation pathways to match specific clinical needs, alongside the use of more sustainable raw materials, will likely play an important role in the future direction of this field.

Emerging Practical Implementation Approaches

The practical implementation of degradable triazole "click" polymers in real-world biomedical applications will require collaboration across multiple disciplines, including materials science, molecular biology, and clinical medicine. Pilot clinical trials and collaborations between academia and industry will be key to moving from theoretical advancements to functional, market-ready products. Innovations such as injectable hydrogels, which can rapidly form in situ and degrade as needed, as well as smart polymers that respond to environmental stimuli, could drive the next wave of biomedical devices and therapeutics. Regulatory challenges and the need for standardized testing protocols will also play a significant role in accelerating the adoption of these materials.

The field of degradable triazole "click" polymers is poised for significant advancements in biomedical innovation. As the library of these polymers expands, it is important to balance the opportunities they offer with the challenges they present. By focusing on controlled synthesis, enhanced biological interactions, and scalable production, researchers and clinicians can harness the full potential of these materials. With continued development and collaboration, these polymers could become a cornerstone of next-generation biomedical therapies, leading to improved patient outcomes and more sustainable healthcare solutions.

Conclusion

The field of degradable triazole "click" polymers is poised for significant advancements in biomedical innovation. As the library of these polymers expands, it is important to balance the

opportunities they offer with the challenges they present. By focusing on controlled synthesis, enhanced biological interactions, and scalable production, researchers and clinicians can harness the full potential of these materials. With continued development and collaboration, these polymers could become a cornerstone of next-generation biomedical therapies, leading to improved patient outcomes and more sustainable healthcare solutions. The study successfully demonstrates the synthesis of new poly(ester ether amide)s (PEEAs) and poly(ester ether)s (PEEs) incorporating 1,4-disubstituted 1,2,3-triazole rings in their backbone. The materials exhibit promising properties that make them potential candidates for a variety of biomedical applications, particularly in controlled drug delivery and tissue engineering. However, further research is needed to fully explore their clinical potential, optimize their properties, and address challenges related to their large-scale production and biological interactions.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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Competing Interests

The authors declare no competing interests.

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Ethical Standards

The research meets all ethical guidelines, including adherence to the legal requirements of the study country.

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MEDICAL SERVICES FOR GIRLS AND WOMEN WITH DISABILITIES IN GEORGIA

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ABSTRACT

Introduction. In Georgia, women and girls with disabilities face intersecting barriers rooted in gender, disability, and socioeconomic disadvantage. Despite legal commitments, systemic obstacles, shaped by post-Soviet legacies and institutional neglect, limit equitable healthcare access, particularly in reproductive services. This study investigates these challenges, revealing a persistent gap between policy frameworks and the everyday healthcare experiences of disabled women.

Methodology. A cross-sectional pilot study was conducted in February 2025 to assess healthcare access among 50 women (aged 18–65) with physical or sensory disabilities in Georgia. Using purposive sampling, participants from various regions were interviewed via structured questionnaires addressing accessibility, finances, transport, insurance, and communication. Data were collected through face-to-face or phone interviews, following ethical standards. Results were contextualized using comparative data from UN, WHO, and UNFPA.

Results and Discussion. This study identified widespread barriers to healthcare for women and girls with disabilities in Georgia, including physical inaccessibility, transport issues, and financial exclusion. Discrimination by providers and lack of accessible information, especially in reproductive health, further hindered access. Most participants were unaware of public programs and had limited involvement in medical decisions. The findings underscore how societal attitudes and institutional neglect perpetuate healthcare inequities beyond infrastructure alone. **Conclusion.** The study shows that women and girls with disabilities in Georgia face multiple barriers to healthcare, including inaccessibility, financial strain, discrimination, and lack of information. These intersecting issues highlight the urgent need for inclusive policies, better infrastructure, and disability-sensitive medical training to ensure equitable care and uphold their rights.

Keywords: Women with disabilities; Access to healthcare; Discrimination; Gender inequality; Accessibility; Georgia.

Introduction

Access to quality medical services is a fundamental human right and a crucial component of inclusive healthcare systems. However, for girls and women with disabilities in Georgia, the reality often falls short of this ideal. The intersection of gender and disability presents complex challenges that are deeply embedded in societal, cultural, infrastructural, and institutional frameworks. While the country has made gradual progress in developing policies for the

protection of individuals with disabilities, significant gaps persist in terms of access to equitable, gender-sensitive, and disability-responsive medical care. These disparities are further exacerbated by widespread social stigma, insufficient professional training in the healthcare sector, limited physical accessibility to healthcare facilities, and a lack of awareness and inclusive public health education programs.

Women and girls with disabilities frequently face systemic discrimination, not only due to their physical or intellectual conditions but also as a result of entrenched gender inequalities. In many cases, healthcare professionals lack the necessary competencies to provide individualized care that aligns with the unique physiological and psychosocial needs of this demographic. The situation is even more severe in rural and remote regions of Georgia, where healthcare infrastructure is underdeveloped and access to specialized services is minimal or nonexistent. The absence of appropriate communication tools and assistive technologies further limits the capacity of healthcare providers to interact effectively with patients who may have sensory or cognitive impairments.

Moreover, social determinants of health—such as poverty, education, transportation, and social inclusion—play a critical role in shaping the health outcomes of girls and women with disabilities. These factors not only influence the availability and affordability of care but also impact patients' ability to seek timely and appropriate medical attention. The lack of disaggregated data by gender and disability further complicates policy development and hinders targeted interventions. Without accurate statistics and evidence-based research, the healthcare system struggles to recognize the extent of the problem and allocate resources accordingly.

International human rights frameworks, including the Convention on the Rights of Persons with Disabilities (CRPD), emphasize the importance of ensuring full and equal access to health services. Georgia, as a signatory to these agreements, bears the legal and moral obligation to implement policies that safeguard the rights of all citizens, particularly those belonging to marginalized populations. However, a critical analysis reveals that practical implementation remains inconsistent. Efforts to integrate disability-inclusive and gender-sensitive approaches into national healthcare planning are still in their infancy, and cross-sectoral coordination between health, education, and social services is weak.

Addressing the key issues surrounding medical services for girls and women with disabilities in Georgia requires a multi-dimensional and collaborative approach. This includes strengthening legal protections, increasing funding for inclusive health infrastructure, fostering professional development in disability competence among healthcare workers, and empowering women with disabilities to participate in decision-making processes that affect their health and well-being. It is only through such a holistic framework that Georgia can fulfill its commitments to equity, social justice, and the right to health for all.

Women and girls with disabilities are among the most marginalized and vulnerable social groups. Women and girls with disabilities constitute one of the most disproportionately marginalized segments of the global population, a status shaped not solely by their impairments but by a complex interplay of social, economic, and structural disadvantages. Across both developed and developing contexts, these individuals face compounded vulnerabilities that emerge at the intersection of disability and gender. The United Nations Population Fund (UNFPA) and the World Health Organization (WHO) have emphasized that this intersectionality amplifies health disparities and social exclusion, as women with disabilities are often subject to double discrimination—based on both gender and physical or

cognitive impairments (UNFPA Georgia, 2020; WHO, 2023). These forms of marginalization are not merely additive but mutually reinforcing, creating a layered system of exclusion that limits access to essential services and undermines fundamental rights.

In Georgia, as in many other countries transitioning from Soviet-era healthcare and welfare systems, the confluence of gender-based stereotypes, inadequate disability services, and infrastructural inaccessibility contributes to entrenched health inequalities. The traditional perception of disability as a private tragedy or charity issue persists in public discourse, often overshadowing rights-based approaches that emphasize dignity, autonomy, and equal participation. This sociocultural backdrop exacerbates the challenges faced by disabled women, who not only struggle with architectural and physical inaccessibility in healthcare settings but also face dismissive attitudes, gendered assumptions, and widespread informational barriers. These realities are compounded by limited public awareness, inadequate data collection, and insufficient representation of women with disabilities in healthcare decision-making (UN Women Georgia, 2021; Office of the Public Defender of Georgia, 2022).

According to the WHO World Health Report (2023), approximately 16% of the global population lives with a disability. This burden is not evenly distributed: women comprise a disproportionately higher share—19.2%, compared to only 12% for men. A similar gender disparity is evident in Georgia, where the National Statistical Office reports that approximately 18.2% of the population lives with a disability, with women outnumbering men by a ratio of approximately 1.5 to 1 (UNDP, 2021). These figures underscore the urgent need for gender-sensitive healthcare strategies that take into account both the prevalence and the lived experiences of disabled women. Public health policies that fail to engage with the gendered dimensions of disability risk perpetuate systemic inequality, even as they nominally aim to promote inclusion.

In response to both global human rights obligations and domestic advocacy, Georgia has taken significant legislative steps in recent years to improve the status of persons with disabilities, with increasing attention to the specific vulnerabilities of women and girls. The ratification of key international instruments—including the Convention on the Rights of Persons with Disabilities (CRPD), the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW), and the Convention on the Rights of the Child (CRC)—signaled the country's commitment to aligning its national legal framework with internationally accepted standards for the protection of marginalized groups (UN Women, 2021; United Nations, 2006). Furthermore, Georgia's alignment with the Beijing Platform for Action and the 2030 Agenda for Sustainable Development has placed gender equality and the inclusion of persons with disabilities at the heart of national development priorities.

These commitments were further solidified through the adoption of the Law on the Rights of Persons with Disabilities in 2020. This law represents a legal and symbolic milestone, introducing the notion of disability not as a medical or charitable condition but as a rights-based social issue. Notably, a dedicated article within the legislation addresses the unique needs of women and girls with disabilities—an explicit recognition that their lived experiences require tailored policy approaches rather than generic solutions. The law mandates the state to ensure equal access to services, promote social inclusion, and safeguard the autonomy of disabled individuals, with particular emphasis on gender-sensitive programming (Law of Georgia on the Rights of Persons with Disabilities, 2020).

Nevertheless, while these legal instruments mark crucial progress, their implementation has faced substantial limitations. The translation of legislative intent into concrete action has been uneven, with critical gaps in service delivery, data monitoring, and inter-agency coordination. National-level strategies, such as the State Healthcare Strategy 2021–2027, acknowledge the inclusion of persons with disabilities as a policy goal but lack the specificity needed to operationalize this inclusion for women and girls, particularly in rural and underserved areas (Georgia Ministry of Internally Displaced Persons from the Occupied Territories, Labour, Health and Social Affairs, 2021). Reports by the Public Defender of Georgia have repeatedly emphasized that systemic oversight, underfunding, and the absence of disaggregated data impede the realization of rights for this group (Office of the Public Defender of Georgia, 2022).

Moreover, despite these legislative frameworks, there is a notable absence of mechanisms for participatory policy-making that would empower women with disabilities to influence the systems that directly affect their lives. Without institutionalized platforms for their engagement, policy remains top-down and disconnected from lived realities. As a result, the progressive language of the law often fails to translate into equitable outcomes, highlighting the disjuncture between normative advances and structural change.

Despite the establishment of a progressive legal and strategic foundation, multiple international and local studies indicate that women and girls with disabilities in Georgia continue to encounter serious obstacles when seeking healthcare services. These challenges go beyond isolated shortcomings and instead reveal systemic dysfunctions rooted in infrastructural, financial, informational, and attitudinal deficiencies (Matin & Williamson, 2021; Saleeby & Hunter-Jones, 2016; Ganle et al., 2020).

A recurring issue in both urban and rural healthcare settings is the inadequacy of physical infrastructure. Although some medical facilities are labeled as “accessible,” this often refers only to minimal physical modifications—such as the presence of a ramp at the entrance—without considering comprehensive accessibility needs. For instance, consultation rooms may not accommodate wheelchairs, restrooms are often inaccessible, and communication services such as sign language interpretation or accessible signage remain rare. This limited conceptualization of accessibility undermines the broader goal of creating an inclusive healthcare environment that addresses diverse needs and fosters patient autonomy (WHO Europe, 2022).

Financial barriers further exacerbate the situation. A significant portion of women with disabilities in Georgia live below the poverty line and rely on inadequate state disability benefits. These financial constraints limit their ability to cover out-of-pocket expenses for diagnostic procedures, medications, or specialized consultations. In some cases, even transportation costs to clinics become insurmountable, especially in rural or high-mountain regions where health facilities are few and far between (UNFPA Georgia, 2020; World Bank, 2020). Consequently, many women delay or entirely forgo necessary medical interventions, contributing to avoidable complications and a deterioration in overall health outcomes.

Compounding these issues is a widespread lack of disability awareness and gender sensitivity among healthcare personnel. Medical education curricula in Georgia seldom include mandatory modules on working with persons with disabilities, particularly from an intersectional perspective that addresses both gender and disability. As a result, providers may exhibit unconscious bias, fail to communicate effectively, or disregard patients’ autonomy and informed consent. These deficiencies are not just professional oversights but constitute violations of human dignity and can

lead to delayed diagnoses, inappropriate treatment, or outright neglect (Parish et al., 2006; WHO, 2022).

Furthermore, the problem is not only infrastructural or technical but deeply cultural. The prevailing societal perception of disability, particularly as it intersects with gender, is often rooted in paternalism and exclusion. Women with disabilities are frequently regarded as dependent, asexual, or incapable of parenthood, which impacts how medical staff approach topics such as reproductive health, family planning, or maternity care. In clinical settings, such assumptions may result in the withholding of services, lack of respectful communication, or even denial of reproductive choices—all of which violate core principles of human rights and bodily autonomy (UNFPA, 2021; WHO, 2021).

Sexual and reproductive healthcare represents one of the most neglected areas for women and girls with disabilities in Georgia. While international human rights instruments unequivocally assert that all individuals have the right to make autonomous decisions regarding their sexual and reproductive lives, this right remains largely unrealized for disabled women. Structural discrimination, compounded by social taboos, continues to marginalize this population within public health discourse and practice (UNFPA Eastern Europe and Central Asia, 2021; UN Women, 2020).

Numerous studies have revealed that women with disabilities often lack access to information about their reproductive rights, contraception, and safe motherhood options. This is partly due to the scarcity of information in accessible formats—such as plain language brochures, audio materials, or Braille—but also reflects the deeply ingrained assumption that disabled women are either not sexually active or are unfit to become mothers (UNICEF, 2013; WHO, 2021). As a result, healthcare providers frequently fail to initiate discussions about sexual health, family planning, or gynecological screening, thereby perpetuating informational deprivation and disempowerment.

Moreover, in some clinical settings, providers may bypass informed consent procedures, assuming that women with cognitive or sensory impairments are incapable of making autonomous decisions. In extreme cases, women have been subjected to forced sterilization or denied access to fertility treatment based on prejudicial criteria. These practices are not only ethically indefensible but also contravene international obligations under the Convention on the Rights of Persons with Disabilities and the Convention on the Elimination of All Forms of Discrimination Against Women (UN Committee on the Rights of Persons with Disabilities, 2016; United Nations, 2006).

Compounding these challenges is the virtual absence of comprehensive sexual education programs for girls with disabilities. Educational institutions rarely integrate inclusive content into their curricula, and teachers are often untrained in delivering sensitive topics in adapted ways. As a result, many girls enter adulthood without basic knowledge of their reproductive systems, their legal rights, or how to access medical support. This lack of preparedness not only places them at higher risk of unwanted pregnancies or abuse but also reinforces lifelong patterns of disempowerment and health inequity (OHCHR, 2018; UN Women, 2020). The invisibility of disabled women in national reproductive health programs and strategies further entrenches these inequalities. National maternal and child health plans in Georgia have historically adopted a one-size-fits-all approach, with little recognition of the specific barriers faced by women with disabilities. Budget allocations rarely prioritize disability-inclusive services, and program indicators seldom disaggregate data by disability status. As a result, progress reports present an

incomplete picture of reproductive health outcomes, masking the disproportionate burden borne by disabled women (Georgia Ministry of Health, 2021; Office of the Public Defender of Georgia, 2022).

This invisibility in policy, combined with stigma in practice, creates a hostile environment where reproductive autonomy is undermined at every stage—from accessing a clinic to making informed decisions. The issue is not merely about physical access to gynecological care, but about inclusion in the full spectrum of rights-based, patient-centered reproductive services. Without targeted reforms that address both the structural and attitudinal dimensions of these barriers, Georgia’s commitments to gender equality and disability inclusion will remain aspirational rather than operational.

Despite the persistent challenges faced by women and girls with disabilities in Georgia, international experiences demonstrate that substantial progress is achievable when inclusive strategies are implemented systematically and in consultation with affected communities. Across various countries, targeted initiatives have succeeded in improving healthcare access, ensuring patient dignity, and institutionalizing disability-sensitive service provision. These cases offer valuable insights for Georgia’s ongoing reforms and underline the importance of moving from legal recognition to practical realization (European Commission, 2021; World Health Organization – Europe, 2022).

For instance, in Finland and Estonia, national health systems have integrated barrier-free communication technologies into primary care settings. Sign language interpreters, visual aids, and telehealth platforms designed with accessibility in mind have enhanced patient-provider interactions and improved service satisfaction among disabled populations. In Canada, health equity is institutionalized through the inclusion of disability advocates in local and provincial health boards, where they actively participate in shaping clinical protocols and evaluating service outcomes (OHCHR, 2018; UN Women, 2018).

Some Central and Eastern European countries, such as Croatia and Romania, have implemented monitoring mechanisms that disaggregate healthcare data by disability, gender, and region. These systems allow for real-time assessment of service disparities and enable policymakers to allocate resources more equitably. In Poland, municipalities provide specialized transportation for individuals with mobility impairments, ensuring that physical distance from healthcare facilities does not translate into de facto exclusion (European Disability Forum, 2019).

These innovations share several common features. First, they adopt a rights-based approach that recognizes disabled women not as passive recipients of care but as active agents whose input is crucial to system design. Second, they prioritize cross-sector coordination—linking health, education, transportation, and social protection services in a cohesive framework. Third, they commit to sustained public investment in both infrastructure and human capacity development, recognizing that inclusion is not a one-time expenditure but a continuous process of adaptation and accountability (UNICEF, 2013; WHO, 2021).

Equally important is the shift toward participatory methodologies in public health planning. In several jurisdictions, including parts of Canada and the Netherlands, health institutions have adopted co-creation models, where women with disabilities collaborate with professionals to co-design sexual health campaigns, develop training curricula for providers, and evaluate patient experience metrics. These efforts not only enhance the relevance of health programs but also foster a sense of ownership and trust among marginalized populations (UNFPA Eastern Europe and Central Asia, 2021; International Disability Alliance, 2022).

For Georgia, the lesson is clear: legislative reform is only the beginning. True transformation requires embedding inclusive values into the daily operations of the healthcare system—through participatory governance, universal design, accessible communication, and accountability mechanisms. By drawing on these global practices and tailoring them to local realities, Georgia can move closer to fulfilling its obligations under the Convention on the Rights of Persons with Disabilities and ensuring that no woman is left behind.

Although Georgia has demonstrated formal commitment to international human rights instruments and adopted national laws designed to guarantee equality and access to services, the translation of these commitments into effective implementation remains uneven. Women and girls with disabilities often encounter a healthcare system that is structurally unprepared to meet their specific needs—despite legal guarantees to the contrary. This disconnect between policy rhetoric and practical outcomes exposes deeper issues related to governance, accountability, and institutional culture (Office of the Public Defender of Georgia, 2022; UN Women Georgia, 2021). One of the core challenges lies in the fragmented nature of service delivery. The division of responsibility across multiple government agencies—without effective coordination or referral mechanisms—creates administrative confusion and leads to gaps in care. For example, although primary care centers may provide certain basic services, the lack of integrated pathways to specialized diagnostic or rehabilitative support often results in missed or delayed treatment. For individuals managing chronic conditions or seeking reproductive care, such delays can have serious health consequences (Disability Rights International, 2020; WHO, 2022).

Even when infrastructure improvements have been made—such as installing ramps or accessible bathrooms—the broader service environment often remains exclusionary. Medical professionals are frequently untrained in disability-sensitive care, and there are few national protocols to guide respectful and inclusive communication. Furthermore, routine consultations frequently assume verbal fluency and visual literacy, effectively excluding patients with hearing or cognitive impairments. The absence of assistive technologies, alternative communication formats, and privacy accommodations continues to compromise both the quality and dignity of care (UNFPA, 2021; WHO Europe, 2022).

Another systemic limitation is the near-total absence of participatory mechanisms for women with disabilities in healthcare planning and oversight. Without their direct input, policies risk reproducing ableist assumptions and overlooking the diverse and intersecting realities of this population. As highlighted in global best practices, the meaningful inclusion of affected individuals in decision-making processes is not only a matter of democratic legitimacy but also a prerequisite for designing effective interventions (OHCHR, 2018; European Commission, 2021).

In addition, the rural–urban divide exacerbates existing inequalities. While women with disabilities living in urban areas may at least theoretically have access to more specialized facilities, those in rural or high-mountain regions often face compounded obstacles—ranging from geographic isolation to cultural taboos that discourage their independent health-seeking behavior. In such areas, healthcare access is further constrained by unreliable public transport, a shortage of qualified providers, and a lack of outreach programs tailored to their needs. This multidimensional exclusion reinforces cycles of poor health, economic dependency, and social invisibility (UNFPA Georgia, 2020; World Bank, 2020).

Ultimately, the failure to bridge the gap between legal norms and lived experience reflects a broader neglect of structural and cultural determinants of health. A rights-based and gender-sensitive transformation of the healthcare system requires not only policy reform but also

institutional restructuring, provider training, accessible infrastructure, and ongoing public engagement. Without this, the promise of equality will remain aspirational rather than transformation.

In light of these multilayered and intersecting challenges, it becomes increasingly evident that formal commitments alone are insufficient to ensure meaningful access to healthcare for women and girls with disabilities in Georgia. Rather than being treated as passive recipients of welfare, these individuals must be recognized as rights-holders with unique needs, perspectives, and entitlements. A transformative approach requires that disability be reframed not as a technical issue of infrastructure or clinical diagnosis, but as a complex social condition shaped by structural injustice, policy neglect, and cultural invisibility (World Health Organization, 2011; UN Committee on the Rights of Persons with Disabilities, 2016).

A key starting point lies in dismantling the pervasive social stigma and institutionalized assumptions that continue to frame women with disabilities as incapable, asexual, or dependent. These misconceptions not only influence public attitudes but also permeate clinical settings and policy decisions, leading to the systematic exclusion of this population from health promotion, sexual and reproductive health services, and patient empowerment frameworks. Overcoming these deeply entrenched barriers calls for a robust, multisectoral, and gender-transformative strategy—one that integrates legal reforms, inclusive education, financial protections, and meaningful public participation (UN Women, 2020; UNFPA EECA, 2021).

Moreover, the monitoring and evaluation of health interventions must move beyond aggregate indicators and incorporate disaggregated data collection that accounts for gender, disability type, geography, socioeconomic status, and age. Only through such nuanced approaches can the hidden layers of exclusion be revealed and addressed. International examples demonstrate the value of embedding intersectionality within data systems, allowing governments to tailor services to real-life conditions rather than to generalize policy assumptions (European Disability Forum, 2019; UNICEF, 2013).

Finally, the research presented in this study aims not merely to document the barriers faced by women and girls with disabilities but to center their voices, experiences, and priorities in the ongoing conversation about healthcare equity in Georgia. Through a mixed-method approach, the study seeks to analyze both the systemic shortcomings and the lived realities that shape health access. The ultimate goal is to generate actionable insights and policy recommendations that will support the development of a healthcare system that is not only technically accessible but also ethically inclusive and socially just.

The social and healthcare experiences of girls and women with disabilities in Georgia reflect broader patterns of marginalization that affect this population worldwide, but with specific regional and historical nuances. The legacy of the post-Soviet healthcare system, combined with entrenched patriarchal norms and insufficient public investment in disability-inclusive infrastructure, has created systemic barriers to accessing medical services. Women and girls with disabilities often find themselves in a doubly disadvantaged position—excluded both on the basis of gender and disability.

In Georgia, disability is still largely viewed through a medical model, emphasizing diagnosis and impairment over rights-based or social models that consider the environment, social attitudes, and institutional frameworks. This has critical implications for healthcare provision. Medical professionals are rarely trained in gender-specific needs for disabled populations, and most healthcare infrastructure lacks physical accommodations such as ramps, elevators, tactile guides,

or sign-language interpreters. As a result, routine health checkups, reproductive health services, mental health support, and emergency care remain difficult or impossible to access for many women and girls with disabilities.

Rural areas in Georgia present even more stark realities. The concentration of specialized services in urban centers like Tbilisi means that individuals in remote or mountainous regions are required to travel long distances, often at great personal and financial cost. Public transport systems remain largely inaccessible. Meanwhile, community-based healthcare outreach programs are underfunded and inconsistently implemented. This geographic disparity deepens health inequities and isolates disabled women from timely and adequate care.

A further complication is the societal perception of women with disabilities. Deep-seated stigma often portrays them as dependent, asexual, or unfit for motherhood. This has a direct impact on the kind of medical treatment they receive, particularly in reproductive and maternal health settings. There have been documented cases of coercive sterilization or neglect during pregnancy due to healthcare providers' biases. Such human rights violations remain underreported due to fear, shame, and a lack of legal recourse.

Education also plays a significant role in shaping access to medical services. Many girls with disabilities face early exclusion from mainstream education systems, particularly when their disabilities are intellectual or sensory. Without education, navigating healthcare systems—already bureaucratically and linguistically complex—becomes even more challenging. A lack of digital literacy, medical literacy, or understanding of patient rights leaves many women at the mercy of a system not designed with them in mind.

Policy-wise, Georgia has made some progress. The ratification of the UN Convention on the Rights of Persons with Disabilities (CRPD) and the development of the National Strategy on Human Rights Protection include commitments to inclusive healthcare. However, these frameworks often lack meaningful enforcement mechanisms, adequate funding, or community-based implementation. Monitoring bodies are understaffed, and healthcare indicators are not systematically disaggregated by gender and disability, leading to gaps in planning and accountability.

Another significant issue is the limited participation of disabled women themselves in healthcare policy-making. Without their voices and leadership, reforms risk being paternalistic or superficial. Grassroots advocacy organizations play a critical role in raising awareness, providing services, and shaping dialogue, but they often operate with minimal support. Strengthening civil society's capacity to influence health policy is essential to achieving sustainable and rights-based change. The background of medical service provision for girls and women with disabilities in Georgia is characterized by systemic neglect, infrastructural deficits, cultural stigmatization, and policy implementation gaps. A coordinated approach is urgently required, involving government institutions, civil society, medical professionals, and international bodies to transform healthcare systems into spaces of inclusion, equity, and dignity. Only through a holistic and sustained commitment to intersectional justice can Georgia fulfill its promise of universal healthcare for all its citizens, regardless of gender or disability status.

Methods

The study was conducted as a descriptive, cross-sectional pilot study aimed at assessing access to health services among girls and women with disabilities in Georgia. The primary purpose of this

pilot study was to explore existing patterns and barriers to healthcare access and to generate evidence that could inform the development of a larger, more comprehensive analysis.

A structured questionnaire, developed specifically for the study, included both closed-ended and open-ended questions. It was designed to investigate multiple dimensions of healthcare access, including physical accessibility of medical facilities, infrastructural and environmental limitations, transportation- related challenges, financial affordability, and access to health-related information, health insurance coverage and experiences with healthcare personnel.

The study employed a non-probability purposive sampling method. Participants were selected according to specific inclusion criteria: having a physical or sensory disability, female sex, age between 18 and 65 years, and at least one recorded interaction with the healthcare system within the past twelve months to ensure that participants' experiences reflected recent and relevant encounters with the health system.

A total of 50 women were enrolled in the study. Participants were recruited from various regions of Georgia, including urban areas as well as rural and semi-rural (non-urban) localities, in order to reflect geographic and contextual diversity. Data collection was carried out in February 2025 through face-to-face or telephone interviews, based on participants' preferences and accessibility requirements. The study was conducted by established ethical standards. Before participation, all individuals were provided with detailed information regarding the objectives and procedures of the study, and verbal informed consent was obtained. Participation was entirely voluntary, and confidentiality and anonymity were strictly maintained throughout the research process.

In the second phase of the study, the findings were compared with international data to place the results within a broader global context. Secondary sources included reports and publications from organizations such as the United Nations (UN), the World Health Organization (WHO), and the United Nations.

Results and Discussion

The findings of this study underscore a multifaceted and deeply entrenched set of obstacles that women and girls with disabilities in Georgia encounter when attempting to access healthcare services. These are not isolated inconveniences but systemic barriers that permeate every aspect of the healthcare

experience—ranging from architectural inaccessibility to socio-cultural exclusion. Physical constraints are compounded by infrastructural limitations, social stigma, financial insecurity, lack of accessible information, and insufficient professional competencies.

Such a constellation of disadvantages results not only in diminished access to healthcare but also in a compromised ability to benefit from preventative measures, early diagnostics, and person-centered, respectful care. These findings align with broader global observations that underscore the intersectionality of health, gender, and disability as a critical axis of inequality (UNFPA Georgia, 2020; WHO, 2021).

Table-1.

Table 1. Socio-Demographic Characteristics of Participants

Living Arrangement	With Family					Alone				
Age City	18-30	31-50	51-65	>65	Total	18-30	31-50	51-65	>65	Total
Tbilisi	30.0 %	13.3%	3.3 %	0.0 %	46.7%	3.3 %	0.0 %	3.3 %	0.0 %	6.7%
Kutaisi	10.0 %	3.3 %	0.0 %	0.0 %	13.3%	0.0 %	3.3 %	3.3 %	3.3 %	10.0%
Rustavi	0.0 %	3.3 %	3.3 %	0.0 %	6.7%	3.3 %	0.0 %	0.0 %	0.0 %	3.3 %
Batumi	3.3 %	0.0 %	0.0 %	0.0 %	3.3%	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Village	0.0 %	3.3 %	3.3 %	0.0 %	6.7%	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Other City	0.0 %	3.3 %	0.0 %	0.0 %	3.3%	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Total	43.3 %	26.7%	10.0%	0.0 %	80%	6.7%	3.3 %	6.7%	3.3 %	20.0%

One of the most pronounced obstacles identified through the study is the inadequacy of physical infrastructure. Merely 10% of respondents reported that medical facilities met accessibility standards in full. A striking 40% rated the accessibility of facilities at the lowest end of the scale. This gap was particularly evident in rural areas, where architectural challenges, such as outdated Soviet-era buildings, steep staircases, narrow hallways, and the absence of elevators or ramps, render clinics physically inaccessible. The problem is not simply architectural but emblematic of a health system that was never designed with inclusivity in mind. As one woman from the Kakheti region expressed, her arrival at a clinic in a wheelchair was met not with assistance, but with an expectation that she “somehow climb the stairs.” The system’s failure to accommodate even the most basic mobility needs signals a disregard for the presence and dignity of disabled patients.

Transportation emerged as an equally formidable barrier. A significant 60% of participants reported being unable to reach medical facilities due to the unavailability of transport services suitable for people with mobility impairments. In rural areas, this challenge is compounded by long distances, infrequent public transportation, and the absence of any specialized or subsidized options. A particularly revealing narrative came from a woman in Samtskhe-Javakheti who recalled giving birth without ambulance access, relying instead on her family to organize transportation, despite not having sufficient funds. Such scenarios highlight how geographic marginalization, poverty, and disability intersect to create a healthcare desert for large segments of the population.

Age was another important axis of inequality revealed in the study. Younger women (ages 18–30) generally demonstrated higher levels of digital literacy and greater familiarity with available services, often due to exposure through educational institutions or online resources. In contrast, older women (ages 50 and above) reported significantly higher levels of social isolation, diminished autonomy in medical decision-making, and limited support networks. A 63-year-old participant recounted how her gynecologist dismissed her concerns on the grounds of age, stating

that she no longer “needed” gynecological care. This paternalistic framing exemplifies how ageism compounds gender and disability-based marginalization, rendering older women invisible within the healthcare system.

Table 2.

Type of Barrier	Agree (%)	Neutral (%)	Disagree (%)
Physically inaccessible facilities	40%	30%	30%
Lack of adapted transport	60%	20%	20%
health insurance coverage problem	20%	30%	50%
Denied private insurance due to disability	53.3%	30%	16.7%
Insured but clinics not adapted	30%	40%	30%
Out-of-pocket expenses limit care	50%	30%	20%
Delayed/avoided treatment due to cost	50%	25%	25%
Inadequate state financial assistance	70%	20%	10%

Population Fund (UNFPA), UN Women, and other institutions working in the fields of disability rights and inclusive healthcare.

Financial constraints constitute another profound and recurring theme in the narratives collected. For women with disabilities, healthcare costs are not merely economic burdens—they represent structural exclusion. A full 20% of participants reported having no health insurance coverage whatsoever, while 53.3% stated that private insurance companies had denied them coverage explicitly due to their disability status. Even among those with formal insurance, multiple respondents described circumstances in which coverage proved illusory. One woman explained that although her package included gynecological services, she was told upon arrival that “the clinic doesn’t have equipment for wheelchair users,” effectively nullifying her entitlement. Such examples illustrate how financial discrimination intersects with infrastructural inadequacies, transforming formal rights into inaccessible promises.

Beyond formal insurance coverage, out-of-pocket expenses, ranging from transportation and medication to diagnostic tests, often exceed the financial capacity of disabled women, many of whom are unemployed or rely on minimal state benefits. Several participants noted that they had postponed or entirely foregone medical consultations due to cost concerns. This dynamic further exacerbates health inequalities by delaying diagnosis and treatment, particularly for chronic conditions or reproductive health concerns that require regular monitoring.

Equally troubling were the widespread reports of negative experiences with medical personnel. Half of the respondents (50%) had, at least once, been explicitly denied care based on their disability. While denial of service is the most extreme form of exclusion, subtler forms of

discrimination were no less damaging. 46.7% of participants reported violations of their privacy or medical data protection, while 26.7% characterized their interactions with healthcare providers as emotionally distressing or humiliating. One woman recounted a consultation in which a gynecologist bluntly asked: “Why do you even need sexual medicine?”—a question that not only dismissed her needs but also invalidated her identity and personhood. Such incidents are not isolated acts of insensitivity; they reflect systemic biases in medical training, where little to no emphasis is placed on disability rights, communication ethics, or inclusive care models.

These findings point to a healthcare environment that frequently fails to meet the standards of dignity, respect, and autonomy to which all patients are entitled. They also highlight a broader cultural issue—where medical knowledge is perceived as hierarchical, and the voice of the patient, particularly a disabled woman, is minimized or dismissed. In this context, healthcare becomes not a site of healing, but of power imbalance, exclusion, and harm.

A particularly pervasive theme that emerged during the analysis was the lack of accessible and comprehensible health information. This deficit operated at both systemic and interpersonal levels. A staggering 90% of respondents reported being unaware of any state-supported health programs or specific services designed for people with disabilities. Even more striking, 96.7% stated that they had never encountered sexual and reproductive health materials presented in accessible formats—such as plain-language brochures, Braille documents, or sign-language videos. These communication gaps not only limited their ability to make informed health decisions but reinforced a broader sense of exclusion and marginalization.

Table 3. Illustrates the extent of informational deprivation and emotional exclusion experienced by participants during their healthcare journeys.

Table 3 – Participant-Reported Informational and Psychosocial Barriers to Equitable Healthcare Access			
Type of Barrier	Agree (%)	Neutral (%)	Disagree(%)
Unaware of healthcare programs	90%	5%	5%
No adapted SRH info available	96.7%	2%	1.3%
Inaccessible digital platforms	70%	20%	10%
Emotionally distressing experiences	26.7%	40%	33.3%
Avoidance due to past mistreatment	40%	30%	30%
Healthcare decisions made without consent	65%	25%	10%
No participation in service planning	100%	0%	0%
No trauma-informed care in system	75%	15%	10%

Several participants expressed frustration with digital health resources, which are often promoted as tools for improving access. In practice, however, many of these platforms are designed without

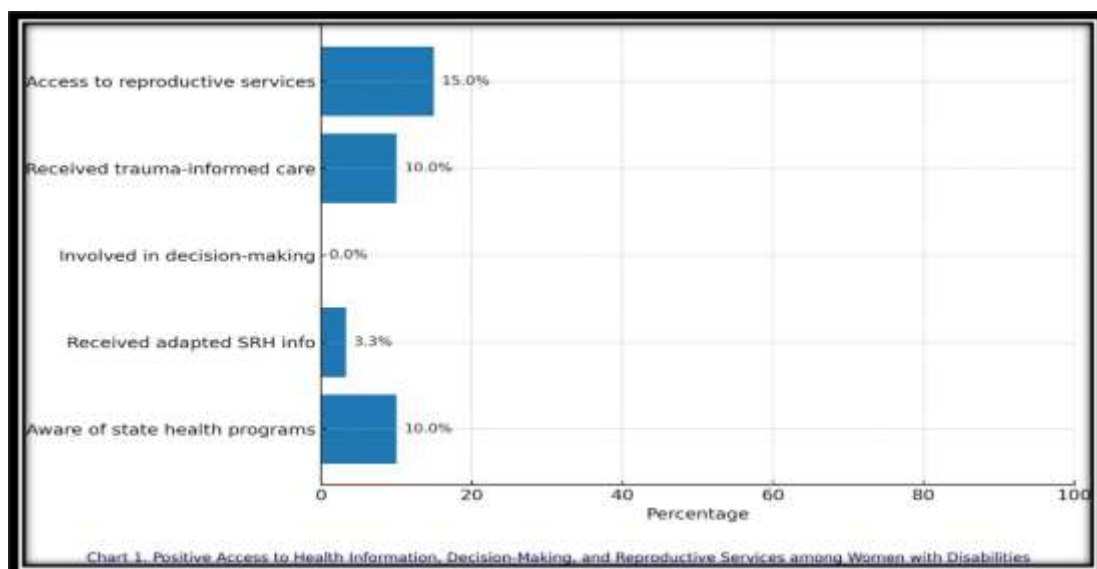
consideration for individuals with sensory, cognitive, or technological limitations. As one woman from Adjara put it, “I can’t read websites, and no one explains what it’s about.” This quote encapsulates a larger problem: digital exclusion, far from being a neutral oversight, actively compounds informational inequalities—particularly in a healthcare system increasingly reliant on online appointments, electronic records, and remote consultations. Beyond information deficits, emotional detachment from the healthcare system emerged as a recurring narrative. Many women described a profound sense of mistrust, fear, and resignation when engaging with medical professionals. This emotional distance was not rooted in irrational fear but in repeated experiences of dismissal, misunderstanding, or humiliation. As one participant explained, “I don’t go for check-ups anymore—I’ve learned that my concerns won’t be taken seriously.” Such sentiments suggest a dangerous cycle in which alienation leads to avoidance of care, which in turn contributes to deteriorating health outcomes.

This emotional disconnection is not simply a psychological reaction; it reflects systemic deficiencies in the healthcare system’s responsiveness and inclusivity. A truly inclusive healthcare model must go beyond architectural access and address the relational and affective components of care—namely, trust, empathy, and mutual respect. Without these elements, formal accessibility remains insufficient, and health equity becomes unattainable.

These findings also underscore the limitations of standard healthcare quality indicators, which often fail to capture patient experience, satisfaction, or perceptions of dignity. A facility may technically meet national accessibility standards, yet still alienate patients through impersonal service, rushed consultations, or culturally insensitive attitudes. Such experiences are particularly detrimental to disabled women, who already navigate intersecting stigmas and power imbalances in medical encounters.

Another core finding of this study was the minimal level of participation that women and girls with disabilities had in decisions concerning their own healthcare. Chart 3 highlights key indicators regarding access to reproductive services, trauma-informed care, participation in health-related decisions, and availability of adapted information.

Chart-1.



This absence was evident at two levels: first, in the clinical sphere, where patients are often excluded from discussions about their treatment options; and second, in the broader healthcare planning and policy process. Across interviews, many respondents reported that healthcare decisions were made on their behalf—by family members, caregivers, or medical staff—without their informed consent or active involvement.

One participant recalled, “No one asked me whether I would prefer to give birth at home or in the hospital. They simply said: The hospital is not for you.” This kind of paternalism reflects deep-seated societal assumptions about the capabilities and autonomy of disabled women, which not only disempower them but also violate the ethical principle of respect for persons. Genuine participation in health-related decisions requires not only the presence of choice but the availability of clear, accessible information and supportive communication.

On the institutional level, no participants reported being consulted in the design or evaluation of medical services. This lack of representation stands in contrast to international best practices, where participatory approaches—such as advisory boards including disabled individuals or community-based feedback mechanisms—are used to tailor services to real needs. The absence of such models in Georgia limits the healthcare system’s ability to evolve in inclusive and responsive ways.

Compounding the issue of limited participation is the pervasive lack of specialized services. Many participants shared experiences in which their medical concerns were dismissed or “collapsed” into their disability. Instead of receiving individualized diagnostics or treatment, their symptoms were attributed to their disability as an undifferentiated category. For example, women with mobility impairments who reported gynecological discomfort were often told that “pregnancy would be too dangerous” without further investigation into the underlying health issue.

This clinical reductionism fails to recognize the diverse health needs of women with disabilities and underscores the urgent need for training medical professionals in intersectional, rights-based care. Currently, specialized services—especially in reproductive and mental health—are either concentrated in urban centers or lacking altogether. In smaller towns and rural areas, women often have no access to gynecologists trained to work with people with disabilities, nor are there programs that offer psychological support tailored to their lived experiences.

One woman reported, “I went to the clinic for a routine checkup, but the doctor didn’t even speak to me directly—he asked my sister everything, as if I wasn’t there.” This erasure of voice and agency contributes

to a broader pattern of exclusion that extends beyond the medical encounter and permeates social institutions more broadly.

Beyond the tangible and logistical challenges outlined above, the study illuminated deeper structural inequalities that fundamentally shape the healthcare experiences of women and girls with disabilities in Georgia. These inequalities are embedded not only in the healthcare system but also in the broader cultural and institutional frameworks that govern social life. They manifest in subtle yet powerful ways—in how needs are defined, how resources are allocated, and whose voices are deemed worthy of inclusion in policy discourse.

For example, while many clinics may technically offer “universal” services, the reality is that these services are standardized around an able-bodied, male-centric norm. Such default assumptions render the needs of disabled women invisible. As one respondent put it, “Everything is set up for a ‘normal’ patient. If you don’t fit that mold, you’re on your own.” This

institutional design bias reinforces exclusion and normalizes neglect, as services are not proactively adapted to the diversity of patients they are meant to serve.

Moreover, cultural stigmas surrounding both disability and gender continue to restrict the autonomy and social integration of these women. Participants repeatedly emphasized that societal narratives often depict them as dependent, fragile, or asexual. These reductive views are internalized not only by the public but also by healthcare providers, policymakers, and even the women's own families. As a result, their health concerns are deprioritized, their reproductive choices questioned, and their pain frequently dismissed.

This culture of disregard has real-world consequences. Some women described avoiding clinics altogether, not because they lacked physical access, but because they feared humiliation, judgment, or mistreatment. Others mentioned being reluctant to disclose their symptoms or concerns, particularly when related to sexual or reproductive health, due to a lack of trust in the system. In this context, healthcare becomes not a site of healing, but one of vulnerability and marginalization.

The emotional toll of this experience is substantial. Feelings of alienation, fear, and powerlessness permeated many of the interviews. These emotions are not incidental—they are the product of sustained exclusion from institutions that are meant to serve the public good. When a woman cannot access routine care without fear of being shamed or silenced, the principle of health as a human right is severely compromised.

Taken together, these findings underscore that access to healthcare is not solely a matter of ramps, elevators, or digital interfaces. It is also about inclusion in the social contract. When women with disabilities are excluded from that contract—through underfunded policies, untrained personnel, inaccessible communication, and a pervasive culture of low expectations—then health equity becomes impossible.

A recurring theme throughout the study was the emotional and psychological impact of exclusion, humiliation, and invisibility within healthcare settings. Many participants described their encounters with the medical system not just as physically difficult or financially burdensome, but as deeply wounding experiences that eroded their sense of self-worth and autonomy. This layer of emotional harm adds a critical dimension to our understanding of healthcare inequality—one that quantitative indicators alone cannot capture.

Several women recalled being infantilized during medical consultations. Others were met with silence, indifference, or overt disbelief when expressing symptoms or requesting reproductive care. These interactions often left long-lasting scars. As one participant from Imereti noted: “It wasn’t the stairs or the lack of ramps that hurt the most, it was when the nurse looked at me like I didn’t belong here.” This comment exemplifies how infrastructural exclusion is often accompanied and compounded by symbolic violence.

This form of psychological marginalization is not an accidental byproduct of underfunded systems; it is embedded in the ethics—or lack thereof—of professional practice. Many healthcare providers lack training in respectful, inclusive communication and often make harmful assumptions based on gender and disability. For instance, one woman described being asked, “Why are you worried about gynecology? That’s not your problem.” Such remarks are not just dismissive; they are forms of epistemic injustice—denying the person’s right to be taken seriously as a knower of their own body and needs.

The failure to uphold informed consent protocols was another deeply troubling finding. Participants with intellectual or sensory impairments frequently reported situations in which

decisions were made on their behalf without proper explanation or acknowledgment of their agency. This not only violates international legal standards such as those outlined in the Convention on the Rights of Persons with Disabilities (CRPD), but also undermines basic principles of medical ethics—autonomy, beneficence, and justice.

Access to medical services for girls and women with disabilities in Georgia remains a critical yet under addressed issue, shaped by systemic barriers, sociocultural attitudes, and gaps in policy implementation. The findings reveal persistent challenges across accessibility, discrimination, reproductive healthcare, financial constraints, and communication, all of which contribute to health disparities for this marginalized population.

Physical and Institutional Barriers to Healthcare Access: A primary concern is the lack of accessible healthcare infrastructure. Many medical facilities, particularly in rural areas, do not comply with basic accessibility standards, such as ramps, elevators, or adapted examination rooms. Women with mobility impairments frequently report difficulties entering clinics, accessing diagnostic equipment, or using restrooms, forcing some to forgo routine check-ups or essential treatments. Furthermore, medical devices such as adjustable examination tables or wheelchair-accessible scales are scarce, leading to inadequate or even humiliating experiences during consultations. This neglect reflects a broader societal oversight of disability inclusion in public health planning.

Discrimination and Sociocultural Stigma: Negative attitudes among healthcare providers further exacerbate disparities. Many women with disabilities encounter dismissive or paternalistic behavior from medical staff, who may assume they are incapable of making informed decisions about their health. Those with intellectual or psychosocial disabilities face heightened stigma, often being denied autonomy in reproductive health choices or subjected to unnecessary institutionalization. Additionally, misconceptions about the sexuality of women with disabilities persist, with some physicians discouraging sexual activity or childbirth based on prejudiced assumptions rather than medical evidence. Such discrimination discourages women from seeking care, perpetuating a cycle of neglect and poor health outcomes.

Gaps in Reproductive and Sexual Healthcare: Reproductive health services for women with disabilities are notably inadequate. Gynecological care often fails to accommodate physical disabilities, leaving many without access to essential screenings like Pap smears or mammograms. Sex education programs rarely cater to girls with disabilities, increasing vulnerabilities to unplanned pregnancies, sexually transmitted infections, and gender-based violence. Maternal healthcare is another critical gap; pregnant women with disabilities frequently encounter hospitals ill-equipped to support their needs, from inaccessible delivery rooms to staff untrained in disability-inclusive obstetric care. These systemic failures violate fundamental reproductive rights and contribute to preventable health complications.

Economic and Systemic Obstacles: Financial barriers further restrict healthcare access. Many women with disabilities live in poverty, unable to afford transportation to specialized clinics, medications, or assistive devices. While Georgia's universal healthcare program nominally covers some services, bureaucratic hurdles and insufficient funding for disability-related treatments limit its effectiveness. For instance, physiotherapy, mental health services, and high-cost medications

often require out-of-pocket payments, placing them out of reach for low-income families. This economic marginalization reinforces health inequities, particularly for women in rural regions where medical resources are already scarce.

Communication and Informed Consent Challenges: Effective patient-provider communication remains a significant hurdle. Deaf or hard-of-hearing women frequently lack access to sign language interpreters during medical appointments, leading to misdiagnoses or improper treatment. Similarly, women with intellectual disabilities are rarely provided with simplified health information, undermining their ability to give informed consent. These communication gaps not only violate disability rights but also erode trust in the healthcare system, deterring many from seeking timely medical intervention.

Policy Shortcomings and Data Gaps: Despite Georgia's ratification of the UN Convention on the Rights of Persons with Disabilities (CRPD), implementation of inclusive healthcare policies lags. Monitoring mechanisms are weak, and disability-specific health data is sparse, obscuring the full extent of disparities. While recent legislative reforms, such as the Law on the Rights of Persons with Disabilities, outline anti-discrimination measures, enforcement remains inconsistent. Without robust data collection and accountability frameworks, policymakers lack the evidence needed to design targeted interventions.

Comparative Perspectives and Pathways for Improvement: Comparative studies from Eastern Europe suggest that Georgia's challenges are not unique but reflect regional trends of underfunded and exclusionary healthcare systems. However, models from countries like Lithuania—where mandatory accessibility standards and disability sensitivity training for medical staff have shown promise—offer actionable insights. In Georgia, civil society organizations have begun advocating for inclusive health policies, yet their efforts require stronger governmental support. Priorities include mandating universal design in medical facilities, integrating disability competencies into medical education, and expanding insurance coverage for assistive technologies.

The findings underscore an urgent need for systemic reform to ensure equitable healthcare for girls and women with disabilities in Georgia. Addressing these issues demands a multifaceted approach: improving physical accessibility, combating stigma through training, expanding reproductive health services, alleviating financial burdens, and strengthening policy enforcement. Without such measures, this population will continue to face preventable health disparities, violating their fundamental human rights and perpetuating cycles of exclusion. Future research should focus on longitudinal studies to track progress and evaluate the impact of potential interventions.

Additionally, the near-complete absence of trauma-informed care frameworks in the Georgian healthcare system was evident. Several women disclosed prior experiences of abuse or institutional neglect, yet found that their histories were never acknowledged or addressed by clinicians. This lack of recognition perpetuates re-traumatization and leaves already vulnerable individuals feeling unsafe in environments meant to promote healing.

The emotional distancing that results from these patterns of exclusion has a chilling effect on health-seeking behaviors. Many women reported avoiding care altogether, even when in pain,

due to previous negative experiences. This creates a feedback loop: exclusion leads to disengagement, which in turn exacerbates health inequalities.

From an ethical perspective, these findings point to a failure not only of technical provision but of moral responsibility. Healthcare systems are not neutral bureaucracies; they are expressions of collective values. When they fail to include the most marginalized, they signal that certain lives are less valued, certain voices less heard. This is why health equity cannot be pursued solely through infrastructure or policy reform. It must also involve a cultural transformation in how dignity, empathy, and justice are embedded in everyday care practices.

A particularly significant aspect of the findings is the near-total absence of women and girls with disabilities from decision-making processes—whether at the level of individual medical care, institutional governance, or national policy formulation. Participants repeatedly emphasized that they were not consulted about their treatment preferences, birth plans, or follow-up care. Instead, decisions were often made for them, based on generalized assumptions rather than individualized assessments.

This exclusion is not merely procedural—it is deeply political. It reflects the structural power imbalances that define the relationship between healthcare institutions and marginalized groups. One participant from Samegrelo recounted: “They told me the hospital wasn’t safe for someone like me. So they decided I would stay home. I didn’t agree, but they didn’t ask.” This experience underscores a broader reality: medical care is frequently designed and delivered in ways that presume passivity on the part of disabled women, denying them the status of active agents in their health journeys.

Institutionalized paternalism—especially in reproductive care—was a recurring theme. Many participants described situations in which their reproductive choices were preemptively judged or limited. Some were advised not to have children based solely on their disability status. Others were offered permanent contraceptive methods without thorough discussion of alternatives or future implications. Such practices reflect not only a lack of medical nuance but also a failure to respect legal and ethical standards around bodily autonomy and reproductive justice.

Moreover, the absence of women with disabilities from institutional and political forums ensures that their needs remain invisible in health policy design and implementation. Despite the existence of legal frameworks that mandate inclusion, practical mechanisms for participation remain weak or symbolic. Very few healthcare boards or committees include representatives of the disabled community. Even fewer initiatives provide accessible consultation formats—such as easy-to-read materials or sign language interpretation—that would enable meaningful engagement.

This lack of participatory infrastructure exacerbates policy blind spots. Health strategies are developed based on the majority needs and generalized indicators, with little recognition of intersectional vulnerabilities. For example, while Georgia’s national health strategy (2021–2027) emphasizes maternal and child health, it lacks specific goals or metrics related to women with disabilities. This omission perpetuates cycles of exclusion, as invisible problems are rarely prioritized in budget planning or service development.

Additionally, community-level support systems—such as patient advocacy groups, self-help collectives, or local health councils—are either non-existent or poorly integrated with national healthcare agendas. Women with disabilities who seek to organize and voice their concerns often face logistical, financial, or social barriers, further weakening collective advocacy capacity. This fragmentation undermines the potential for transformative change.

These dynamics collectively amount to structural marginalization. They show that barriers to healthcare are not accidental or isolated but are embedded in institutional norms, bureaucratic procedures, and political hierarchies. The effect is a systematic denial of agency, voice, and presence in spaces where critical health-related decisions are made.

To redress this imbalance, it is not enough to “include” disabled women as passive beneficiaries of reform. Instead, they must be recognized and empowered as co-creators of healthcare systems—through inclusive planning, accessible policy platforms, and participatory monitoring mechanisms. Without this shift, even the most well-intentioned policies risk reproducing the very inequalities they aim to eliminate.

Conclusions

This study demonstrates that access to healthcare for women and girls with disabilities in Georgia is hampered not only by visible physical barriers, but also by deeply entrenched social inequalities and institutional neglect. The challenges identified point to structural failures in a system that, in its current form, is unable to fairly reflect diversity.

This reality highlights that simply referring to legal frameworks and international conventions is not enough. As long as these standards are not actively translated into political strategies, medical practices, and societal attitudes, they remain ineffective for those who need support most.

Critical is the recognition that discrimination is not always loud or visible – it often operates through silence, through a lack of communication, through the passive ignoring of individual needs. When women with disabilities are structurally excluded from decision-making processes, when their perspectives are missing from planning, care, and communication, then equality becomes an empty promise.

Healthcare is a reflection of societal values. When patients are reduced to objects, they not only lose their status as citizens with rights, but also their self-efficacy as agents in their own lives. This is precisely why a systemic response is needed – one that sees institutional inclusion not as an add-on, but as a prerequisite for quality.

It is not enough to simply remove barriers. It is important to create spaces where participation is actively promoted – through accessible information, through trained and empathetic professionals, and through targeted programs for disadvantaged groups. Only in such a framework can women with disabilities experience healthcare as something that is not distant, abstract, or degrading – but accessible, fair, and respectful.

The conclusion of this study is therefore not purely academic: it is a call for responsibility – at the political, institutional, and societal levels. Health must not be negotiated based on gender, disability, or socioeconomic status. It must be treated as a universal human right – concrete, binding, and inclusive.

Recommendations

After analyzing the existing challenges, it becomes clear that Georgia needs more than political declarations of intent – it needs concrete, systemically embedded measures to effectively improve access to healthcare for women and girls with disabilities. The recommendations presented here are based not only on the findings of this study, but also on best international practices and existing commitments under human rights conventions.

A key area of action is the structural accessibility of medical facilities. Accessibility must not be viewed as a voluntary measure but must be enshrined in law as a binding standard. This includes

ramps, adapted entrances, tactile guidance systems, and accessible sanitary facilities. In countries such as Romania and Croatia, systematic modifications have been implemented with the support of the European Commission, leading to a significant increase in the use of medical services by people with disabilities (European Disability Forum, 2021).

The issue of limited mobility, especially in rural areas, requires special attention. Many women simply cannot reach medical facilities. In Poland, municipal transport services specifically for people with disabilities were introduced, significantly increasing participation in planned medical interventions (UNFPA, 2020). A similar model could also be implemented in Georgia – for example, through cooperation between municipalities and civil society organizations.

Another focus is on training medical professionals. The study's findings demonstrate a lack of sensitivity and knowledge in dealing with patients with disabilities. This affects not only practical procedures but also fundamental attitudes towards sexual and reproductive health. The WHO's guidelines emphasize the need for mandatory training for professionals who address the needs of people with disabilities (WHO, 2022). Such training should become an integral part of medical education and professional development in Georgia.

Access to understandable information also urgently needs to be improved. 96.7% of the women surveyed reported never being informed about their reproductive rights or existing programs – certainly not in accessible formats. Finland and Estonia are demonstrating how things can be done differently: Materials in simple language, with symbols, and in Braille have sustainably strengthened the health literacy of people with disabilities (UN Women, 2021). A similar offering is also needed in Georgia, both online and in local facilities.

In addition to structural changes, greater political participation is also needed. In Croatia, an indicator-based monitoring system was introduced that regularly assesses access to healthcare and feeds into policy planning processes (European Commission, 2021). Such an evidence-based steering instrument could also help Georgia not only document progress but also drive it forward in a targeted manner.

Ultimately, it is clear that the implementation of these recommendations is not possible without a long-term political commitment. If Georgia is willing to undertake comprehensive structural and educational reforms, a health care system can emerge that not only appears inclusive on the surface but respects the rights, needs, and dignity of all citizens – regardless of disability, place of residence, or social status.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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Competing Interests

The authors declare no competing interests.

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Ethical Standards

The research meets all ethical guidelines, including adherence to the legal requirements of the study country.

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MANIFESTATION OF COMPREHENSIVELY INVESTIGATING THE CRITICAL INFLUENCES, PERSISTENT EXISTING BARRIERS, AND EMERGING POTENTIAL FUTURE CHALLENGES IMPACTING OF PHARMACISTS' PROFESSIONAL CAREER ADVANCEMENT IN GEORGIA

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ABSTRACT

The main aim of this study was to assessing the key determinants of pharmacists' employment development, setbacks and future potential in Georgia in general. A quantitative approach was used to examine the primary elements influencing pharmacists' career advancement and vocational challenges, utilizing structured questionnaires as the main tool for data collection. The research included a survey and in-depth interviews with participants. Validated questionnaires were employed with randomly selected participants, and a combination of systematic sociological analysis, comparative methods, statistical, and graphical techniques was applied. Data processing and analysis were performed using SPSS software, with descriptive statistics and regression analyses conducted to investigate relationships between variables. Statistical significance was determined using the Chi-square test with a p-value threshold of <0.05 for all analyses. This study was composed of several sub-studies aimed at assessing the main factors affecting pharmacists' career growth and the challenges within their professional environment in Georgia. The results emphasize the urgent need to address the factors that impact pharmacists' career progression and work-related challenges, identifying key areas that require improvement. Solutions to these issues will demand a holistic approach, including reforms in education, updates to regulatory frameworks, enhanced interdisciplinary collaboration, and improved workplace support systems. These steps will better equip Georgia's pharmacy profession to meet the evolving demands of healthcare and significantly improve patient outcomes. In many developing countries, the pharmacy profession is tightly regulated, akin to family medicine. A Chi-square test was conducted to compare different groups' views on the necessity of government-mandated pharmacist certification. Public health specialists were more likely than managers (Chi-square = 45.2, $p < 0.001$) and pharmacists (Chi-square = 68.9, $p < 0.001$) to support mandatory certification, while there was no significant difference between managers and pharmacists. Patients were also more inclined to support certification than pharmacists (Chi-square = 44.2, $p < 0.001$). Employed students were more likely to endorse certification than pharmacists (Chi-square = 57.3, $p < 0.001$). The current pharmaceutical services related to self-care and the critical role of pharmacists in directing healthcare systems towards modern practices are significant. The collaboration between physicians and pharmacists is growing and has shown positive outcomes for patient health. The study found that including pharmacists in the drug therapy process reduces drug-drug interactions, adverse drug reactions, and treatment costs. The research also showed that when pharmacists' interventions were considered, therapeutic effects improved for most patients, and adverse drug reactions were avoided in many cases. The professional growth of pharmacists in Georgia faces several significant hurdles, particularly in education, job satisfaction, and professional acknowledgment. Addressing these challenges will require coordinated efforts from government bodies, educational institutions, and healthcare organizations. By aligning the pharmacy profession with global standards and offering more opportunities for ongoing education, Georgia can ensure that its pharmacists are adequately prepared to meet the increasing demands of the healthcare system. Pharmacists in Georgia encounter a unique set of challenges compared to their

peers in Western nations. In many developed countries, pharmacy is regulated similarly to other healthcare professions, such as family medicine, with pharmacists undergoing extensive training, continuous education, and periodic licensing reviews to maintain high professional standards. In contrast, the profession in Georgia has not yet been fully integrated into the healthcare system. Many pharmacists feel underrecognized, both professionally and financially. Furthermore, the absence of continuing education programs and a cohesive professional organization to advocate for pharmacists' rights and responsibilities has limited their role. The global pharmaceutical industry continues to evolve, with pharmacists assuming more specialized roles, particularly in clinical environments. This paper aims to identify the disparities between Georgian pharmacists and their international peers, stressing the need for reforms in education, certification, and professional integration.

Keywords: Pharmacists, professional growth, vocational challenges, Georgia, pharmacy practice, educational frameworks.

Introduction

The article provides an in-depth analysis of the indicators that alter pharmacists' professional trajectories. By examining both the positive advancements and persistent challenges within the profession, the study aims to offer insights into potential solutions and policy recommendations for overcoming these vocational obstacles. Ultimately, the goal is to contribute to the ongoing discourse on enhancing the role of pharmacists in Georgia's healthcare system, ensuring that the profession continues to evolve in ways that benefit both practitioners and the communities they serve. The evaluation of key determinants affecting pharmacists' professional formation and occupational setbacks in Georgia highlights significant areas for improvement. Addressing these issues requires a multifaceted approach involving educational reform, regulatory updates, enhanced inter professional collaboration, and adequate workplace support. By focusing on these aspects, the pharmacy profession in Georgia can better align itself with the evolving demands of healthcare and ultimately improve patient outcomes. The role of a pharmacist as a health profession provider requires not only higher education but also postgraduate and continuous professional development in pharmacy. Pharmacists must obtain a license and undergo periodic accreditation to maintain their professional standing. In Western nations, only individuals with accredited higher pharmaceutical education are permitted to practice. The process of opening a pharmacy is also strictly regulated, with permits granted exclusively to those who have completed recognized pharmacy programs and earned the credentials necessary to operate a pharmacy. It is important to note that in both developed and developing nations, pharmacy is a tightly regulated profession, akin to family medicine. Pharmacists, viewed as family healthcare providers, must possess advanced pharmaceutical education, a diploma, ongoing professional training, a pharmaceutical license, and undergo regular accreditation. These regulations ensure the highest standards of care and accountability in the profession [1-7].

On the basis of theoretical analysis of the process of professional development will be developed by a set of common criteria for the effectiveness of this process, which will be based on the regularities of formation, reflecting its focus and dynamics: an interest in their chosen profession, changing choice motives, increased satisfaction of occupational choice and labor, increasing the motivation to knowledge and professional development, change career planning purposes. The goal, purpose and objectives of the planned research. The main aim is to develop a methodological approach to study and improve the process of professional development

specialists' pharmaceutical profile, regulation requirements for pharmaceutical staff in drugstore professional career improvement strategy and jobsatisfaction among pharmacists. A systematic analysis identified factors which had influence the formation of personal-professional position of a pharmaceutical professional and realization of their personal resources. On the basis of theoretical analysis of the process of professional development there will be developed a set of common criteria for the assessment of the effectiveness of this process, based on which will be identified the regularities of formation, reflecting its focus and dynamics: their interest in profession of choice, changes in choice making motivation, growing job satisfaction, increasing the desire to acquire more knowledge and professional skills and making appropriate adjustments in their career goals. Based on the theoretical analysis of the main approaches to the study of the process of professional development, taking account the concept of pharmaceutical assistance, a set of related criteria for the effectiveness of this process. Based on common performance criteria, the patterns of formation are revealed, reflecting its direction and dynamics: interest in the chosen profession, changing the determinants of choice motives, increasing satisfaction with choice of profession and work, increasing motivation for cognition and continuous professional development, changing career planning goals. On the basis of specific criteria, the specifics of the formation are revealed, which include: incomplete correlation of the internal resources of the individual with the needs of the pharmacist/pharmacist profession, insufficient awareness of individual aspects of future activities, the difficulties of production adaptation, and low satisfaction with the work of pharmaceutical professionals [8-12].

Deficiency of knowledge and functions of pharmaceutical professions in Georgia is not exists only in the non-medical section of the society, but also in the medical staff like health-care specialists. Developing a continuous pharmaceutical education system, will enhance the professionalism of pharmaceutical personnel. We also measure the perception of job satisfaction among Georgian pharmacists and future proposals to improve pharmacists' job satisfaction. Using described above questionnaire, the purpose of our study was: To obtain data on job satisfaction retail environment; To distinguish aspects of the community of practice that have the greatest contribution to work gratification; To investigate the precision and reliability of the questionnaire in a study sample community pharmacies. We have been studied "the peculiarities of professional pharmacists, career satisfaction and service improvement strategy". It is necessary to obtain a grade of key issue factors influence of pharmacists' professional development according occupational vision of health care professionals and pharmacy students in Georgia. [13-16].

Development of organizational and functional models for licensing pharmaceutical activities, is considered as one of the mechanisms to improve the efficiency of public administration, and has great relevance and scientific and practical value. An integral part of the state system of measures to implement the rights of citizens to protect their health is pharmaceutical care, the quality of the provision which is largely dependent on the qualifications of the personnel pharmacist. In this regard, the professional qualification of experts is under the control of the state and is one of the objects of state regulation of relations in the field of drug- medicine, whose purpose - maintaining the competence of expert specialists on throughout their careers with varying requirements for professional quality [17-20].

The modern system of pharmaceutical care to improve the quality of life of patients depends on highly skilled professionals in drug-store whose competence has been growing in the process of professional development. The pharmacists require not only the use of earned at the institution of knowledge and skills, but also the willingness to professional self-development. Since the scope

of drug treatment is one of the most socially significant areas of state regulation, the sequence in carrying out reform measures, conservation experience, and smooth introduction of new methods become crucial. However, comprehensive studies aimed at understanding the process of professional formation pharmaceutical worker, for to provide quality pharmaceutical care has not yet been carried out. Development of organizational and functional model of the licensing of pharmaceutical activities, pharmacists job as one of the mechanisms to improve the efficiency of public pharmaceutical and public administration, has great relevance, scientific and practical value [21-24].

- **High Workload and Stress:** Increased responsibilities, coupled with staffing shortages, can lead to overwhelming workloads, resulting in stress and burnout.
- **Public Perception:** Misunderstandings regarding the role of pharmacists can limit their recognition as vital healthcare providers, impacting job satisfaction and career advancement.
- **Regulatory Constraints:** Overly stringent regulations can stifle innovation and restrict pharmacists from fully utilizing their training to enhance patient care.
- **Economic Factors:** Financial pressures within healthcare systems can lead to resource constraints, affecting the availability of training and professional development opportunities for pharmacists.

Pharmacist profession has undergone significant changes in recent years, particularly in the realm of clinical responsibilities and patient care. Traditional roles, where pharmacists primarily dispensed medication, have expanded globally, with pharmacists now playing a crucial part in healthcare teams. In Georgia, however, pharmacists still face challenges in professional recognition, continuing education, and collaboration with other healthcare professionals. This paper aims to explore the professional development of pharmacists in Georgia and suggest areas for improvement by comparing local trends with global advancements [25-29].

The advent of online pharmacies and other technological developments has further shifted the landscape of the profession. While these changes meet consumer demand, they have also impacted the direct, personal connection pharmacists traditionally had with patients. This erosion of pharmacist-patient relationships, coupled with inadequate government support for pharmacists' professional development, has raised concerns about the future of the profession in Georgia. Globally, the role of pharmacists is increasingly being recognized, particularly in fields such as pharmacotherapy and clinical pharmacy. This paper will examine the Georgian context and evaluate how pharmacists' roles can be enhanced through targeted reforms in education, regulation, and professional collaboration [30-33].

The role of pharmacists has evolved significantly in recent years, with increasing responsibilities that extend beyond traditional dispensing duties. In Georgia, as elsewhere, pharmacists are now expected to contribute actively to patient care, medication management, and public health initiatives. However, the professional formation of pharmacists faces various challenges that can hinder their effectiveness and the overall impact they have within the healthcare system [34-37].

A systematic analysis will identify factors which influence the formation of personal-professional position of a pharmaceutical professional and realization of their personal resources. On the basis of theoretical analysis of the process of professional development there will be developed a set of common criteria for the assessment of the effectiveness of this process, based on which will be identified the regularities of formation, reflecting its focus and dynamics: their interest in profession of choice, changes in choice making motivation , growing job satisfaction, increasing

the desire to acquire more knowledge and professional skills and making appropriate adjustments in their career goals. The stage of professional development of specialists is the adaptation to work activity: the beginning of an independent professional activity and the accumulation of experience by young specialists. This stage reflects the student's transition to a new type of activity - to professional work in its various forms in the conditions of real situation, performance of official duties, production relations, finding oneself in the system of work collectives. In the course of adaptation, the system of professional knowledge and skills is acquired in the required volume; the emergence of interest in the work, which begins to play an increasingly important role in life, a sense of the connection between success and the profession, is self-determination for professional development [38].

The article examines the key factors that influence the professional development and career challenges faced by pharmacists in Georgia. It seeks to provide a scholarly analysis of the changing landscape of pharmacy practice, emphasizing the various indicators that shape professional growth within the region. The study looks at how educational structures, policy reforms, and shifts in the industry have reshaped the opportunities and obstacles encountered by pharmacists. By conducting a thorough review of existing literature and professional insights, the article evaluates the socio-economic and regulatory influences on the profession. It also investigates the role of ongoing education, professional advancement, and the integration of pharmacists into collaborative healthcare settings. The findings highlight the critical need to address these challenges in order to create a stronger, more inclusive professional environment within Georgia's pharmaceutical sector.

Goal:

The main aim of the study was to analyze and grade the key determinants of pharmacists' employment development, setbacks and future potential in Georgia in general.

Methodology:

Research objectives are materials of sociological research: the study was quantitative investigation by using survey (Questionnaire). The study was quantitative investigation by using survey (Questionnaire). The in-depth interview method of the respondents was used in the study. The approved questionnaires were used (Respondents were randomly selected. Were used methods of systematic, sociological (surveying), comparative, segmentation, mathematical-statistical, graphical analysis. Research objectives are materials of sociological research: the study was quantitative investigation by using survey – questionnaire. The in-depth interview method of the respondents was used in the study. Different types of approved questionnaires were used (respondents were randomly selected), e.g.

- Questionnaire for chief pharmacists: 410 chief pharmacists;
- Questionnaire for patients: 1506 patients (customers of drug-stores);
- Questionnaire for employed pharmacy faculty-students: 222 employed students;
- Questionnaire for health-care specialists: 307 public health specialists;
- Questionnaire for pharmacist specialists: 810 pharmacist specialists.

Totally 3888 respondents were interviewed in Georgia.

The data was processed and analyzed with the SPSS program. Results and discussion: Questions and answers are given in the tables. On each question are attached diagrams or table. Questionnaire and diagrams are numbered. Study of the data was processed and analyzed with the

SPSS program. We conducted descriptive statistics and regression analyses to detect an association between variables. Statistical analysis was done in SPSS version 11.0. A Chi-square test was applied to estimate the statistical significance and differences. We defined $p < 0.05$ as significant for all analyses. The study's ethical items. In order to provide the study's ethical character each participant of it was informed about the study's goal and suggested of willingness of the work to be done. So, the respondents' written or oral compliance was got on that issue. All the studies were carried out by the selected organizations administrations' previous compliance. Were used Informed consent form for each respondent to participate in an anonymous survey. During the whole period of research, the participants incognita was also provided. For the international rules and criteria' conformity this human subject comprising given study was discussed and confirmed on the Bioethics Committee sessions of the YSMU. In order to meet the objectives, set in the research we also used the results obtained through analysis of available official information, studies and opinions about pharmacists, as well as the methods of quantitative studies. We conducted descriptive statistics and regression analyses to detect an association between variables. Statistical analysis was done in SPSS version 11.0. A Chi-square test was applied to estimate the statistical significance and differences. The research implementation required the following sub studies: Assessing the key determinants of pharmacists' employment development, setbacks and future potential in Georgia in general.

Results and discussion:

The manifestation of scientific discussions regarding the key determinants of pharmacists' employment development, setbacks, and future potential in Georgia reveals a complex landscape shaped by a variety of factors. The professional growth of pharmacists in Georgia is influenced by educational frameworks, regulatory changes, and the evolving demands of the healthcare system. Despite significant advancements, the profession faces numerous setbacks, including gaps in continuing education, professional recognition, and the integration of pharmacists into collaborative healthcare settings. These challenges hinder the full potential of pharmacists to contribute to the healthcare system effectively.

Educational reforms and the modernization of training programs are vital for addressing these issues. By aligning pharmacy education more closely with international standards and incorporating contemporary practices, Georgia can help equip its pharmacists with the skills necessary to navigate the rapidly changing healthcare environment. Furthermore, strengthening the regulatory framework that governs pharmacy practice could improve professional recognition and support the career development of pharmacists.

Pharmacists in Georgia also face challenges related to job satisfaction and compensation, which can impact their overall career progression. Many pharmacists report feeling undervalued, and this lack of recognition further complicates efforts to improve their professional development. Overcoming these barriers will require a multi-faceted approach, involving the government, educational institutions, and healthcare organizations. Collaborative efforts between these entities can pave the way for better support systems for pharmacists, ensuring that their contributions to healthcare are properly acknowledged and rewarded.

In terms of future potential, the pharmacy profession in Georgia has a significant opportunity to evolve in response to global trends. As the role of pharmacists expands internationally, particularly in clinical settings, there is a growing recognition of their ability to improve patient outcomes through their expertise in drug therapy management. By embracing these shifts,

Georgia's pharmacists could take on more specialized roles and contribute more directly to improving healthcare delivery. However, this will only be possible if the barriers hindering their professional growth are addressed through thoughtful reforms and systemic changes.

Pharmacists, as healthcare providers, require not only advanced education but also postgraduate and continuous professional training. They must obtain licenses and undergo periodic accreditation to maintain professional status. In Western countries, only individuals with accredited pharmaceutical education can practice pharmacy. The establishment of a pharmacy is also strictly regulated, with permits granted solely to those holding recognized qualifications. Whether in developed or developing countries, the pharmacy profession remains highly regulated, akin to family medicine. Pharmacists, regarded as providers of family healthcare, must possess advanced pharmaceutical education, professional diplomas, continuous training, valid licenses, and regular accreditation to ensure the highest standards of practice and accountability. In Georgia, pharmacists face significant challenges in professional development, particularly in areas such as education, job satisfaction, and professional recognition. Overcoming these barriers will require collaborative efforts among government bodies, academic institutions, and healthcare organizations. By aligning the pharmacy profession in Georgia with global standards and expanding opportunities for continuous education, the country can ensure that its pharmacists are well-equipped to meet the growing demands of the healthcare system.

On the question what is your interest in regard of your future work (workplace)? (You can indicate several answers) pharmacy faculty students' 34.2% answer content (essence) of the work, pharmacy faculty students' 35.7% answer labor conditions, necessary equipment, pharmacy faculty students' 66.8% answer the system of labor and rate of wage (salary of labor), pharmacy faculty students' 23.5% answer peculiarities of team of collective, where I have to work, pharmacy faculty students' 17.6% answer employment opportunities, pharmacy faculty students' 31.0% answer demand for such specialist at the labor market. See Illustration 1.

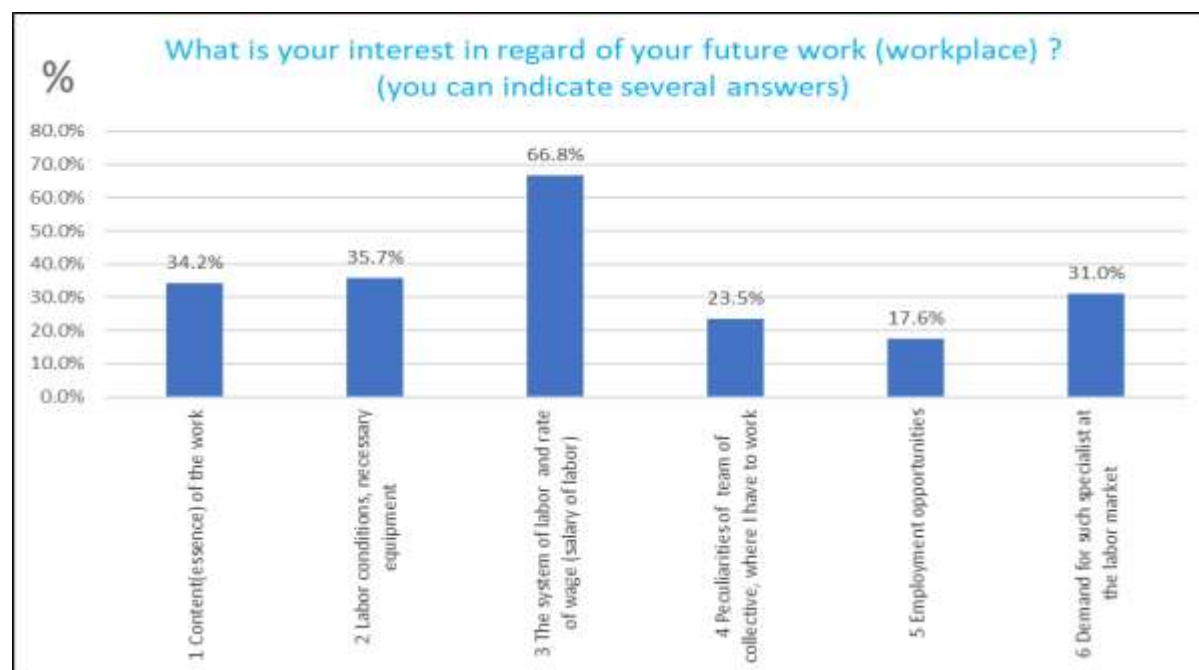


Illustration 1. Respondents interest issues regarding of future work (workplace).

Source – study results.

Would you like to change your chosen specialty? On the question would you like to change your chosen specialty? Pharmacy faculty students' 13.2% answer yes, pharmacy faculty students' 86.8% answers no.

What is main reason for change your direction of learning? On the question- What is main reason for change your direction of learning? Pharmacy faculty students' 31.7% answer I understand that the given work is not interesting to me, pharmacy faculty students' 46.3% answer future work will not correspond to my aspirations, and inclinations (affections), pharmacy faculty students' 9.8% answer I am not satisfied with the quality of education, pharmacy faculty students' 7.3% answer I do not like the quality of teaching, pharmacy faculty students' 4.9% answer other reason.

On the question do you know where to work after graduating? Pharmacy faculty students' 40.8% answer yes, pharmacy faculty students' 17.9% answer no, pharmacy faculty students' 41.4% answer I know roughly, but it may be change.

On the question -Are you engaged in the search of your future work by specialty (training)? Pharmacy faculty students' 63.3% answer yes, pharmacy faculty students' 36.7% answers no. See Illustration 2.

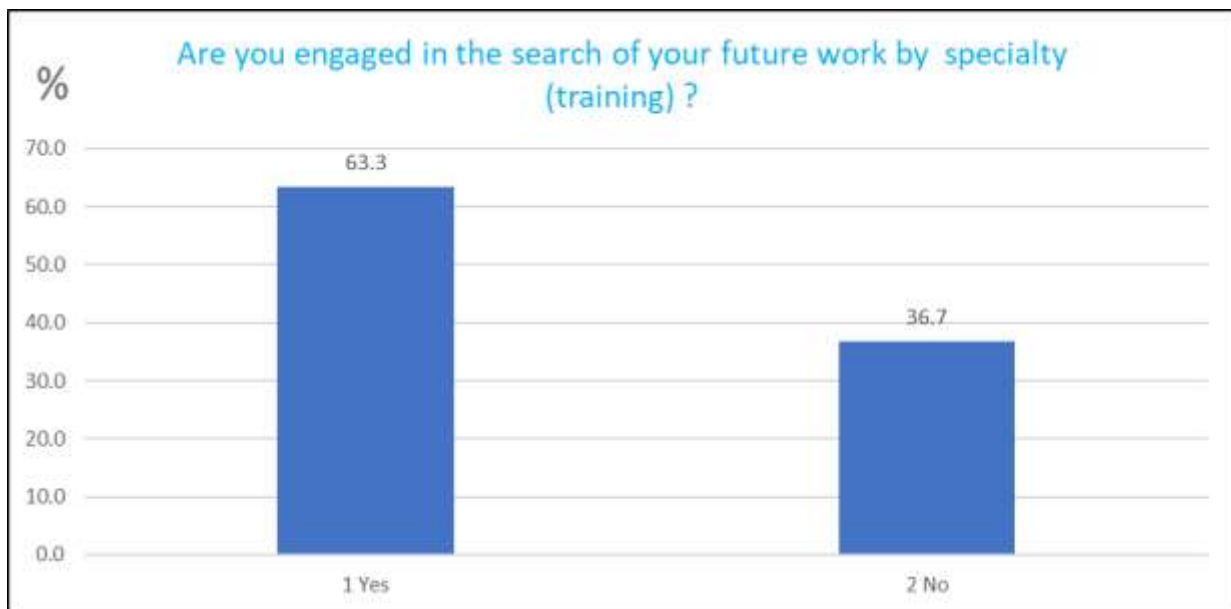


Illustration 2. If respondents are you engaged in the search of future work by specialty (training). Source – study results.

On the question-What goals do you want to achieve as a result through professional career? - Obtain more power and authority-pharmacists' 7.5% evaluate by 1 point, pharmacists' 11.2% evaluate by 2 points, pharmacists' 16.8% evaluate by 3 points, pharmacists' 31.1% evaluate by 4 points, pharmacists' 33.3% evaluate by 5 points. See Table-1.

Table 1. Obtain more power and authority of respondents, as goals to achieve as a result through professional career, evaluated by 5 points scale system.

What goals do you want to achieve as a result through professional career? -Obtain more power and authority

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	61	7.5	7.5	7.5
	2	91	11.2	11.2	18.8
	3	136	16.8	16.8	35.6
	4	252	31.1	31.1	66.7
	5	270	33.3	33.3	100.0
	Total	810	100.0	100.0	

Source – study results

On the question-What goals do you want to achieve as a result through professional career? - Much higher status-pharmacists' 6.7% evaluate by 1 point, pharmacists' 8.8% evaluate by 2 points, pharmacists' 15.2% evaluate by 3 points, pharmacists' 32.6% evaluate by 4 points, pharmacists' 36.8% evaluate by 5 points. See Ill.-3.



Illustration 3. Much higher status of respondents, as goals to achieve as a result through professional career, evaluated by 5 points scale system.

Source – study results.

On the question-What goals do you want to achieve as a result through professional career? – Independence-pharmacists' 7.8% evaluate by 1 point, pharmacists' 8.1% evaluate by 2 points, pharmacists' 14.2% evaluate by 3 points, pharmacists' 28.4% evaluate by 4 points, pharmacists' 41.5% evaluate by 5 points. See illustration-4.

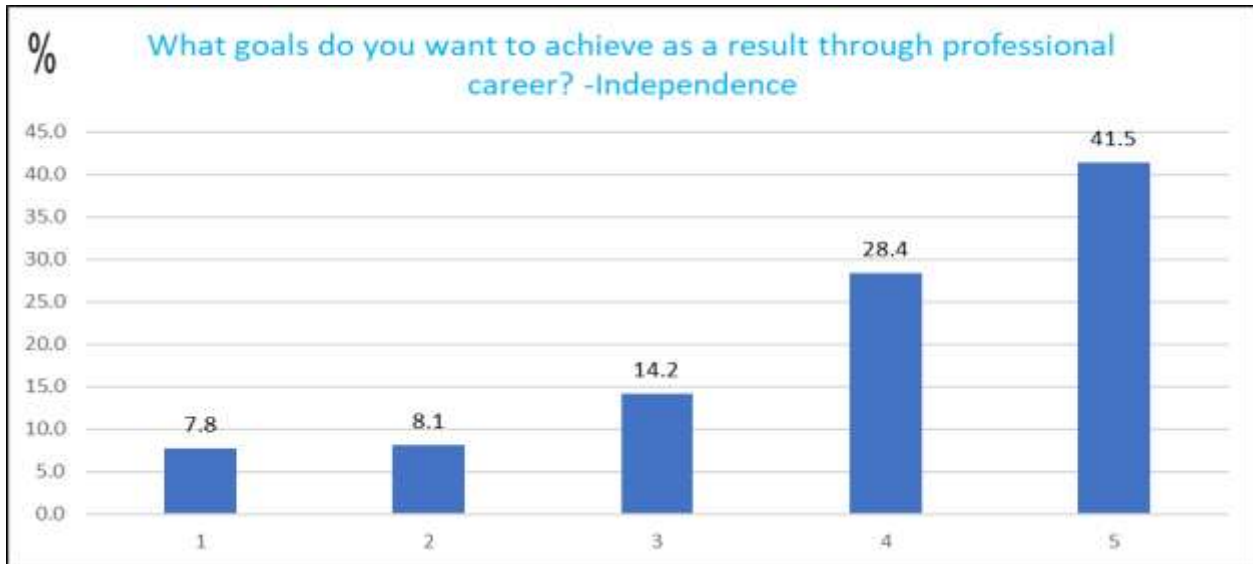


Illustration 4. Independence of respondents', as goals to achieve as a result through professional career, evaluated by 5 points scale system.

Source – study results.

On the question-What goals do you want to achieve as a result through professional career? -Self-realization-pharmacists' 5.9% evaluate by 1 point, pharmacists' 6.9% evaluate by 2 points, pharmacists' 12.3% evaluate by 3 points, pharmacists' 23.1% evaluate by 4 points, pharmacists' 51.7% evaluate by 5 points. See Table-2.

Table 2. Self-realization of respondents', as goals to achieve as a result through professional career, evaluated by 5 points scale system.

What goals do you want to achieve as a result through professional career? -Self-realization					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	48	5.9	5.9	5.9
	2	56	6.9	6.9	12.8
	3	100	12.3	12.3	25.2
	4	187	23.1	23.1	48.3
	5	419	51.7	51.7	100.0
	Total	810	100.0	100.0	

Source – study results

On the question-What goals do you want to achieve as a result through professional career? – Power-pharmacists' 20.5% evaluate by 1 point, pharmacists' 13.7% evaluate by 2 points, pharmacists' 18% evaluate by 3 points, pharmacists' 24.8% evaluate by 4 points, pharmacists' 23% evaluate by 5 points. See Table-3.

Table 3. Power of respondents, as goals to achieve as a result through professional career, evaluated by 5 points scale system.

What goals do you want to achieve as a result through professional career? -Power					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	166	20.5	20.5	20.5
	2	111	13.7	13.7	34.2
	3	146	18.0	18.0	52.2
	4	201	24.8	24.8	77.0
	5	186	23.0	23.0	100.0
	Total	810	100.0	100.0	

Source – study results

On the question-What goals do you want to achieve as a result through professional career? -Economic (material) welfare-pharmacists' 2.2% evaluate by 1 point, pharmacists' 2.3% evaluate by 2 points, pharmacists' 5.6% evaluate by 3 points, pharmacists 21.5% evaluate by 4 points, pharmacists' 68.4% evaluate by 5 points. See Ill.-5.

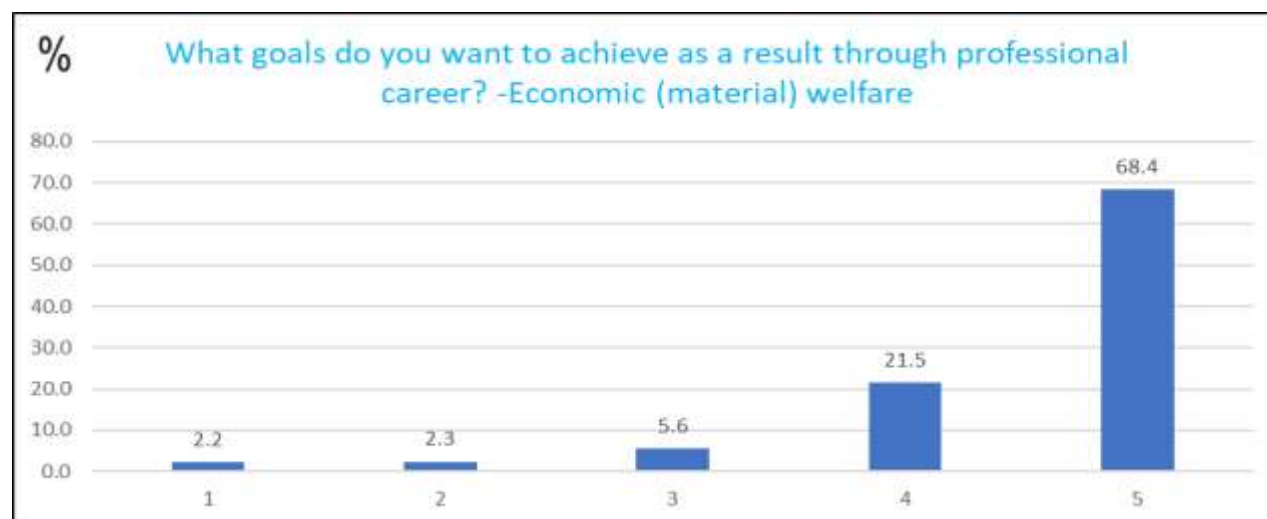


Illustration 5. Economic (material) welfare of respondents', as goals to achieve as a result through professional career, evaluated by 5 points scale system.

Source – study results.

On the question-What goals do you want to achieve as a result through professional career? -Professional growth-pharmacists' 2.1% evaluate by 1 point, pharmacists' 1.7% evaluate by 2 points, pharmacists' 6.5% evaluate by 3 points, Pharmacists' 18.9% evaluate by 4 points, pharmacists' 70.7% evaluate by 5 points. See Ill-6.



Illustration 6. Professional growth of respondents, as goals to achieve as a result through professional career, evaluated by 5 points scale system.

Source – study results.

On the question-What goals do you want to achieve as a result through professional career? - Career advancement (growth)-pharmacists' 2.8% evaluate by 1 point, pharmacists' 2.7% evaluate by 2 points, Pharmacists' 6.2% evaluate by 3 points, Pharmacists' 18.5% evaluate by 4 points, Pharmacists' 69.8% evaluate by 5 points. See Table-4.

Table 4 . Career advancement (growth) of respondents, as goals to achieve as a result through professional career, evaluated by 5 points scale system.

What goals do you want to achieve as a result through professional career? -Career advancement					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	23	2.8	2.8	2.8
	2	22	2.7	2.7	5.6
	3	50	6.2	6.2	11.7
	4	150	18.5	18.5	30.2
	5	565	69.8	69.8	100.0
	Total	810	100.0	100.0	

Source – study results

Report on the question - What goals do you want to achieve as a result through professional career? (Please evaluate each of the chosen option by 5 points scale system). See Table-5.

Table 5. Report of respondents on the question – “What goals do you want to achieve as a result through professional career?”

What goals do you want to achieve as a result through professional career? (Please evaluate each of the chosen option by 5 points scale system)			
	Mean	Median	Std. Deviation
What goals do you want to achieve as a result through professional career? - Obtain more power and authority	3.71	4.00	1.245
What goals do you want to achieve as a result through professional career? - Much higher status	3.84	4.00	1.203
What goals do you want to achieve as a result through professional career? - Independence	3.88	4.00	1.253
What goals do you want to achieve as a result through professional career? - Self-realization	4.08	5.00	1.203
What goals do you want to achieve as a result through professional career? - Power	3.16	3.00	1.449
What goals do you want to achieve as a result through professional career? - Economic (material) welfare	4.51	5.00	.877
What goals do you want to achieve as a result through professional career? - Professional growth	4.54	5.00	.858
What goals do you want to achieve as a result through professional career? - Career advancement (growth)	4.50	5.00	.937

Source – study results

On the question- Are you satisfied with the balance between the workload and your personal life? Pharmacists’ 28.6 % answer yes, pharmacists’ 37.2% answer partially, pharmacists’ 34.2% answer no.

In many developing countries in the field of pharmacy are regulated, as well as family medicine. The pharmacist as family doctor needs of higher education, post-graduate and continuing education in pharmacy, a pharmacist license and periodic accreditation. In western countries in pharmacy, allowed to work only with higher pharmaceutical education specialists who have graduated from state-recognized and accredited colleges. The opening of a pharmacy permit is issued only to a person of higher pharmaceutical education, who passed the diploma courses in pharmacy and earned the right to open the pharmacy. It should be noted that in developed countries and in many developing countries pharmaceuticals are regulated profession, as well as family medicine, pharmacist as a family doctor, need higher pharmaceutical education, diploma and continuous pharmaceutical education, pharmaceutical license and periodic accreditation. Only pharmacists with higher pharmaceutical education have the right to work as pharmacists in pharmacies, who have graduated from universities recognized and accredited by the state. Despite the significant contributions pharmacists can make, they encounter various setbacks that impact their occupational effectiveness.

Statistically significant was association between the buyers' educational level and their opinion about the necessity of pharmacists' certification ($p < 0.04$): customers with higher education considered certification of pharmacists as mandatory more often, than did buyers (patients) with secondary education. The respondents' vast majority considered that the issues to for pharmacists were in need of the further regular studies or trainings in the following fields: new medications, issues of pharmacotherapy of certain diseases, pharmacology and pharmacotherapy, drugs toxicity. From study results it is obvious that in the higher pharmaceutical institutions' pharmaceutical educational programs and curriculum need upgrade, renewal, modernization and adaptation to the new modern medical challenges. Therefore, continuous pharmaceutical educational programs should be created. These programs should be more focused on new medications, pharmacotherapy, drugs toxicity and dosage, routes of drug administration, selection of OTC drugs, cost-effectiveness and cost-benefits of drugs. Pharmacist provide contribution and assistance in teaching of patients to understand the prescribed drugs intake rules, pharmacists need in deep knowledge in basics of medicine, pharmacology, pharmacotherapy, pharmaceutical chemistry, pharmaceutical care, clinical pharmacy and other pharmaceutical disciplines. Properly educated pharmacists have great importance and value for the provision higher quality health care services, for the provision higher quality pharmaceutical care and very essential for patient's safety. The respondents' vast majority considered that the Government should make the certification of pharmacists. It is very essential and important that higher pharmaceutical educated pharmacists to have pharmacist license issued by the Government. The vast majority of the public health specialists considered that the professional activity of pharmacist is very important for the society.

It is necessary to provide a deep cooperation between pharmacists and physicians on the issues of pharmacotherapy and healthcare to ensure the patients' health state effective improvement, and also to provide the best feedback regulation and revision in the healthcare specialists' team work. Pharmacists also should be responsible for registration of the drugs' side effect, as well as be attentive in case of improperness and professional defects of drugs they provide. To achieve that it is necessary to raise awareness of specialists on the essence of pharmacists' profession and functions among the medical personnel and general public.

On the question is a pharmacist responsible for treatment together with a physician? Health care specialists' 25.4% answer yes, health care specialists' 54.1% answer no, health care specialists' 20.2% answer partially, health care specialists' 0.3% answer cannot say. See Illustration 7.

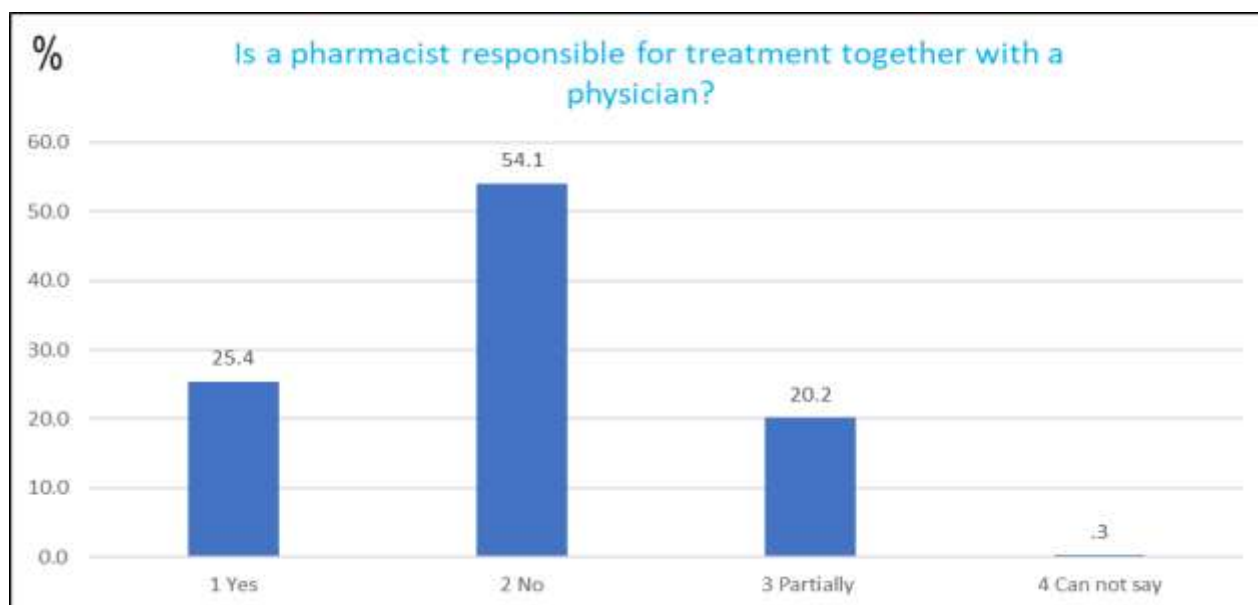


Illustration 7. Respondents' opinion if pharmacist responsible for treatment together with a physician.

Source – study results.

On the question- Should a pharmacist provide assistance in teach patients to understand rules of intake of prescribed drugs (medications)? Health care specialists' 79.5% answer yes, health care specialists' 6.5% answer no, health care specialists' 14% answer partially.

On the question - Is the pharmacist responsible for registration of side (adverse) effects of the drug (medication)? Health care specialists' 30.6% answer yes, health care specialists' 49.5% answer no, health care specialists' 14.3% answer partially, health care specialists' 5.5% answer cannot say.

On the question- Do you think that the government should make the certification of pharmacists? Health care specialists' 94.8% answer I agree, health care specialists' 4.6% answer I partly agree, health care specialists' 0.7% answer I do not agree.

On the question -what most of all had influence on your professional (occupational) choice (indicate only one answer)? Pharmacy faculty students' 25.7% answer parents' advice (or will), pharmacy faculty students' 4.4% answer teachers' advices , pharmacy faculty students' 7.2% answer worker-specialist's advice, pharmacy faculty students' 3.8% answer friends advice, pharmacy faculty students' 3.4% answer relatives or acquaintances' advice, pharmacy faculty students' 29.2% answer this profession corresponds to my aspiration, and inclination (affection) , pharmacy faculty students' 26.3% answer interest in profession.

On the question-What underlying motives did you have while selection of the given direction of education? (Indicate no more than 5 answers) pharmacy faculty students' 53.6% answer desire to obtain high-quality professional training, pharmacy faculty students' 26.3% answer prestige of specialty, pharmacy faculty students' 22.9% answer the existence of abilities to this (the given) type of activity, pharmacy faculty students' 8.8% answer family tradition, pharmacy faculty students' 39.8% answer desire to develop own capabilities, aspirations, and inclinations (affections), pharmacy faculty students' 29.8% answer the desire (ambition) to be included in a student community as a special social environment, pharmacy faculty students' 36.1% answer the

desire to expand horizons (desire to widen sense of vision), pharmacy faculty students' 18.5% answer desire to extend (lengthen) carefree period of life, pharmacy faculty students' 16% answer opportunity to take high social position, pharmacy faculty students' 49.8% answer guarantee to be employed, pharmacy faculty students' 27% answer desire to get high level to material well-being (security) , pharmacy faculty students' 28.5% answer the possibility to develop further (future) social promotion , pharmacy faculty students' 10.7% answer desire to obtain self-respect in the eyes of others who are close to me , pharmacy faculty students' 10% answer the desire (ambition) and interests to obtain certain circle of contacts, connections with friends and acquaintance, pharmacy faculty students' 1.9% answer deferring from military service , pharmacy faculty students' 13.5% answer desire to have needful social well-being, pharmacy faculty students' 39.8% answer interest in a profession, pharmacy faculty students' 21.6% answer desire to be useful to people. See Table 6.

Table 6. Underlying motives of respondents, while electing of the given direction of education.

What underlying motives did you have while selection of the given direction of education? (indicate no more than 5 answers)		
Answers:	Count	Column N %
1 Desire to obtain high-quality professional training	171	53.6%
2 Prestige of specialty	84	26.3%
3 The existence of abilities to this (the given) type of activity	73	22.9%
4 Family tradition	28	8.8%
5 Desire to develop own capabilities, aspirations, and inclinations (affections)	127	39.8%
6 The desire (ambition) to be included in a student community as a special social environment	95	29.8%
7 The desire to expand horizons (desire to widen sense of vision)	115	36.1%
8 Desire to extend (lengthen) carefree period of life	59	18.5%
9 Opportunity to take high social position	51	16.0%
10 Guarantee to be employed	159	49.8%
11 Desire to get high level to material well-being (security)	86	27.0%
12 The possibility to develop further (future) social promotion	91	28.5%
13 Desire to obtain self-respect in the eyes of others who are close to me	34	10.7%
14 The desire (ambition) and interests to obtain certain circle of contacts, connections with friends and acquaintance	32	10.0%
15 Deferring from military service	6	1.9%
16 Desire to have needful social well-being	43	13.5%
17 Interest in a profession	127	39.8%
18 Desire to be useful to people	69	21.6%

Source – study results

On the question- Are you satisfied with your professional (occupational) choice? Pharmacy faculty students' 77.4% answer yes, I am satisfied with my professional choice, pharmacy faculty

students' 9.1% answer in general, I am satisfied, but I have some doubts about the preciseness of my professional (occupational) choice, pharmacy faculty students' 8.5% answer I am partly satisfied with my professional choice, pharmacy faculty students' 3.8% answer I am mostly disappointed with my professional choice, pharmacy faculty students' 1.3% answer I am not satisfied with my professional choice. See Illustration 8.



Illustration 8. Satisfaction of respondents with professional (occupational) choice.
 Source – study results.

Key determinants of pharmacists' professional formation

several principal determinants influence the professional formation of pharmacists in Georgia. These include:

- ✓ **Educational Framework:** The quality and relevance of pharmacy education play a crucial role in shaping the competencies of future pharmacists. Continuous updates to curricula that reflect current practices and technologies are essential.
- ✓ **Regulatory Environment:** The legal and regulatory framework governing pharmacy practice significantly affects how pharmacists operate. Regulations can either empower pharmacists to expand their roles or create barriers that limit their scope of practice.
- ✓ **Interprofessional Collaboration:** Effective teamwork among healthcare professionals is vital for optimizing patient care. Barriers to communication and collaboration can impede pharmacists' contributions to the healthcare team.
- ✓ **Technological Integration:** The integration of advanced technologies, such as electronic health records and tele pharmacy, is critical in modernizing pharmacy practice. However,

insufficient training and resources can limit pharmacists' ability to utilize these technologies effectively.

- ✓ **Workplace Support and Resources:** Adequate support from healthcare institutions, including access to continuing education and professional development opportunities, is essential for pharmacists to thrive in their roles.

Pharmacy practice in Georgia, as in many regions, has undergone significant transformations in recent years, driven by advancements in healthcare, changes in educational frameworks, and evolving regulatory environments. Pharmacists, once seen primarily as dispensers of medications, now play a critical role in patient care through collaborative practice models, disease management, and preventive healthcare initiatives. However, despite these opportunities for professional expansion, numerous vocational obstacles continue to challenge the workforce in Georgia.

The study explore and critically examine the key issues influencing the professional growth and development of pharmacists in Georgia. It addresses the complex array of factors—educational, economic, regulatory, and societal—that impact the practice of pharmacy in the state. These factors shape not only the scope of the profession but also the opportunities available for professional expansion. At the same time, they create barriers that hinder pharmacists' ability to fully engage in these expanded roles.

The future of pharmacists in Georgia depends on overcoming the current challenges they face. Addressing the gaps in education, regulatory frameworks, and professional development will create a stronger foundation for the profession. By doing so, Georgia can ensure that its pharmacists are well-prepared to meet the future demands of healthcare, contributing meaningfully to improved patient care and the overall development of the healthcare system.

The professional development of pharmacists in Georgia faces substantial challenges, particularly in areas such as education, job satisfaction, and professional recognition. Overcoming these challenges will require collaborative efforts from the government, educational institutions, and healthcare organizations. By aligning the profession more closely with global standards and enhancing opportunities for ongoing education, Georgia can ensure that its pharmacists are well-prepared to meet the growing demands of the healthcare system.

Building on the initial insights, the future of pharmacy practice in Georgia hinges on overcoming the barriers that currently impede the professional development of pharmacists. A critical aspect of this process lies in addressing the regulatory and policy frameworks that govern pharmacy practice. In many countries, pharmacists operate within well-defined, updated regulatory systems that support their professional autonomy and growth. However, in Georgia, these systems are still evolving. Without strong regulatory oversight and policies that recognize the full range of pharmacists' capabilities, the profession struggles to gain the recognition and support it deserves. Strengthening these regulatory frameworks would provide pharmacists with more opportunities for career advancement, ensuring they are not only valued as essential members of the healthcare team but also equipped to contribute at the highest levels.

In addition to policy improvements, enhancing the scope of pharmacy education is paramount. Georgian pharmacy schools must adopt contemporary curricula that focus on clinical pharmacy, patient counseling, and the integration of pharmacists into multidisciplinary healthcare teams. Continuing education programs are equally crucial in keeping pharmacists up to date with the latest pharmaceutical innovations and treatment protocols. The introduction of specialized training

opportunities would enable pharmacists to work more effectively in areas like pharmacogenomics, immunization, and chronic disease management, all of which are critical to advancing the healthcare system.

Moreover, professional development goes beyond just educational and regulatory changes. Pharmacists need platforms for professional networking and advocacy, which can help raise awareness of their role in the healthcare system and ensure their voices are heard in policy discussions. A unified professional body or association could help foster a sense of community among pharmacists in Georgia, creating a stronger collective presence that can advocate for better working conditions, salary improvements, and recognition within healthcare teams. This would also enable pharmacists to more effectively advocate for patients' needs, ensuring that their input on drug therapy management and other pharmaceutical concerns is valued by other healthcare providers.

The evolving nature of the pharmaceutical industry also presents numerous opportunities for growth. With global trends moving toward personalized medicine, precision healthcare, and more patient-centric approaches to treatment, pharmacists have the potential to take on more specialized roles. Pharmacists could play an even greater role in managing drug therapy, preventing medication errors, and improving patient adherence to treatment plans. The future of pharmacy in Georgia would be greatly enhanced by incorporating pharmacists into more direct patient care roles, such as medication therapy management, chronic disease management, and preventative healthcare. This would require greater collaboration between pharmacists, physicians, and other healthcare providers to ensure that patients receive comprehensive and coordinated care.

In terms of setbacks, one of the most pressing challenges remains job satisfaction. Many pharmacists in Georgia report dissatisfaction with their roles, citing limited opportunities for career advancement, low salaries, and a lack of professional recognition. These issues can lead to burnout, job turnover, and a diminished sense of professional fulfillment. Addressing these challenges will require a concerted effort to improve the workplace environment, not just in terms of compensation but also by fostering a culture that values pharmacists' contributions to healthcare. By creating better working conditions and career advancement opportunities, Georgia can ensure that its pharmacists are motivated and equipped to meet the demands of a rapidly changing healthcare landscape.

Finally, as Georgia works to integrate its pharmacists more fully into the healthcare system, the importance of interprofessional collaboration cannot be overstated. Pharmacists, physicians, nurses, and other healthcare providers must work together as a cohesive team to improve patient outcomes. This collaborative approach will not only enhance the quality of care but also help pharmacists to build stronger professional relationships with other healthcare professionals, gaining greater recognition and respect for their expertise. To facilitate this integration, Georgia's healthcare system must foster a more inclusive approach to healthcare delivery that fully embraces the diverse contributions of all healthcare professionals, including pharmacists.

The professional development of pharmacists in Georgia faces several critical challenges, but these can be overcome through systematic reforms in education, regulation, and professional development. With the right support, pharmacists in Georgia have the potential to significantly improve patient care, contribute to the healthcare system's growth, and enhance their own professional satisfaction. Addressing the barriers to their development will pave the way for a more dynamic and integrated pharmacy profession, one that is well-equipped to meet the needs of modern healthcare and contribute to the advancement of the field globally.

Conclusion

Pharmacists in Georgia encounter a distinct set of challenges compared to their peers in Western countries. In many developed nations, the pharmacy profession is regulated similarly to other healthcare fields, such as family medicine, with pharmacists undergoing extensive training, continuous education, and periodic licensing evaluations to maintain high professional standards. However, in Georgia, the profession has not yet been fully integrated into the healthcare system. Many pharmacists report feeling undervalued in terms of both professional recognition and compensation. The absence of continuing education programs and a unified professional organization to advocate for pharmacists' rights has further constrained their role. As the global pharmaceutical industry evolves, pharmacists are assuming increasingly specialized roles, particularly in clinical settings. This paper aims to highlight the disparities between Georgian pharmacists and their international counterparts, underscoring the need for reforms in education, licensing, and professional integration. A Chi-square test of independence was conducted to compare various groups' perspectives on the need for government-regulated pharmacist certification. The view that pharmacist certification should be mandatory was more prevalent among public health specialists than among managers (Chi-square = 45.2, $p < 0.001$) and pharmacists (Chi-square = 68.9, $p < 0.001$), though no significant difference was found between managers and pharmacists. Patients also expressed stronger support for mandatory certification than pharmacists (Chi-square = 44.2, $p < 0.001$). Additionally, employed students were more likely to advocate for certification than pharmacists (Chi-square = 57.3, $p < 0.001$). Current pharmaceutical services are closely tied to self-health care, with a growing recognition of the crucial role pharmacists play in shaping modern healthcare systems. The collaboration between physicians and pharmacists is increasing, demonstrating positive effects on patient health outcomes. The study found that involving pharmacists in the drug therapy process significantly reduces drug-drug interactions, adverse drug reactions, and treatment costs. Furthermore, when pharmacists' interventions were considered, the therapeutic effects improved for most patients, and adverse drug reactions were successfully prevented in numerous cases.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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Competing Interests

The authors declare no competing interests.

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Ethical Standards

The research meets all ethical guidelines, including adherence to the legal requirements of the study country.

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THE MANIFESTAION OF SCIENTIFIC DISCUSSION OF PROGNOSIS, ACHIEVEMENT, AND CHALLENGES OF CHARASTERISTICS OF DENTAL HEALTH CARE IN MODERN MEDICINE IN GENERAL

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ABSTRACT

Dental healthcare has undergone significant transformations in recent years, driven by advancements in technology, research, and clinical practices. This article provides a scientific discussion on the prognosis, achievements, and challenges of dental healthcare within the framework of modern medicine. The study examines key developments in dental care, including innovations in diagnostic tools, treatment methods, and preventive measures that have led to improved patient outcomes. Despite these advancements, several challenges persist, particularly in areas of accessibility, affordability, and health disparities. Additionally, the evolving role of dental professionals within the broader healthcare system, including the increasing emphasis on interdisciplinary collaboration, is explored. By analyzing both the progress made and the obstacles faced, this article offers a comprehensive perspective on the state of dental healthcare and its integration into modern medical practice. Ultimately, the findings aim to inform future strategies for improving dental health outcomes and ensuring equitable access to care for all populations. However, despite these notable achievements, numerous challenges remain within the field of dental healthcare. Issues such as accessibility to quality care, high treatment costs, and significant disparities in dental health among different socio-economic and demographic groups continue to hinder the widespread delivery of effective care. Furthermore, the integration of dental care with broader healthcare systems poses challenges related to interprofessional collaboration and aligning treatment approaches. The role of dental professionals is expanding, with increased emphasis on prevention and early intervention, yet barriers to achieving optimal care persist due to systemic and financial limitations. This article provides an in-depth examination of the progress made in dental healthcare, while also critically assessing the ongoing challenges that must be addressed to further enhance care delivery. It offers insights into the future direction of dental healthcare, proposing strategies for overcoming existing obstacles, improving patient access, and promoting greater collaboration between dental and medical practitioners. By highlighting both the achievements and the challenges, the article aims to inform policy development and clinical practice, ultimately contributing to the continued evolution of dental care within the broader context of modern medicine. Dental healthcare has made remarkable strides in modern medicine, contributing significantly to improving overall patient health and quality of life. Innovations in diagnostic techniques, treatment modalities, and preventive care have not only advanced clinical practices but also expanded the role of dental professionals within the broader healthcare system. The integration of technology, such as digital imaging and laser therapy, has enabled more precise, efficient, and less invasive treatments, benefiting both practitioners and patients alike.

However, despite these achievements, several challenges remain that continue to affect the effectiveness and accessibility of dental care. Disparities in care, high treatment costs, and limited access to dental professionals, particularly in underserved areas, still represent major barriers to optimal oral health for many populations. Furthermore, while interdisciplinary collaboration between dental and medical fields holds great promise, there are still significant hurdles to overcome in fostering seamless integration and holistic care delivery. Looking forward, the future of dental healthcare lies in addressing these challenges through policy reforms, improved public health initiatives, and enhanced interprofessional cooperation. Increased investment in dental education, accessibility programs, and public awareness campaigns is essential for reducing disparities and improving outcomes. Additionally, continuing advancements in dental technology and research will undoubtedly further shape the evolution of the profession, enhancing both the prevention and treatment of oral diseases. While dental healthcare has made tremendous progress, its integration within modern medicine requires ongoing effort to overcome remaining obstacles. The collective focus on improving access to care, reducing inequalities, and fostering collaboration across healthcare disciplines will be pivotal in ensuring the continued advancement of dental health in the coming years. Only by addressing these challenges can we fully realize the potential of dental care as a vital component of overall health and well-being. The field of dental healthcare has made remarkable progress, with numerous achievements in technology, patient care, and preventative measures. These advancements have led to significant improvements in patient outcomes and the overall quality of dental care. However, challenges such as access to care, disparities in treatment, and the high cost of dental services continue to hinder the widespread delivery of effective dental care. To address these challenges, there needs to be continued focus on policy reform, increasing accessibility to dental care, and fostering stronger interdisciplinary collaborations between dental and medical professionals. The future of dental healthcare in modern medicine is bright, but it requires concerted effort from healthcare providers, policymakers, and educators to ensure that these advancements benefit all individuals, regardless of their socio-economic status or geographic location.

Keywords: Dental health care, features, general, oral care, modern medicine.

Introduction

Dental healthcare has evolved significantly over the years, driven by advances in technology, research, and clinical practices. This article discusses the prognosis, achievements, and challenges related to the characteristics of dental healthcare within the modern medical landscape. With technological advancements, new treatment methodologies, and preventative care practices, dentistry has progressed significantly, leading to improved patient outcomes. However, challenges related to accessibility, affordability, and healthcare disparities continue to persist. This article critically examines these issues and suggests strategies for overcoming these barriers to enhance the effectiveness of dental care in modern medicine. Dental healthcare plays a vital role in overall health, contributing to both physical and psychological well-being. Over the years, it has evolved from a largely restorative practice to a comprehensive field incorporating preventive care, patient education, and integrated treatment approaches. Modern dentistry now encompasses a wide range of specialties and employs innovative technologies that have revolutionized the way dental professionals diagnose and treat oral health issues. However, despite these advancements, challenges remain in achieving equitable access to quality dental care. Factors such as high treatment costs, disparities in care, and the integration of dental healthcare into broader medical

practices still represent significant obstacles to improving patient outcomes. This article aims to explore the prognosis of dental healthcare, its key achievements, and the ongoing challenges it faces in the context of modern medicine.

Dental healthcare has seen tremendous evolution in recent years, driven by technological innovations, advancements in clinical practices, and a deeper understanding of the relationship between oral health and overall well-being. This article examines the prognosis, achievements, and challenges that shape the characteristics of dental healthcare in modern medicine. While significant strides have been made in early detection, preventive care, and treatment options, challenges such as access, affordability, and health disparities remain. The article highlights the progress made in the field and provides a critical analysis of the ongoing issues that need to be addressed for optimal integration of dental health into overall healthcare systems.

Dental healthcare is no longer confined to simple tooth extraction or cavity treatment. Modern dentistry has transformed into a sophisticated field, incorporating advanced diagnostic tools, cutting-edge treatment techniques, and a focus on prevention rather than reaction. As a fundamental aspect of overall health, dental care significantly contributes to the physical and mental well-being of individuals. From cosmetic dentistry to restorative and preventive care, dental professionals now play a key role in enhancing patients' quality of life.

Despite the progress made in dental health, many challenges still impede the full potential of the profession. Disparities in access to care, the rising costs of treatments, and the integration of dental care into the broader healthcare system present significant barriers to the equitable provision of services. This article delves into the prognosis of dental health, its major achievements, and the challenges facing modern dental healthcare, offering a comprehensive understanding of the current landscape of the profession.

Dental healthcare is a critical component of modern medicine, serving not only as a preventative measure but also as a key element in the overall well-being of individuals. Over the years, the field of dentistry has evolved through significant advancements, from diagnostic tools to treatment methodologies, leading to improved patient outcomes and enhanced quality of life. As scientific research in the field continues to progress, new challenges and opportunities have emerged, presenting both advancements in dental care and obstacles that require further attention [1-2].

This article aims to provide a comprehensive scientific discussion on the prognosis, achievements, and challenges associated with dental healthcare in the context of modern medicine. By exploring the latest developments in dental technology, clinical practices, and patient care strategies, the study highlights the positive strides made within the field. At the same time, it critically examines the challenges that remain, particularly in terms of accessibility, cost, and disparities in care. The discussion also addresses the evolving role of dental healthcare providers, integration with broader medical practices, and the increasing need for interprofessional collaboration [3-5].

Through an analysis of current trends and future projections, this article offers insight into the ongoing transformation of dental healthcare, aiming to identify both the milestones achieved and the critical issues that need to be tackled to ensure continued progress in the field. Ultimately, the goal is to shed light on how the integration of dental care into modern medicine can enhance patient outcomes and contribute to a more holistic approach to healthcare. The importance of personal oral hygiene for supragingival plaque removal is a central paradigm in periodontal management. Periodic patient extractions are important because dental bacterial biofilm is the most important modifiable risk factor for periodontitis. Therefore, there is strong evidence that

mechanical removal of dental biofilm (eg, brushing, flossing) can significantly affect periodontal tissue stability. In periodontology, attention is paid to tooth buckle formed from non-mineralized plaques, soft dental plaques and also supragingival and subgingival calculus formed from mineralized dental plaques. Thus, tartar is formed at the expense of mineralization of the plaque. The formation of dental calculus is influenced by the alkaline phosphatase and aldolase present in the bacterial plaque, as well as by the high ATP content in dental plaque and saliva. The relationship between education and health status is well documented for a wide range of medical interventions. Mortality is inversely proportional to years of study, health problems and level of education. The relationship between education and health is complex and cannot be fully explained by income, labor market or marital status. Therefore, there are variety of possible mechanisms that influence the relationship between education and health. Dark and pale calculus differ morphologically and biochemically. Light-colored tartar is considered the initial stage of stone formation, and dark - the final stage [6-9]

The relationship between education and health is complex and cannot be fully explained by income, labor market or marital status. Therefore, there are a variety of possible mechanisms that influence the relationship between education and health. Like systemic health, a person's periodontal health is positively correlated with education. The importance of personal oral hygiene for supragingival plaque removal is a central paradigm in periodontal management. Periodic patient extractions are important because dental bacterial biofilm is the most important modifiable risk factor for periodontitis. Therefore, there is strong evidence that mechanical removal of dental biofilm (eg, brushing, flossing) can significantly affect periodontal tissue stability. In periodontology, attention is paid to tooth buckle formed from non-mineralized plaques, soft dental plaques and also supragingival and subgingival calculus formed from mineralized dental plaques. Thus, tartar is formed at the expense of mineralization of the plaque. The formation of dental calculus is influenced by the alkaline phosphatase and aldolase present in the bacterial plaque, as well as by the high ATP content in dental plaque and saliva. Dark and pale calculus differ morphologically and biochemically. Light-colored tartar is considered the initial stage of stone formation, and dark - the final stage [11-14].

Dental healthcare has made remarkable progress in modern medicine, with substantial advancements in technology, patient care, and preventive practices. These developments have led to improved patient outcomes and a more comprehensive approach to oral health. However, challenges such as access to care, high treatment costs, and health disparities continue to hinder the equitable delivery of dental services. The future of dental healthcare will depend on addressing these challenges through policy reforms, increasing investment in preventive care, and fostering stronger integration between dental and medical professionals. By overcoming these obstacles, we can ensure that dental healthcare continues to evolve, ultimately leading to better health outcomes for all populations.

Objectives

The aim of the research was to study and analyze peculiarities, prospects, challenges, opportunities and features of dental health care in general.

Methods

The material of the article was the data from scientific publications, which were processed, analyzed, overviewed and reviewed by generalization and systematization. Research studies are

based on a review/overview assessment of the development of critical visibility and overlook of the modern scientific literature. use the following databases (for extensive literature searches to identify the peculiarities, prospects, challenges, opportunities and features of dental health care in general.): pubmed, web of science, clinical key, tomson reuters, google scholar, cochrane library, and elsevier foundations. National and international policies and guidelines were also reviewed and as well as grey literature.

Results and discussion

The prognosis of dental healthcare is promising, particularly with the continued integration of advanced technologies and innovations. Key developments in dental imaging, laser treatments, digital dentistry, and minimally invasive procedures have significantly improved both diagnosis and treatment. The ability to detect oral health issues at an early stage has led to better prevention and management of conditions such as periodontal disease, cavities, and oral cancers.

Preventive dentistry, emphasizing early intervention and patient education, is expected to continue growing. The rise in awareness about the importance of oral health, coupled with the shift towards preventive care rather than reactive treatments, signals a positive future for dental healthcare. Additionally, the integration of dental professionals into broader healthcare teams is likely to improve both access to care and patient outcomes, particularly in underserved communities.

Modern dental care has made significant achievements, particularly in the areas of technology, patient care, and interdisciplinary collaboration:

1. **Technological Advancements:** The development of digital imaging, CAD/CAM (computer-aided design/computer-aided manufacturing) systems, 3D printing, and laser dentistry has greatly enhanced diagnostic accuracy and treatment effectiveness. These technologies enable precise restorations, quicker recovery times, and less discomfort for patients.
2. **Preventive Care and Early Detection:** There has been a strong emphasis on preventive dental care, including the use of fluoride treatments, sealants, and education on proper oral hygiene. Early detection techniques such as digital X-rays and salivary diagnostics have allowed dental professionals to identify issues before they develop into serious conditions.
3. **Patient-Centered Care:** The shift towards more patient-centered approaches has resulted in better communication between dental professionals and patients, leading to increased patient satisfaction and adherence to treatment plans. The availability of sedation options and pain management strategies has also improved the patient experience.
4. **Interdisciplinary Collaboration:** Dentists are increasingly working alongside medical professionals, such as doctors, dietitians, and public health specialists, to address the interconnection between oral health and overall health. This collaborative approach is leading to a more holistic understanding of health and better treatment outcomes.

Periodontal diseases are among the most common diseases in children and adolescents. These include gingivitis, aggressive localized or generalized periodontitis (or early periodontitis, which includes prepubertal generalized or localized periodontitis and juvenile periodontitis), and periodontitis associated with systemic disorders. The best approach to treating periodontal disease is prevention, followed by early diagnosis and treatment. The term "periodontitis diseases" includes all diseases of individual tissues of the periodontium, which are accompanied by inflammatory atrophic or dystrophic changes. The importance of the problems of periodontal

diseases is explained, first of all, by their significant distribution in the world. That is why a large number of dentists are working on a deeper and thorough study of this pathology [1-3].

Many disease classifications have been made in periodontology over the years. They share a common application of the concept of natural health and define periodontal health as the absence of any clinical manifestation of a current or past disease. The American Academy of Periodontology has defined health as the condition of a functioning patient with no evidence of disease or abnormality. Applied specifically to a periodontal structure, this definition predicts the absence of signs and symptoms of devastating periodontal and gum disease or a tissue condition outside of the normal range. Periodontal diseases are among the most common diseases in children and adolescents. These include gingivitis, aggressive localized or generalized periodontitis (or early periodontitis, which includes prepubertal generalized or localized periodontitis and juvenile periodontitis), and periodontitis associated with systemic disorders. The best approach to treating periodontal disease is prevention, followed by early diagnosis and treatment. The term "periodontitis diseases" includes all diseases of individual tissues of the periodontium, which are accompanied by inflammatory atrophic or dystrophic changes. The importance of the problems of periodontal diseases is explained, first of all, by their significant distribution in the world. That is why a large number of dentists are working on a deeper and thorough study of this pathology. The main role in the development of periodontal disease is played by local and general factors, or their combined effects. As a result, this idealistic demand for a flawless periodontium somehow disgusts. The proposed model of periodontal health is unrelated to disease processes as it is a paradigm for maintaining periodontal health. Explain the factors that influence periodontal health (function, comfort, stability and well-being). Comfort, function and positive well-being are defined and expressed by the patient; however, periodontal stability requires observation by the dentist. Essentially, a stable periodontium is one in which the level of attachment has not changed, as measured clinically with a periodontal probe. Although there are many limitations in using clinical levels of attachment to determine periodontal stability, it is currently the gold standard used to determine changes in the periodontal attachment apparatus. A multifactorial genetic effect in their etiology is more common in periodontal diseases. A further complication of the relationship between genes, environment and disease is that environmental genetic influences are necessary to maintain periodontal health. In addition, epigenetic changes in the environment also affect periodontal health. It is clear that many genetic traits (eg, type and quality of bone around the tooth root) and epigenetic changes in the oral cavity are important factors in determining the host's response to potential injury and conferring periodontal predisposition [26-29].

Microbial biofilms cover the human skin, intestines, urogenital system, nasopharynx and mouth. The bacterial composition of these biofilms is characteristic of the habitat, diverse and stable for the parent species. Together with the environment of their habitats, biofilms form dynamic ecosystems. They contribute significantly to homeostasis and tissue health, but in severe conditions they can contribute to or cause pathology. Maintaining balanced ecosystems has been proposed as a disease prevention strategy [30-32].

Mental stress is thought to be a contributing factor to several diseases including depression, cardiovascular disease and asthma to name a few. It is known that chronic stress can compromise the immune system and wound healing and contribute to pathogenic infections that can lead to periodontal destruction in susceptible patients. Unfortunately, the complex biological nature of stress makes it difficult to understand how it affects periodontal health in conjunction with many

environmental factors (eg, biofilm, hygiene, diet, and smoking). Although there is currently no full understanding of how stress can alter susceptibility or progression to periodontitis, how we manage stress can play an important role in our periodontal health [20-22].

Among the local causes, first of all, we should mention the infectious factor. Gingivitis is a typical inflammatory reaction of the connective tissue in response to plaque microflora that causes damage to the dentin-gingival epithelium. If treatment is not carried out, then gingivitis as a primary disease progresses and turns into periodontitis. Gingivitis is more often of infectious origin, where anaerobes and actinomycetes predominate in the local microflora [23-24].

There are different definitions of "plaque", but the most commonly used term is "plaque". The majority of researchers explain the development of inflammatory processes in the periodontium by the influence of the tooth buckle. It contains a large number of microbes; one milligram of dental plaque contains 100 to 300 million microbes. The growth of the tooth buckle directly depends on the amount of carbohydrates in the food. The growth of dental plaque under the gum causes tissue irritation due to microorganisms and their toxins, which leads to damage to the epithelium of the gum pocket and inflammation of the surrounding tissues [25-26].

In periodontology, attention is paid to non-mineralized plaques, tooth buckle, soft dental plaques, as well as supragingival and subgingival calculus formed from mineralized dental plaques. Thus, tartar is formed at the expense of plaque mineralization. Tartar formation is influenced by the presence of alkaline phosphatase and aldolase in the bacterial plaque, as well as the high ATP content of dental plaque and saliva. Dark and pale calculus differ morphologically and biochemically. Light-colored tartar is considered the initial stage of stone formation, and dark - the final stage [27-28].

The condition of periodontal tissues is affected by the products of microbial vitality - toxins. Exotoxins do not have a pronounced pathogenic potential. The formation of dental plaque is influenced by the alkaline phosphatase and aldolase present in the bacterial plaque, as well as by the high ATP content in dental plaque and saliva. Dark and pale calculus differ morphologically and biochemically. Light-colored tartar is considered the initial stage of stone formation, and dark - the final stage [29-30].

The prognosis of dental healthcare is positive, fueled by continuous advancements in technology, education, and clinical practice. Over the past few decades, the field has shifted toward a more patient-centered approach, focusing on prevention, early detection, and minimally invasive treatments. The future of dental care looks promising, with several key factors contributing to this optimistic outlook:

1. **Advancements in Technology:** The integration of digital tools, such as 3D imaging, digital X-rays, and CAD/CAM systems, has revolutionized the way dental professionals diagnose and treat patients. These technologies enable faster, more accurate diagnoses, improve treatment planning, and allow for more precise restorations. Laser dentistry and computer-assisted design are leading to less invasive procedures, reducing patient discomfort and recovery time.
2. **Emphasis on Preventive Care:** Modern dentistry increasingly prioritizes prevention. Fluoride treatments, dental sealants, and educational programs on proper oral hygiene are reducing the incidence of preventable conditions like cavities and periodontal disease. Early detection methods, such as salivary diagnostics and enhanced imaging techniques, are allowing professionals to identify issues before they escalate, leading to more effective, less costly interventions.

3. **Integration with Overall Health Care:** The growing recognition of the connection between oral health and general health is leading to better integration of dental care within the broader healthcare system. Dentists are collaborating with physicians to manage chronic conditions such as diabetes, cardiovascular disease, and respiratory disorders, where oral health plays a critical role. This integrated approach is expected to continue expanding, creating more opportunities for holistic patient care.

In immunological aspect, Saliva from the mumps salivary gland contains antibodies that destroy oral bacteria. According to some authors, salivary peroxidase from the salivary gland plays an important role in the ecology of the tooth buckle. Mixed saliva contains two peroxidases that can stop bacterial growth. At the same time, salivary peroxidase, has an antibacterial effect on lactobacilli and streptococci [31-32].

The role of all these enzymes in the development of periodontal disease is not completely certain. The condition of periodontal tissues is affected by the products of microbial vitality - toxins. Exotoxins do not have a pronounced pathogenic potential, while endotoxins show resistance to temperature effects, stimulate the activity of antibodies, because vasomotor changes, disrupt cell turnover, which is accompanied by hyperglycemia with subsequent hypoglycemia and necrosis. The condition of periodontal tissues is affected by the products of microbial vitality - toxins. Exotoxins do not have a pronounced pathogenic potential. The contact between dental floss microbes and periodontal tissues leads to autoimmune processes that determine a chain reaction, and the latter is accompanied by progressive alteration in the periodontal tissue. That is why the microbial flora of the tooth-gum pocket, the possibility of microbial allergy of the body and the development of autoimmune reactions will be widely studied [33-34].

A number of authors indicate that the microflora and its enzymes can cause allergy in the oral cavity and cause Artius and Schwartzman's allergic type phenomenon. Polymorphonuclear leukocytes and lysosomal enzymes take part in the pathogenesis of the latter. In the gingival tissue damaged by endotoxins, the degranulation of polymorphonuclear leukocytes was observed with the help of an electron microscope, with the release of the accompanying lysosome from the cell. Enzymes and other products of lysosomal origin enter into interaction with the surrounding structures, which leads to disruption of histohematal barrier penetration. It should be noted that as a result of the increased penetration of the histohematal barrier, bacterial antigens pass through the epithelial attachment, which appears to be a serious tissue barrier [35-36].

Enzymes produced by the mycobacteria of the bacterial loop provide the alteration changes that ultimately contribute to the formation of the periodontal pocket. In the exudate of the gingival pocket, factors have been found that lead to the attachment of epithelial cells and the disintegration of damaged leukocytes. Local changes can also be accompanied by general immunological changes [37-38].

The field of dental healthcare has achieved considerable milestones in both clinical practice and patient care over the past few decades. Some of the most notable achievements include:

1. **Technological Innovations:** The incorporation of cutting-edge technologies such as 3D imaging, intraoral cameras, and CAD/CAM systems has transformed the way dental professionals approach diagnosis and treatment. These innovations allow for more accurate assessments, custom-designed implants, crowns, and bridges, which improve the overall quality of care.

2. **Improved Patient Experience:** Patient care in dentistry has also advanced with a focus on reducing anxiety and pain during treatment. Sedation dentistry, laser treatments, and the development of minimally invasive techniques have significantly improved the patient experience, making dental visits less stressful and more comfortable. These improvements in patient-centered care are fostering increased trust and cooperation from patients.
3. **Preventive Measures:** Preventive care has become a cornerstone of modern dentistry. Fluoride treatments, the introduction of dental sealants, and advancements in oral hygiene education have contributed to a decline in the incidence of cavities and other preventable conditions. Early detection of oral cancers and other diseases through regular check-ups is also a key achievement in enhancing long-term health outcomes.
4. **Interdisciplinary Collaboration:** As the link between oral health and overall health becomes more apparent, the integration of dental professionals into interdisciplinary healthcare teams is gaining momentum. Collaborations with medical professionals, including cardiologists, endocrinologists, and dietitians, have helped patients manage conditions where oral health plays a critical role, such as diabetes and heart disease.

The main role in the development of periodontal disease is played by local and general factors, or their combined effects. Periodontal evaluation was based only on various physical measurements such as: attachment height, probing depth, bone loss, mobility, recession, degree of inflammation, etc. Periodontal health was often taken for granted and defined simply as the absence of signs and symptoms of periodontitis. Because of this, these strict and sometimes differing definitions of periodontitis have led to the idealistic necessity of a pristine periodontium for the periodontal health that affects us all in one way or another. In addition, potentially questionable recommendations were made in the absence of a realistic definition of health. The purpose of this manuscript was to assess the biological, environmental, sociological, economic, educational, and psychological relationships relevant to the development of a paradigm for defining periodontal health using a modified model of well-being. The paradigm includes four key characteristics such as dental function, pain-free dental function, periodontal stability, and psychological and social well-being of the individual. Finally, strategies and guidelines for periodontal health promotion were evaluated [4-6].

The majority of authors believe that polymorphonuclear leukocytes, with the help of a chemotactic reaction, ensure the gathering of immunocompetent cells that produce antibodies in the area of damage. An important role is played by complement, which is the leading mediator in the inflammatory process. To date, it is known that the complement binding reaction occurs as a result of the stepwise interaction of 9 separate components. However, the final stage of these reactions is the lysis of erythrocytes of microbial cells. It is during this process that important side products are formed that have a direct relationship with inflammation.

Chemotaxis is induced by the bacterial cell, as well as the antigen-antibody and complement system reaction mechanism. Cellular and humoral mechanisms are involved in this reaction. The most significant antigens are cell membrane mucoproteins of gram-positive bacteria and lipopolysaccharides of gram-negative bacteria. Proteins produced by bacteria can also function as antigens. The immune mechanism of action of the bacterial ingredients of the buckle is complex and has not been conclusively studied. Of the local factors, special importance is given to saliva. It should be noted that enzymes have a great role in the development of inflammatory-dystrophic processes in periodontal tissues. About 30 enzymes have been found in mixed saliva: amylase, lipase, acetylcholinesterase, pseudocholinesterase, catalase, peroxidase, anhydrase, aldolase,

succinate dehydrogenase and others. Examination of enzyme activity showed that the main amount of amylase is in the liquid fraction. This fact is explained by the fact that salivary glands are the source of amylase, lysozyme and peroxidase; lactate dehydrogenase-emigrated leukocytes; In case of protease and phosphatase, gingival epithelium and oral mucosa. During periodontal disease, amylase activity increases in saliva, along with lactate dehydrogenase, acid and alkaline protease, RNase and peroxidase activity in both salivary fractions. It is worth noting the action of the protective system of salivary glands during periodontal diseases.

According to saliva immunoglobulin, which is adsorbed on the bacteria in the oral cavity, acts on the principle of antigen-antibody. Saliva from the mumps salivary gland contains antibodies that destroy oral bacteria. Salivary peroxidase from the salivary gland plays an important role in the ecology of the tooth buckle. Mixed saliva contains two peroxidases.

The traumatic factor plays an important role in the development of periodontal disease. The latter is caused by the effect of poor-quality orthopedic constructions, hanging edges of teeth, orthodontic equipment and others on periodontal tissues. We should also mention the anatomical features of the teeth, their incorrect location in the tooth row and carious damage, that is, the factors that contribute to the appearance of dental plaque. The reasons listed above can cause: papillitis, gingivitis, less often other deeper damage to the periodontium. In addition, the damage has a local character.

Overloading of periodontal tissues leads to pathological changes in periodontal tissues. The latter can be caused by occlusal anomalies, early loss of molars and premolars, extraction of a large number of teeth, incorrect determination of the indication of a bridge prosthesis, improper formation of the oral cavity, and others. The increase in the adaptive capacity of the periodontium may lead to the disruption of blood supply and subsequent resorption of bone tissues. Overloading of periodontal tissues affects the bone tissue. In an experiment on dogs, resorption of the alveolar ridge, extraction of the apex of the tooth root and destruction of nerve cells of the periodontium were found. During periodontal trauma, clinical and radiological changes are observed.

Periodontal congestion is always accompanied by hemo- and lymphostasis, violation of histohematal barrier penetration, perivascular edema, and diapedesis of blood-shaped elements, erythrocyte aggregation, embolism, and blood vessel thrombosis. All this affects the structure of periodontal tissues.

As it is known, teeth loosening develops as a result of disruption of the function of collagenous and elastic fibers of the periodontium. Later, their destruction is observed, the integrity of the epithelial layer is broken, a pathological pocket is formed, and then an inflammatory process develops as a result of the infection. Subsequently, inflammatory destructive processes lead to the resorption of bony ridges between the teeth. Functional failure is one of the causes of periodontal disease and the functional failure of the chewing apparatus. At this time, inflammatory changes of periodontal tissues develop most often. It is worth noting the type of functional failure that develops during occlusal anomalies, for example in the case of open occlusion. Failure of chewing function is a characteristic of modern civilization. Processed soft food prevents the full load of the periodontium, as a result of which atrophic processes develop. It should be noted that inflammatory changes most often develop during chewing function failure.

Psychosomatic factor has the main role as stress and emotional factors in the etiology of periodontal disease is noteworthy. Based on the research, it was established that chronic psychoemotional stress affects periodontal tissues. A situation that leads to prolonged negative psychoemotional stress causes hemomicrocirculatory changes and trophic disturbances in the

tissues around the tooth. The development of periodontitis during long-term psychoemotional stress intensifies fibrinolysis and changes in blood coagulation system indicators, which appear to be one of the reasons for the development of pathological determinants. Among the systemic factors, genetic disposition, sexual maturation disorders, structural changes of polymorphonuclear leukocytes are also important.

Avitaminosis is an important factor. The majority of authors believe that avitaminosis plays a major role in the etiology of periodontal disease, especially the deficiency of vitamins C, B, A, E. During vitamin C deficiency, inflammatory-destructive changes are observed in the periodontium. It primarily affects collagen fibers. The formation process of the latter is disturbed, the tissues are stretched, the permeability of capillaries and intercellular layers increases. During avitaminosis, the bone tissue formation process in the body is inhibited and the resistance of periodontal tissues to infection decreases. In case of avitaminosis, the barrier function of the gum decreases, which is followed by inflammation of the latter. Vitamin E deficiency causes dystrophic processes, affects cellular respiration and the structure of collagen and elastic fibers. Oxidative processes and blood circulation are disturbed in the periodontium during avitaminosis.

Microcirculatory disorders are known that the development of dystrophic processes plays an important role in the pathogenesis of periodontal disease. Hypoxia plays a major role in the genesis of dystrophy itself. The authors have identified a sharp decrease in the oxygen level in the initial stage of periodontosis. Disruption of oxygen supply and its utilization during periodontosis is primarily related to disturbances in the microcirculation ring. In the initial stage of periodontitis, changes are most pronounced in the capillary, precapillary and arterial rings of microcirculation, which leads to the development of hypoxia and metabolic disorders, while the generalization of the process is due to the presence of numerous anastomoses. When we talk about microcirculation disorders, we should take into account the increased permeability of the blood vessel wall and the fact that the dynamic activity of platelets and the state of permeability of the capillary wall of the gums are closely related. Factors that affect the functional capacity of platelets contribute to a decrease in capillary permeability.

Despite the significant achievements, several challenges continue to impact dental healthcare, hindering access and the delivery of equitable care. Some of the key challenges include:

1. **Access to Care:** One of the biggest challenges in dental healthcare is ensuring access to care for all individuals, particularly in rural or underserved areas. Many people, especially those in lower-income brackets, struggle to afford dental insurance or treatment, leading to poor oral health outcomes. There is also a shortage of dental professionals in some regions, further limiting access to care.
2. **Health Disparities:** Socioeconomic status, race, and geographic location play significant roles in determining the quality of dental care received. Certain populations, including children, the elderly, and minority groups, face greater barriers to accessing dental care, which contributes to disparities in oral health outcomes.
3. **Cost of Dental Care:** The cost of dental treatments remains a significant barrier to access for many individuals. Although dental insurance exists, it often does not cover the full range of treatments needed, leaving patients to bear high out-of-pocket costs. High treatment costs, especially for complex procedures like implants, orthodontics, and crowns, deter many individuals from seeking timely care.
4. **Fragmented Healthcare System:** While the connection between oral and general health is widely recognized, the integration of dental care into the broader healthcare system

remains a challenge. Dental care is often treated separately from medical care, which can lead to fragmented treatment plans and missed opportunities for coordinated care between healthcare providers.

It has been suggested that disruption of host defenses due to malnutrition can significantly alter the response of periodontal tissues to biofilm bacteria. Unfortunately, the precise role of diet in the initiation or progression of periodontitis in humans remains to be elucidated. Perhaps the clinical definition of severe vitamin C deficiency or scurvy was one of the first and best documented of all oral nutritional deficiencies. Therefore, an adequate intake of vitamin C is an important prerequisite for periodontal health. Like vitamin C, antioxidants are another potential dietary component that may be associated with periodontal health. A showed the relationship between serum levels of antioxidants and periodontal health. While good nutrition is important for a person's long-term survival, there is not enough scientific evidence to recommend specific micronutrients for oral health [15, 22,36].

Atherosclerotic lesion factors define periodontitis as a dystrophic process develops as a result of atherosclerotic changes in periodontal blood vessels. According to Evdokimov, the manifestation of periodontosis against the background of atherosclerosis of periodontal blood vessels is caused by osteodystrophy of the bone of the alveolar ridge of the jaw. At this time, the pathogenicity of the microflora of pathological pockets is increased and the activity of enzymes is changed. Atherosclerotic changes in periodontal blood vessels play a major role in the development of periodontal tissue dystrophy. It has been shown by many authors that patients with dystrophic form of periodontal inflammation, against the background of general atherosclerosis, had a violation of lipid metabolism: hypercholesterolemia, hyperbetalipoproteinemia, a decrease in lecithincholesterol ratio and lecithin level in blood. During the narrowing of the lumen of the nutrient blood vessel, bone hardening (eburnation) or osteoporosis occurs. Clinical and morphological observations show that bone resorption is observed during periodontosis, the latter is explained by secondary inflammatory processes, therefore, against the background of primary dystrophy of already existing periodontal tissues, by inflammatory bone resorption. Bone resorption can be observed without sclerotic changes of bone tissue, which violates the monopoly of the term "periodontosis" and indicates a periodontal damage with mainly inflammatory-destructive changes.

Many disease classifications have been made in periodontology over the years. They share a common application of the concept of natural health and define periodontal health as the absence of any clinical manifestation of a current or past disease. The American Academy of Periodontology (AAP) has defined health as "the condition of a functioning patient with no evidence of disease or abnormality." Applied specifically to a periodontal structure, this definition predicts the absence of signs and symptoms of devastating periodontal and gum disease or a tissue condition outside of the normal range [7-9]. When it comes to the periodontium, wellness is a dynamic situation that changes from day to day. Each person will have an individual interpretation of periodontal wellness (i.e., health) based on their personal values and cultural orientations. Such a definition of periodontal health differs markedly from the traditional biomedical (i.e., natural) approach, which defines periodontal health as the complete absence of signs of disease. Using our current knowledge base as well as cultural norms and values, the proposed definition of a healthy periodontium in wellness should encompass simple and consistent characteristics to enable the individual to achieve positive goals. Life. These simple

characteristics of periodontal health include four key elements. They form the basis of a proposed model of periodontal health that includes aspects affecting the health-disease continuum [10-12]. The proposed model of periodontal health is unrelated to disease processes as it is a paradigm for maintaining periodontal health. Explain the factors that influence periodontal health (function, comfort, stability and well-being). Comfort, function and positive well-being are defined and expressed by the patient; however, periodontal stability requires observation by the dentist. Essentially, a stable periodontium is one in which the level of attachment has not changed, as measured clinically with a periodontal probe. Although there are many limitations in using clinical levels of attachment to determine periodontal stability, it is currently the gold standard used to determine changes in the periodontal attachment apparatus [13-15]. All medical practices, including dentistry, focus on one aspect of health. The preamble to the Constitution of the World Health Organization defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". The preamble goes on to say that "one of the fundamental rights of every human being is the maintenance of the highest attainable standard of health". Therefore, WHO global health is an important and desirable visionary goal for individuals and society. Health is not the meaning of life, but the source of everyday life. In short, health is characterized as a positive concept that emphasizes social and personal resources in addition to physical capabilities. It is clear that the WHO definition is neither useful nor functional in everyday life, as it is difficult to obtain [16-17].

Endocrine disorders are the relationship between the endocrine system and periodontal disease. As a result of clinical and experimental studies, the influence of the functional state of the thyroid gland on the periodontal tissues was confirmed. He also notes that thyrotoxicosis is characterized by a picture of generalized periodontitis, the formation of deep pathological pockets, the release of purulent exudate from them, and active resorption of the alveolar ridge. Periodontal disease with hyper- and hypofunction of the existing gland has been described by many authors. Changes in the periodontium have been studied in more detail. In 90-93% of diabetic patients, there are changes in the periodontium that have a generalized character. The main role in the pathogenesis of periodontal syndrome in diabetes is given to periodontal angiopathy, and in the genesis of damage to small blood vessels - dysproteinemia and mainly the increase of glycosaminoglycans in the blood. Pathomorphological changes of blood vessels are noted against the background of diabetes. Diabetic microangiopathy is based on plasmorrhagic processes that lead to primary damage to the basal membrane, subsequent wall sclerosis and hyalinosis. Hypoxia developed during diabetes causes a decrease in the stability of periodontal tissues, against the background of which the role of the microbial factor increases, and the increase in the concentration of glucose in the gum fluid and saliva contributes to the multiplication of microbes and the rapid formation of tartar [18-19].

Diseases of the gastrointestinal tract contribute to the development of pathological processes in the oral cavity. A number of authors found periodontal diseases in 98% of patients with gastric and duodenal ulcers. According to their data, the damage of periodontal tissues during gastric ulcer is expressed in the area of the frontal teeth of the lower jaw. In the case of duodenal ulcer, periodontal disease is expressed in the area of the teeth next to the lower jaw.

The increase in morphometric index during periodontal disease was more pronounced in patients with duodenal ulcer than without background pathology. An increase in local cellular immunity in the gingiva expresses some pathogenic mechanisms that contribute to the development of inflammatory-destructive changes in the periodontium. Blood serum phosphatase activity was

examined in periodontal disease, ulcer patients, and the level was within the normal physiological range [20-21].

A number of authors, when explaining the development of pathological processes in the gums, attach importance to the biochemical changes in the blood, this is what the research points to. They noted an increase in blood histamine levels and a decrease in histaminase activity in patients with gastric and duodenal ulcers. Pathological changes in the periodontium are accompanied by an increase in the level of histamine in the blood, and during the period of remission, its level is within the normal range. It seems that in the pathogenesis of periodontal changes in patients suffering from duodenal and gastric ulcers, the increase in the concentration of histamine in the blood has a certain importance. Therefore, local changes in the periodontium in people with ulcers are due to increased permeability of blood vessels [22-23].

Due to already existing metabolic disorders and against the background of increased permeability of the periodontal connective tissue structure, microflora of the gingival fissure causes inflammatory and destructive changes, and overloading of the periodontal tissues aggravates the existing condition. As can be seen from the literature, when the depth of the pathological pockets increases, the total number of neutrophilic leukocytes decreases. A sharp decrease in their phagocytic activity, a decrease in dystrophically changed neutrophils and epithelial cells and glycogen and RNA in them. The deeper the form of diabetes, the more the reactivity of the periodontal tissues is reduced and the more severe their damage. Periodontal diseases are also described in diabetes insipidus.

The concept of holistic health states that a person is healthy if they can achieve all important goals under normal conditions. Default conditions should not be confused with normal conditions, but in reference to a cultural norm. Therefore, a person is considered healthy if they have had high blood pressure for a long time, but continue to perform all desired daily activities. Taking only the example of the tooth, a person with stable gingival recession, who can chew effectively and without pain and without aesthetic problems is considered periodontally healthy [24-25].

Despite the many advancements, dental healthcare continues to face several challenges:

1. **Access to Care:** One of the most significant challenges is ensuring equitable access to dental care, particularly for underserved populations, rural communities, and lower-income groups. Many people lack access to affordable dental insurance or live in areas with limited availability of dental providers.
2. **Health Disparities:** Socio-economic status, race, and ethnicity play a significant role in disparities in dental health. Certain populations, including children, the elderly, and minority groups, often experience poorer oral health outcomes and face barriers to obtaining proper care.
3. **Cost of Dental Care:** Dental treatment can be expensive, particularly for advanced procedures such as implants, orthodontics, or oral surgeries. High out-of-pocket costs can prevent many individuals from seeking timely dental care, contributing to the progression of preventable oral diseases.
4. **Integration into Broader Healthcare Systems:** While there is growing recognition of the connection between oral health and overall health, dental care remains somewhat separate from mainstream medical services. The lack of integrated care models between dental and medical professionals can lead to fragmented healthcare, where important connections between oral health and systemic conditions are overlooked.

The field of dental healthcare has made remarkable progress, with numerous achievements in technology, patient care, and preventative measures. These advancements have led to significant improvements in patient outcomes and the overall quality of dental care. However, challenges such as access to care, disparities in treatment, and the high cost of dental services continue to hinder the widespread delivery of effective dental care. To address these challenges, there needs to be continued focus on policy reform, increasing accessibility to dental care, and fostering stronger interdisciplinary collaborations between dental and medical professionals. The future of dental healthcare in modern medicine is bright, but it requires concerted effort from healthcare providers, policymakers, and educators to ensure that these advancements benefit all individuals, regardless of their socio-economic status or geographic location.

Conclusions

Dental healthcare has made remarkable strides in modern medicine, contributing significantly to improving overall patient health and quality of life. Innovations in diagnostic techniques, treatment modalities, and preventive care have not only advanced clinical practices but also expanded the role of dental professionals within the broader healthcare system. The integration of technology, such as digital imaging and laser therapy, has enabled more precise, efficient, and less invasive treatments, benefiting both practitioners and patients alike. However, despite these achievements, several challenges remain that continue to affect the effectiveness and accessibility of dental care. Disparities in care, high treatment costs, and limited access to dental professionals, particularly in underserved areas, still represent major barriers to optimal oral health for many populations. Furthermore, while interdisciplinary collaboration between dental and medical fields holds great promise, there are still significant hurdles to overcome in fostering seamless integration and holistic care delivery. Looking forward, the future of dental healthcare lies in addressing these challenges through policy reforms, improved public health initiatives, and enhanced interprofessional cooperation. Increased investment in dental education, accessibility programs, and public awareness campaigns is essential for reducing disparities and improving outcomes. Additionally, continuing advancements in dental technology and research will undoubtedly further shape the evolution of the profession, enhancing both the prevention and treatment of oral diseases. In conclusion, while dental healthcare has made tremendous progress, its integration within modern medicine requires ongoing effort to overcome remaining obstacles. The collective focus on improving access to care, reducing inequalities, and fostering collaboration across healthcare disciplines will be pivotal in ensuring the continued advancement of dental health in the coming years. Only by addressing these challenges can we fully realize the potential of dental care as a vital component of overall health and well-being.

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WEARABLE DEVICE-IDENTIFIED VENTRICULAR ARRHYTHMIA – EVALUATING DIGITAL HEALTH INNOVATIONS IN REAL-WORLD MEDICAL PRACTICE (A CASE ANALYSIS)

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ABSTRACT

The integration of wearable technology into cardiovascular monitoring has revolutionized the early detection of arrhythmias, particularly in asymptomatic or high-risk patients. Smartwatches equipped with photoplethysmography (PPG) and single-lead electrocardiogram (ECG)

capabilities enable continuous heart rhythm assessment outside clinical settings. Ventricular tachycardia (VT), a potentially life-threatening arrhythmia, traditionally requires in-hospital ECG or Holter monitoring for diagnosis. However, consumer-grade wearables now provide real-time arrhythmia alerts, bridging gaps in outpatient cardiac surveillance. This case report highlights the role of smartwatch-detected VT in facilitating timely clinical intervention. We present a 40-year-old male with a history of ST-segment elevation myocardial infarction (STEMI) involving the left anterior descending artery (LAD), treated with delayed coronary stent implantation. The patient had significant post-infarction complications, including total akinesis of the LAD territory and a reduced ejection fraction (EF) of 35%. Despite recommendations for a primary prevention implantable cardioverter-defibrillator (ICD), the patient initially declined the procedure. During follow-up, the patient reported recurrent episodes of palpitations and near-syncope. He submitted ambulatory heart rhythm tracings obtained via his Apple Watch during symptomatic episodes. The smartwatch recordings demonstrated wide-complex tachycardia consistent with ventricular tachycardia (VT), correlating temporally with his symptoms. This objective data provided critical evidence of life-threatening arrhythmia, prompting reevaluation of his refusal of ICD therapy. Following thorough counseling, the patient consented to ICD implantation, which was subsequently performed without complications. This case illustrates three key points: (1) Wearable technology can detect clinically significant VT even in ambulatory settings, serving as a valuable adjunct to traditional monitoring; (2) Patient-acquired data may overcome psychological barriers to life-saving interventions when patients initially decline recommended therapy; (3) The temporal correlation between smartwatch tracings and symptoms strengthens diagnostic certainty. Current limitations include potential false positives (though less likely with wide-complex tachycardias) and lack of insurance coverage for device-detected arrhythmia evaluations. The 2023 AHA Scientific Statement on wearables acknowledges their growing role in arrhythmia detection but emphasizes need for physician interpretation. Smartwatch-detected VT provided decisive diagnostic and therapeutic guidance in this high-risk patient with structural heart disease. As wearable technology evolves, integration with clinical care pathways will become increasingly important. This case supports expanding research into optimal implementation strategies for wearable-derived arrhythmia data in cardiology practice. This case demonstrates three critical aspects of wearable ECG monitoring: (1) ability to detect life-threatening arrhythmias outside clinical settings, (2) potential to overcome patient reluctance toward guideline-directed therapy through objective data visualization, and (3) value in correlating symptoms with cardiac rhythms. While current guidelines caution against overreliance on consumer devices, this example aligns with recent AHA statements recognizing wearables as diagnostic adjuncts when integrated with clinical evaluation. Key challenges remain, including false-positive alerts and reimbursement barriers. However, as evidenced here, smartwatch-detected VT can be pivotal in managing structural heart disease. The immediate availability of rhythm documentation facilitated shared decision-making, converting patient refusal into acceptance of definitive therapy. This report underscores the need for standardized protocols integrating wearable data into cardiovascular care pathways while maintaining physician oversight. Future developments should focus on improving algorithm specificity for VT and establishing reimbursement frameworks for device-detected arrhythmia evaluations.

Keywords: Cardiac arrhythmia; Smartwatch; Ventricular tachycardia.

Introduction

The story of arrhythmia detection begins with Willem Einthoven's invention of the electrocardiogram in 1903, a breakthrough that required patients to immerse their limbs in saline solutions to capture cardiac electrical activity. For nearly a century thereafter, arrhythmia diagnosis remained confined to clinical settings, dependent on bulky machines and intermittent recordings. The advent of Holter monitors in the 1960s brought portable monitoring to the forefront, yet these devices were cumbersome, expensive, and typically reserved for patients with established symptoms. This paradigm persisted until the digital revolution of the early 2000s, when miniaturized sensors and machine learning algorithms converged to create an unprecedented opportunity: continuous, consumer-grade heart rhythm monitoring.

Ventricular tachycardia occupies a unique space in cardiology as both a harbinger of sudden cardiac death and a treatable condition when detected early. Epidemiological studies reveal that VT occurs in approximately 20% of post-myocardial infarction patients within five years, with the risk escalating sharply when left ventricular ejection fraction falls below 35%. Traditional monitoring strategies have consistently failed this population due to the paroxysmal nature of VT; standard 24-hour Holter monitors capture less than 5% of clinically significant episodes. Implantable loop recorders improved detection rates but introduced surgical risks and significant costs, while their use remained limited to patients already under cardiology care. This diagnostic gap created a perfect storm where lethal arrhythmias could develop unnoticed until catastrophic events occurred—precisely the scenario wearable technology began to address.

The emergence of smartwatch-based arrhythmia detection represents more than technological progress; it signifies a philosophical shift in healthcare delivery. When the Apple Watch Series 4 received FDA clearance for its ECG feature in 2018, it marked the first time a consumer device could provide clinically actionable cardiac data without medical supervision. This watershed moment triggered both enthusiasm and skepticism across the medical community. Cardiologists recognized the potential to identify previously undiagnosed arrhythmias in high-risk populations, while critics warned about false positives, data overload, and the ethical implications of patient-managed diagnostics. The tension between these perspectives continues to shape the integration of wearables into clinical practice today.

Photoplethysmography stands as the unsung hero behind this revolution. Unlike traditional ECG electrodes that measure electrical activity, PPG sensors detect blood flow changes through LED light absorption in the skin. This deceptively simple technology enabled passive, continuous heart rate monitoring—a feature initially marketed for fitness tracking that serendipitously proved capable of flagging arrhythmias. Modern PPG algorithms can identify irregular pulse patterns with 97% accuracy for atrial fibrillation, as demonstrated by the Apple Heart Study involving over 400,000 participants. However, ventricular tachycardia presents distinct challenges due to its often regular rhythm at the pulse level, necessitating complementary ECG confirmation. This technological duality explains why current-generation smartwatches combine both PPG for screening and single-lead ECG for verification, creating a two-tiered detection system unprecedented in medical history.

The physiological nuances of VT detection via wearables reveal fascinating complexities. Unlike the clearly identifiable P-wave abnormalities of atrial fibrillation, ventricular tachycardia generates wide QRS complexes that smartwatch algorithms must distinguish from artifacts caused by motion or poor skin contact. Studies of Apple Watch's ECG app show 71% sensitivity for VT detection—a promising start but far from the 99% sensitivity of hospital telemetry systems. These limitations become particularly consequential when considering the stakes: a false negative might

delay life-saving intervention, while a false positive could trigger unnecessary invasive testing. Recent advancements in machine learning offer solutions, with newer algorithms incorporating QRS morphology analysis and adaptive noise cancellation. The Huawei Heart Study's 2023 subanalysis demonstrated how these improvements increased VT detection specificity to 89%, though real-world performance varies significantly based on patient factors like skin tone and activity level during recording.

Clinical validation studies paint a nuanced picture of wearables' role in VT management. The WEARIT-II trial showed that smartwatch-detected VT episodes correlated strongly with subsequent ICD interventions in heart failure patients, suggesting prognostic value. Conversely, the Vanderbilt Wearables Registry revealed that 62% of patient-reported "VT alerts" were actually sinus tachycardia or artifact, highlighting the critical need for clinician oversight. This duality mirrors medicine's historical experience with other screening tools—from PSA tests to mammograms—where technological capability outpaces consensus on appropriate use. The American Heart Association's 2023 Scientific Statement on wearables reflects this balance, endorsing their use for arrhythmia screening while emphasizing that "no clinical decision should be based solely on consumer device data without physician interpretation."

Beyond the technical aspects, the psychosocial impact of wearable ECGs warrants examination. Our case patient's initial refusal of an ICD—followed by acceptance after seeing his own VT recordings—exemplifies a broader phenomenon. Behavioral research indicates that visualization of physiological abnormalities increases treatment adherence by 40% compared to verbal counseling alone, according to a Johns Hopkins study published in *JACC: Clinical Electrophysiology*. This "seeing is believing" effect has profound implications for preventive cardiology, particularly when managing asymptomatic but high-risk conditions like VT. However, it also raises ethical questions about patient anxiety induced by incidental findings and the medicolegal ramifications of device inaccuracies.

The regulatory landscape struggles to keep pace with these developments. FDA's 510(k) clearance process for wearable ECG features evaluates safety but not clinical utility, creating a gap where companies can market arrhythmia detection capabilities without proving they improve outcomes. Europe's CE Mark system faces similar challenges, while Asian markets employ varying standards. This patchwork of regulations becomes particularly problematic when considering global data flows—a Japanese patient's Apple Watch VT detection might be interpreted by a U.S.-based telehealth service using algorithms never validated in Asian populations. Such scenarios underscore the urgent need for international standards as wearable technology blurs traditional healthcare boundaries.

Economic factors further complicate adoption. While the \$399 price of an Apple Watch compares favorably to \$2,000+ for a traditional event monitor, insurance reimbursement remains nonexistent for wearable-derived diagnostics in most healthcare systems. This creates disparities where only affluent patients can benefit from continuous monitoring, paradoxically leaving high-risk underserved populations reliant on outdated methods. The recent CMS pilot program reimbursing remote physiologic monitoring hints at potential policy shifts, but widespread coverage for wearable-based arrhythmia detection likely remains years away.

Historical parallels offer valuable perspective. Just as the stethoscope transformed medicine in the 19th century by extending the physician's senses, wearables now provide patients with unprecedented access to their own physiologic data. This democratization carries both promise and peril—early stethoscope users similarly struggled with interpretation errors and overreliance

on new technology. The key lesson from medical history suggests that wearable ECG integration will follow an inevitable but nonlinear path: initial enthusiasm, followed by sober reassessment, and ultimately evidence-based standardization.

Looking ahead, the convergence of wearable technology with artificial intelligence promises to address current limitations. Experimental systems already combine smartwatch data with electronic health records to predict VT episodes hours before they occur, using patterns invisible to human analysis. Such advancements could transition wearables from diagnostic tools to preventive instruments, fundamentally altering the management of life-threatening arrhythmias. However, this future depends on resolving today's challenges—improving algorithm transparency, establishing physician training protocols, and creating ethical frameworks for data usage.

The case of our 40-year-old post-MI patient encapsulates this complex landscape. His smartwatch-detected VT represents more than a technological novelty; it embodies medicine's ongoing transformation from reactive to proactive care, from hospital-centric to patient-empowered models. As we stand at this inflection point, the medical community must guide this transition with rigorous science while remaining open to innovation that can save lives. The stakes are nothing less than redefining how cardiovascular risk is detected, managed, and prevented in the digital age.

Modern smartwatches detect arrhythmias through two parallel systems: photoplethysmography (PPG) for passive screening and single-lead ECG for active recording. While PPG algorithms excel at identifying atrial fibrillation through irregular pulse patterns, VT detection poses unique challenges due to its often paroxysmal nature and broader QRS complexes that may be misinterpreted as motion artifacts.

In recent years, wearable technology has revolutionized how we monitor health, providing unprecedented opportunities for early detection of critical medical conditions. Among these innovations, smartwatches have emerged as invaluable tools for cardiovascular health, with their ability to detect arrhythmias such as ventricular tachycardia (VT) standing out as a remarkable breakthrough. This capability is reshaping clinical practice, bridging the gap between consumer technology and advanced healthcare [15-16].

In modern era different types of electronic devices, such as smartwatches, have become very popular for the monitoring of health, especially for people with heart conditions.

Arrhythmia symptoms are frequent complaints in patients with heart problems, often require a repeated electrocardiogram (ECG) and Holter monitoring. Data regarding the clinical utility of wearable technologies are limited in that population. We hypothesize, that an Apple Watch can capture life threatening arrhythmias in cases, when it has not been detected with Holter monitor.

In this case report we present the heart electrical recordings of a 40 years old male patient with previous history of acute myocardial infarction (MI), who submitted recordings obtained from his Apple Watch during moments, when he had feeling of palpitations and sense of near fainting. Past history was remarkable with coronary stent implantation due to ST segment elevation acute anterior myocardial infarction (STEMI). It was delayed admission to the hospital with total akinesis of the left anterior descending artery (LAD) zone and decreased ejection fraction (EF) 35%. Implantable cardioverter defibrillator (ICD) was recommended, but the patient refused. The Apple Watch captured rhythm abnormalities that matched patient's complaints. Smartwatch detected ventricular tachycardia (VT) and finally patient underwent successful implantation of ICD.

This case demonstrates, that use of smartwatches can be helpful and enable clinicians to identify abnormalities that many traditional at-home monitoring devices do not detect. Thus, wearable devices, such as the Apple Watch, could be used to help identify heart rhythm disorders in patients with high susceptibility having arrhythmias.

Ventricular tachycardia is a life-threatening arrhythmia originating in the heart's ventricles. It is characterized by an abnormally fast heart rate that can compromise cardiac output, leading to symptoms like dizziness, palpitations, syncope, or even cardiac arrest. Early detection is crucial, as untreated VT can escalate to ventricular fibrillation, a condition that requires immediate medical intervention [17-19].

Traditional detection methods, such as Holter monitors and implantable cardiac devices, are effective but often limited by accessibility, patient compliance, and cost. This is where smartwatches equipped with advanced sensors and algorithms offer a promising alternative.

VT and ventricular fibrillation (VF) are leading causes of sudden cardiac death (SCD) in patients with heart failure with reduced ejection fraction (HFrEF) [20-22].

Smartwatches are a widespread technology in this world and represent an innovation among most wearable devices. Modern smartwatches have developed in such a way that they can combine various functions, including making an ECG recording.

Smartwatches have mainly been studied to detect and monitor atrial arrhythmias, especially atrial fibrillation (AFB) [1-2] while there is a limited data in literature on detection of life-threatening ventricular arrhythmias [3,4,5]. We have no definite recommendations on use of new smartwatches for monitoring these arrhythmias.

The Role of Smartwatches in VT Detection

Modern smartwatches are equipped with photoplethysmography (PPG) sensors and electrocardiogram (ECG) capabilities that enable continuous monitoring of heart rhythms. These devices utilize machine learning algorithms to analyze patterns and detect irregularities indicative of arrhythmias. Several key features make them effective in VT detection:

1. **Continuous Monitoring:** Unlike traditional devices that are used intermittently, smartwatches provide 24/7 monitoring, increasing the likelihood of capturing transient arrhythmias.
2. **ECG Functionality:** Many smartwatches allow users to record single-lead ECGs on demand. These recordings can detect VT and other arrhythmias with clinically relevant accuracy.
3. **Real-Time Alerts:** Smartwatches can notify users when abnormal rhythms are detected, prompting timely medical attention.
4. **Data Sharing:** Most smartwatches integrate with health apps, enabling seamless sharing of data with healthcare providers for further evaluation.

The integration of smartwatch technology into clinical practice has far-reaching implications:

1. **Early Diagnosis:** Early detection of VT can prevent adverse outcomes by facilitating timely intervention.
2. **Accessibility:** Smartwatches make arrhythmia detection more accessible to a broader population, including those in remote areas.
3. **Patient Engagement:** The use of consumer-friendly devices empowers patients to take an active role in their health management.

4. **Cost-Effectiveness:** Compared to traditional cardiac monitoring solutions, smartwatches offer a more affordable and scalable option.

As technology advances, smartwatches are likely to become even more sophisticated, with multi-lead ECG capabilities, improved algorithms, and integration with artificial intelligence for predictive analytics. Collaborative efforts between tech companies and healthcare providers will be pivotal in realizing the full potential of these devices in cardiology [23-27].

Our article is the one of the few published case reports of smartwatch-detected VT. Ease of use makes smartwatches a promising modern technology in the service of clinical practice for identifying ventricular arrhythmias and potentially improving patient outcomes [28-29].

Advancements in wearable technology have significantly influenced healthcare, particularly in the management of cardiovascular diseases. Smartwatches, initially designed for general fitness tracking, now feature sophisticated health-monitoring capabilities, such as heart rate tracking, photoplethysmography (PPG), and single-lead electrocardiogram (ECG) functionalities. These features have gained popularity among individuals with known cardiac conditions, offering continuous monitoring and immediate feedback [30-31].

Arrhythmias, including ventricular tachycardia (VT), are common in patients with heart disease and pose significant risks if undetected or untreated. Standard diagnostic tools like Holter monitors and implantable cardiac devices are effective but are often limited by availability, patient compliance, and cost. Wearable devices, such as the Apple Watch, provide a patient-friendly alternative that bridges the gap between clinical monitoring and daily health management [32-33].

Despite the potential of wearable devices, data on their utility in detecting life-threatening arrhythmias in high-risk populations remain limited. This highlights the need for further exploration of their role in clinical practice. This case report examines how a smartwatch detected VT in a patient with a history of myocardial infarction and reduced ejection fraction, leading to timely and effective intervention [34-35].

The integration of wearable technology into clinical practice is redefining how arrhythmias, including life-threatening conditions like ventricular tachycardia (VT), are detected and managed. This case report exemplifies the potential of smartwatches, particularly the Apple Watch, as diagnostic tools in cardiac care. The patient's ability to capture VT episodes during symptomatic events provided crucial diagnostic data that traditional Holter monitoring failed to identify. This capability demonstrates the smartwatch's value as a patient-centric monitoring tool and highlights its broader implications for cardiovascular medicine [36-37].

Smartwatches equipped with electrocardiogram (ECG) capabilities enable real-time monitoring of cardiac activity. In this case, the Apple Watch identified VT during episodes of palpitations and near-syncope, aligning with the patient's symptoms and leading to the timely implantation of an implantable cardioverter defibrillator (ICD). These devices empower patients to document their symptoms and provide healthcare professionals with actionable data, bridging gaps in traditional cardiac diagnostics [38].

Unlike Holter monitors, which are used for a limited duration and require clinical oversight, smartwatches offer continuous, non-invasive monitoring and can be worn indefinitely. The convenience, accessibility, and affordability of these devices make them particularly beneficial for patients with high arrhythmic risk, such as those with reduced ejection fraction or prior myocardial infarction. This case demonstrates how wearable devices can complement conventional methods, offering additional insights when standard tools fall short.

This case underscores the transformative potential of wearable devices in arrhythmia detection. As technology evolves, smartwatches could be equipped with advanced features such as multi-lead ECG capabilities, real-time arrhythmia alerts, and automated reporting to healthcare providers. Moreover, their use could expand beyond arrhythmia detection to include other aspects of cardiac health, such as ischemia monitoring and heart failure management.

Case study

We present a case of 40 years-of-age Caucasian male patient who had signs of an arrhythmia documented by an Apple Watch. He already had a formal arrhythmia diagnosis not yet conformed on other ambulatory cardiac monitoring studies, findings of Holter monitoring were nonconclusive, which did not detect arrhythmias matched his clinical symptoms.

Remarkable moments from the patient's past and family history: otherwise healthy person with stressful profession, nonsmoker, non-diabetic, with mild insulin resistance, physically active, mildly overweight, mildly elevated blood pressure, no complaints, coronary artery disease (CAD) genetically presented (his father and uncle suffered from MI in their 40-45 years). At first planned cardiologic checkup: normal ECG, normal echocardiography, normal exercise stress test, blood test revealed high level of low-density lipoprotein (LDL) 220 mg/dl; Statin for dyslipidemia and perindopril for hypertension were prescribed, healthy life style, hypolipidemic diet and moderate physical activity had recommended.

Few weeks after, the patient was admitted to our hospital with new onset severe chest pain. Acute anterior STEMI due to total occlusion of proximal LAD had angiographically confirmed. Admission was delayed 16-18 hours from the onset of the pain, patient was successfully treated by percutaneous coronary intervention, and one drug eluting stent had implanted in LAD followed with medical therapy. Case was complicated with early effusive pericarditis, moderate mitral regurgitation, bilateral pleural effusion, heart failure. The left ventricular ejection fraction (EF) decreased to 32% due to total akinesia of the LAD zone. After recovery the patient was discharged with full guideline directed medical treatment (GDMT) of HFrEF, ICD implantation was strongly recommended to prevent SCD. The patient followed all recommendations, but refused to implant the device. As of his three-six-month evaluation, he remained well, but due to reduced EF 35% ICD implantation was still recommended. The patient refused again. After a period, he developed signs of an arrhythmia, ambulatory Holter monitoring revealed supraventricular and monomorphic ventricular extrasystoles, which have been managed with short course of amiodaron, unfortunately it caused subclinical hyperthyroidism and therefore was discontinued. Periodically patient felt as though his heart rhythm was abnormal and he had feeling of irregular heartbeat-palpitations and sense of near fainting. VT was considered. Repeated ambulatory Holter monitoring did not reveal any arrhythmia. The patient refused to have the device. After Holter monitoring failed to capture a symptomatic event, the patient with his cardiologist decided to purchase a smartwatch for home monitoring. He recorded his ECG-s with Apple Watch. In few days he developed chest discomfort associated with palpitations and lightheadedness. He was on a routine job at his office, when these symptoms started abruptly and persisted for approximately several seconds (from 20 to 40). Recurrence of his symptoms resulted in a recording of a wide complex tachycardia suggestive and labeled by the device algorithm as potential "VT". The patient sent recordings to his doctor. It turned out, that his Apple Watch recorded a wide complex tachycardia concerning for VT (Figure1) and a representative example of sinus rhythm (Figure 2).



Figure 1: Ventricular tachycardia.



Figure 2: Normal sinus rhythm

Figure1: Apple Watch recording of symptomatic VT. Apple Watch recording demonstrating a regular, wide complex tachycardia-VT; the patient reported symptoms of chest discomfort associated with palpitations and lightheadedness.

Figure 2: Apple Watch recording in normal sinus rhythm without symptoms.

Finally, the patient agreed and shortly after this incident underwent successful implantation of ICD.

Discussion

The integration of smartwatch technology into cardiac care represents a paradigm shift in arrhythmia detection and management, as exemplified by this case of ventricular tachycardia (VT) identification in a high-risk post-myocardial infarction patient. This discussion examines the multifaceted implications of wearable cardiac monitoring through several critical lenses: diagnostic capabilities, clinical utility, patient engagement, technological limitations, healthcare system integration, and future directions in digital cardiology.

From a diagnostic perspective, the ability of consumer-grade wearables to capture life-threatening arrhythmias outside clinical settings addresses a longstanding gap in cardiac monitoring. Traditional methods like Holter monitors and event recorders have inherent limitations - their intermittent use often fails to capture paroxysmal arrhythmias, while implantable loop recorders require invasive procedures. The Apple Watch in this case provided continuous monitoring capability that proved decisive when conventional methods returned inconclusive results. This aligns with emerging research showing wearable devices can detect arrhythmias that would otherwise go undiagnosed, particularly in patients with transient symptoms. The single-lead electrocardiogram (ECG) functionality, when combined with photoplethysmography (PPG) for heart rate monitoring, creates a complementary detection system that balances sensitivity and specificity. While hospital-grade multi-lead ECG remains the gold standard, the accessibility and convenience of wearable monitoring offers clear advantages for initial screening and ongoing surveillance in high-risk populations.

The clinical impact of wearable-detected arrhythmias extends beyond diagnostic confirmation to influence therapeutic decision-making. In this case, the objective evidence of VT obtained via smartwatch proved pivotal in overcoming patient reluctance toward implantable cardioverter-defibrillator (ICD) placement - a phenomenon supported by behavioral research showing visual confirmation of physiological abnormalities enhances treatment acceptance. This "seeing is believing" effect has profound implications for shared decision-making in cardiology, particularly for preventive interventions where patients may not perceive immediate symptoms. The temporal correlation between recorded arrhythmias and clinical symptoms also strengthens diagnostic certainty, helping clinicians distinguish between benign and malignant rhythms when symptoms are nonspecific.

Patient engagement represents one of the most transformative aspects of wearable cardiac monitoring. By empowering individuals to actively participate in their cardiac surveillance, these devices foster greater health literacy and adherence. The patient in this case transitioned from passive recipient to active participant in his care, capturing symptomatic episodes and collaborating with his care team. This shift aligns with broader trends toward patient-centered care and could potentially improve outcomes through earlier intervention and enhanced monitoring compliance. However, this empowerment comes with responsibility - patients and

providers must work together to interpret findings appropriately and avoid unnecessary anxiety over benign variants or device artifacts.

Technological limitations remain an important consideration in assessing wearable arrhythmia detection. Current generation smartwatches demonstrate good but imperfect accuracy for VT identification, with studies reporting sensitivity around 70-80% compared to clinical ECG. False positives can occur due to motion artifacts or poor skin contact, while false negatives may miss some arrhythmias, particularly those with subtle electrical changes. The algorithms powering these devices continue to evolve, incorporating machine learning to better distinguish true arrhythmias from artifacts. Future iterations may improve detection through multi-lead configurations, advanced signal processing, and integration with other physiological sensors. These technological advancements must be balanced against the need for simplicity and usability that makes wearables accessible to diverse patient populations.

The integration of wearable data into clinical workflows presents both opportunities and challenges. While the immediacy of patient-acquired ECGs can accelerate diagnosis and treatment, healthcare systems must develop protocols for efficiently reviewing and acting on this information. Electronic health record integration, standardized reporting formats, and clear guidelines for clinical response will be essential to prevent data overload while ensuring critical findings receive appropriate attention. Reimbursement models also need adaptation to recognize the value of wearable monitoring while avoiding incentivizing unnecessary testing. The current lack of insurance coverage for device-detected arrhythmia evaluations creates disparities in access that must be addressed as these technologies become standard of care.

From a regulatory perspective, wearable cardiac monitors occupy an evolving space between consumer electronics and medical devices. The FDA's 510(k) clearance process evaluates safety but not necessarily clinical utility, creating potential gaps in evidence-based implementation. International standards vary, complicating global use of these technologies. A balanced regulatory approach is needed - one that encourages innovation while ensuring devices meet minimum performance standards for arrhythmia detection. Post-market surveillance will be crucial as these devices proliferate, with real-world performance data informing iterative improvements in both technology and clinical guidelines.

The economic implications of widespread wearable cardiac monitoring warrant careful analysis. While individual devices are relatively affordable compared to traditional monitors, system-wide adoption could have significant cost implications. Value assessments must consider not just device costs but downstream effects - potentially reduced hospitalizations through early detection balanced against increased testing prompted by false positives. Cost-effectiveness studies comparing wearable-enhanced pathways to conventional care will help guide appropriate use. The current economic model where patients bear device costs risks exacerbating healthcare disparities unless reimbursement policies evolve to support equitable access.

Ethical considerations surrounding wearable cardiac monitoring are multifaceted. Patient privacy concerns arise from continuous physiological data collection and cloud storage. Informed consent processes must clearly communicate both benefits and limitations - including the possibility of incidental findings and imperfect accuracy. The medicolegal implications of wearable data are still evolving, particularly regarding responsibility for acting on patient-shared arrhythmia detections. A collaborative framework involving clinicians, technologists, ethicists, and patients will be essential to navigate these challenges as adoption grows.

The case presented here exemplifies how wearable technology can bridge critical gaps in cardiac care delivery. For patients like ours - with structural heart disease and elevated arrhythmia risk but reluctance toward invasive monitoring - smartwatches offer a patient-friendly alternative that maintains diagnostic rigor. The ability to capture symptomatic episodes in real-world settings provides clinicians with data that would otherwise be unavailable, enabling more confident management decisions. This is particularly valuable for ventricular arrhythmias where delayed diagnosis can have catastrophic consequences.

Looking ahead, the convergence of wearable technology with artificial intelligence and telehealth promises to further transform arrhythmia care. Predictive algorithms analyzing longitudinal wearable data may identify arrhythmia risk before episodes occur, enabling truly preventive interventions. Integrated digital platforms could automatically alert care teams to critical findings while filtering benign variants, reducing clinician burden. As these technologies mature, they may expand beyond arrhythmia detection to encompass comprehensive cardiac risk assessment including ischemia, heart failure decompensation, and other acute events.

The successful implementation of wearable cardiac monitoring requires addressing several key challenges. Standardized training for clinicians in interpreting wearable-derived ECGs will be essential to maintain diagnostic accuracy. Patient education must emphasize appropriate use - understanding device capabilities and limitations, proper recording techniques, and when to seek medical evaluation. Healthcare systems need infrastructure to manage increased data flows without overwhelming providers. Payers must develop sustainable reimbursement models that recognize the value of remote monitoring while controlling costs. Regulatory bodies should continue refining oversight frameworks that balance innovation with patient safety.

Comparative effectiveness research will be crucial to determine which patients benefit most from wearable monitoring and how to optimally integrate it with existing care pathways. Studies comparing outcomes between wearable-enhanced and conventional monitoring in various risk groups can guide evidence-based adoption. Research should also explore how to leverage wearable data for population health - identifying patterns that could inform screening strategies or public health interventions for cardiac conditions.

The psychosocial dimensions of wearable cardiac monitoring deserve particular attention. While devices can empower patients, they may also provoke anxiety through false alarms or excessive self-monitoring. The psychological impact of continuous physiological surveillance - particularly in patients with health anxiety - requires careful study. Developing best practices for counseling patients on appropriate device use and interpretation will help maximize benefits while minimizing distress. The clinician-patient relationship may evolve in this new paradigm, with technology serving as both connector and potential barrier that must be thoughtfully managed.

From a global health perspective, wearable cardiac monitoring holds promise for expanding access to arrhythmia diagnosis in resource-limited settings. The relatively low cost and minimal infrastructure requirements could bring cardiac screening to populations previously underserved by conventional cardiology services. However, this potential must be balanced against the need for clinical support systems to interpret findings and provide appropriate follow-up care. International collaborations can help adapt these technologies to diverse healthcare contexts while ensuring equitable benefit distribution.

The educational implications of widespread wearable adoption are substantial. Medical training must evolve to incorporate interpretation of wearable-derived data and appropriate integration into clinical decision-making. Continuing education will help practicing clinicians stay current as

technologies advance. Patient education materials need development to explain device capabilities in accessible language while setting realistic expectations. Collaborative efforts between medical schools, professional societies, and technology companies can ensure training keeps pace with innovation.

This case of smartwatch-detected ventricular tachycardia illustrates the transformative potential of wearable technology in modern cardiology. By providing continuous, patient-initiated monitoring outside clinical settings, these devices address critical gaps in arrhythmia detection and management. The technology empowers patients, enhances diagnostic capabilities, and facilitates timely interventions - particularly valuable for high-risk individuals who may be reluctant to undergo conventional monitoring. While challenges remain in accuracy, integration, and equitable access, the trajectory of innovation suggests wearable cardiac monitoring will become increasingly central to cardiovascular care. As the field evolves, maintaining rigorous standards of evidence, thoughtful implementation, and patient-centered design will be essential to fully realize the promise of these technologies while mitigating potential risks. The coming years will likely see wearable devices transition from adjuncts to essential components of comprehensive cardiac care, fundamentally reshaping how we detect, monitor, and manage arrhythmias in the digital age. The integration of smart watch technology into clinical practice represents a paradigm shift in cardiac monitoring and patient care. This case exemplifies the unique advantages and challenges associated with these devices, particularly in the detection of life-threatening arrhythmias like ventricular tachycardia (VT).

Key Strengths

1. **Early Detection of Critical Events:** The Apple Watch successfully identified VT, which traditional methods, such as Holter monitoring, might have missed due to intermittent usage or logistical challenges. This highlights the smartwatch's ability to provide continuous, non-invasive monitoring.
2. **Patient Empowerment:** The patient-driven nature of the monitoring process allowed the individual to capture and document symptomatic events as they occurred. This patient-initiated approach fosters engagement and enhances the reliability of diagnostic data.
3. **Clinical Correlation:** The smartwatch recordings directly aligned with the patient's reported symptoms, demonstrating their potential clinical relevance. This correlation between subjective complaints and objective data strengthens the case for their integration into routine practice.
4. **Cost and Accessibility:** Compared to traditional monitoring tools, smartwatches offer a more affordable, accessible solution for patients, particularly those in resource-limited settings or individuals reluctant to use invasive options.

Challenges and Limitations

1. **Accuracy and Reliability:** While the Apple Watch detected VT in this case, concerns about false positives and negatives persist. Variability in algorithm sensitivity and specificity across different devices must be addressed to ensure reliable clinical utility.
2. **Regulatory and Legal Considerations:** As consumer devices transition into medical-grade tools, stringent regulatory oversight is essential to validate their use in clinical practice. Clear guidelines on their application are necessary to establish trust among healthcare providers and patients.

3. **Integration into Healthcare Systems:** Seamless integration of wearable data into electronic health records (EHR) and clinical workflows remains a logistical challenge. Addressing this issue would maximize their impact in healthcare settings.
4. **Data Privacy and Security:** The collection and transmission of sensitive health data by smartwatches raise concerns about privacy and cybersecurity. Ensuring robust safeguards will be crucial in building confidence in these devices.

Implications for Clinical Practice

This case underscores the potential of wearable technology to complement traditional monitoring methods, particularly in high-risk cardiac patients. While challenges exist, the successful detection of VT and subsequent intervention in this case demonstrate the tangible benefits of smartwatch integration into clinical care. By addressing existing limitations and enhancing the technology, smartwatches could become indispensable tools for arrhythmia detection and broader cardiovascular health management.

The case of a 40-year-old male with a history of acute myocardial infarction (MI) and reduced ejection fraction highlights the transformative potential of smartwatch technology in detecting life-threatening arrhythmias. Despite previous recommendations for an implantable cardioverter defibrillator (ICD), the patient declined the procedure. Using his Apple Watch, the patient captured electrical heart recordings during episodes of palpitations and near-fainting sensations. These recordings revealed ventricular tachycardia, aligning with the patient's clinical symptoms and prompting successful ICD implantation.

This case underscores several critical points:

1. **Enhanced Detection Capability:** The Apple Watch successfully identified VT, a life-threatening condition that may have been missed by traditional Holter monitoring. This demonstrates the added value of wearable devices in capturing transient arrhythmias that occur sporadically.
2. **Patient-Initiated Monitoring:** Wearable devices empower patients to actively participate in their health monitoring. By recording symptoms as they occur, patients provide clinicians with valuable diagnostic data, bridging gaps in conventional monitoring.
3. **Clinical Utility in High-Risk Populations:** Patients with significant cardiac history, like the one in this case, can benefit immensely from smartwatch technology. These devices offer a non-invasive, accessible, and real-time monitoring solution for high-risk individuals.
4. **Integration into Standard Care:** The successful outcome in this case highlights the potential for smartwatches to complement existing diagnostic tools, particularly in cases where conventional methods fail or are declined by patients.

Although in recent years the popularity of smartphones has been increasing in terms of health monitoring, especially in arrhythmia monitoring, data regarding the use of wearable technologies in clinical practice are limited. Most studies include detection of AFB with smart-watches there is less information about the detection of other arrhythmias [9,10,11].

Our case illustrates the potential benefits of this technology. This particular case turned out to be crucial in getting the right decision for the patient. However, caution and additional studies are needed to implement modern technologies in the cardiology service. With the Apple Watch, episodes of atrial fibrillation can be detected with the same success, which will allow us to think about prescribing adequate anticoagulation and protecting the patient from stroke⁸. Wearable devices have been well-studied in adults to recognize atrial fibrillation, however there is less

information available on their effectiveness in monitoring of other rhythm disorders, especially life threatening arrhythmias, such as VT [3,4,5].

Our case was interesting in that, despite maximal GDMT, the systolic function of left ventricle EF did not exceed 35%, the expected risks of SCD were explained to the patient many times and ICD implantation was strongly recommended, but it was difficult for a patient to make a correct decision, he declined to have a device.

By the time a 12-lead surface ECG was performed, it was a normal sinus rhythm with T-wave inversions in leads V1–V4 due to past anterior MI. Later the patient developed intermittent palpitations, feeling of an irregular heartbeat, rapid palpitations associated with near syncope. Holter monitoring was performed several times, not a single VT episode was observed. The patient was young and abstained from implantation for almost one year after acute episode, in the meantime he had acquired an Apple Watch and was sending normal cardiograms to his cardiologist. However, the recommendation for the ICD remained in force, he doubted the implantation until the end. Faintly decisive ECG was taken with a smartwatch and a VT episode was recorded (the watch makes a record in the form of a pdf file and the patient easily sends it to your mobile phone). According to this, implantation of ICD had performed successfully.

This case highlights that use of Apple Watch can enable clinicians to identify abnormalities that many traditional at-home monitoring devices do not detect. Thus, wearable devices, such as the Apple Watch, could be used to help identify heart rhythm disorders especially in cardiologic patients with high susceptibility having various arrhythmias.

Smartphones and connected devices allow patients to monitor their health condition in a different way. In our case a patient had complaints of palpitations and near faintness. Standard studies were unremarkable. However, an ECG recorded through his Apple Watch showed VT episode. This case underlines the importance of proactively requesting such information from patients. Controlled clinical studies are needed to confirm this practice.

It seems that this will greatly help the users to identify and monitor different types of arrhythmias in order to diagnose and treat them in time. According to most of scientific papers AFB is frequently detected type of arrhythmias, which is often detected using the Apple Watch. Therefore, most of the studies are related to AFB detection [6,7,8], less to other arrhythmias (supraventricular tachycardia (SVT), VT, heart block, atrial flutter etc.) [9,10]. Levent Pay et al. showed in a review, that cardiac arrhythmias other than atrial fibrillation are also frequently detected using smartwatches and smartwatches offer important potential beyond traditional arrhythmia detection methods in clinical practice [11].

Aydin Zahedivash et al. reviewed the heart electrical 145 recordings in a group of children who provided recordings obtained from their Apple Watches at times when they felt their heart rhythm was abnormal. The Apple Watches captured rhythm abnormalities in 28 % of patients: 88% SVT, 7% VT, 2.5 % heart block, that matched the diagnoses obtained using heart monitors used clinically [12].

Most of published articles are case reports or case series [3,4,5,13], few cohort studies detecting various arrhythmias another then AFB and several reviews in this field [10,11,14]. We believe that, further studies may contribute to the development of protocols for the appropriate use of smart devices to detect different arrhythmias, especially life-threatening types, allowing the patients timely receive appropriate medical care, as well as the monitoring and assessment of effectiveness already existing antiarrhythmic therapy.

The advent of smartwatch-detected ventricular tachycardia marks a new era in cardiovascular care. By combining continuous monitoring, user-friendly interfaces, and real-time analytics, these devices offer an effective and accessible tool for arrhythmia detection. While challenges remain, ongoing advancements in wearable technology hold the promise of transforming clinical practice and improving outcomes for patients with cardiac arrhythmias.

This case report highlights the transformative role of wearable technology, specifically the Apple Watch, in detecting life-threatening arrhythmias such as ventricular tachycardia (VT). A 40-year-old male with a history of acute myocardial infarction and significantly reduced ejection fraction utilized his smartwatch to record heart rhythms during episodes of palpitations and near-fainting. The smartwatch recordings revealed VT, a finding consistent with his symptoms, ultimately leading to the successful implantation of an implantable cardioverter defibrillator (ICD).

This case underscores the clinical potential of smartwatches as complementary tools for arrhythmia detection, especially in patients who are unable or unwilling to undergo conventional monitoring methods. By providing continuous monitoring, patient-initiated recordings, and real-time alerts, smartwatches enable early detection and timely interventions. Despite challenges such as algorithm accuracy and data security, wearable technology holds great promise in improving the management of arrhythmias and advancing personalized cardiac care.

This case report demonstrates the profound potential of smartwatch technology, specifically the Apple Watch, in detecting and facilitating timely intervention for life-threatening arrhythmias such as ventricular tachycardia (VT). By providing continuous, non-invasive monitoring and patient-driven data collection, smartwatches bridge critical gaps in traditional cardiac diagnostics, offering a novel solution for individuals with significant cardiac risk factors. The ability to capture transient and symptomatic arrhythmias in real time, as illustrated in this case, underscores their value as a complementary tool in modern cardiology.

Despite their advantages, challenges such as accuracy variability, data security, and integration into healthcare systems remain. Addressing these issues will be essential to fully realize the potential of wearable technology in clinical practice.

Considerations:

Clinical Adoption and Integration: Healthcare systems should explore incorporating smartwatch technology into routine monitoring for high-risk cardiac patients. Integrating wearable data into electronic health records (EHRs) could enhance diagnostic accuracy and improve patient outcomes.

Regulatory Oversight and Standards: Regulatory bodies should establish clear guidelines and standards for wearable devices to ensure they meet medical-grade accuracy and reliability requirements.

Public Awareness and Education: Patients and healthcare providers must be educated on the appropriate use and limitations of smartwatch technology. Empowering patients to understand their role in health monitoring will maximize the effectiveness of these devices.

Future Research: Further studies are needed to validate the clinical efficacy of smartwatches in detecting arrhythmias, particularly in larger, diverse populations. Research should also focus on optimizing algorithms to minimize false positives and negatives.

Collaboration and Innovation: Partnerships between technology companies, healthcare providers, and regulatory authorities will be vital in advancing wearable technology. Collaborative efforts can ensure the development of more accurate, secure, and integrated systems for widespread use.

Different cardiac arrhythmias in addition to atrial fibrillation are also often detected by smartwatches. We demonstrate that the Apple Watch can record life threatening arrhythmia events, such as VT, not identified on traditionally used ambulatory monitors. Smart watches, in addition to traditional methods, have significant potential in arrhythmia detection. Therefore, modern technology can be used in service of clinical practice. Considering all the above mentioned, we believe that there is a need to conduct trials in this direction, taking into account smartwatches as additional diagnostic tool of arrhythmia detection and monitoring.

By addressing these recommendations, smartwatches and other wearable devices can play an increasingly critical role in cardiovascular care, providing both patients and clinicians with reliable, real-time tools to manage and mitigate the risks of arrhythmias effectively.

The integration of smartwatch technology into cardiovascular care represents a transformative advancement in the detection and management of life-threatening arrhythmias, as exemplified by this case of ventricular tachycardia (VT) in a high-risk patient. The ability of consumer-grade wearable devices, such as the Apple Watch, to capture clinically significant arrhythmias outside traditional healthcare settings underscores their potential as valuable adjuncts to conventional diagnostic tools. This case highlights three critical contributions of wearable technology to modern cardiology:

- **Enhanced Diagnostic Capability:** Smartwatches bridge the diagnostic gap for transient arrhythmias that evade detection by intermittent monitoring methods like Holter monitors. By providing continuous, patient-initiated recordings, these devices enable the capture of symptomatic episodes that correlate with clinical events, offering clinicians objective data to guide therapeutic decisions.
- **Patient Empowerment and Engagement:** Wearable devices empower patients to actively participate in their healthcare, fostering adherence to treatment plans through visual confirmation of arrhythmias. This "seeing is believing" effect, as demonstrated in this case, can overcome psychological barriers to life-saving interventions like implantable cardioverter-defibrillator (ICD) implantation.
- **Accessibility and Preventive Potential:** The ubiquity and affordability of smartwatches democratize arrhythmia monitoring, particularly for underserved populations and those reluctant to undergo invasive procedures. Early detection of VT and other arrhythmias may facilitate timely interventions, potentially reducing morbidity and mortality associated with sudden cardiac death.

However, the widespread adoption of wearable technology in clinical practice necessitates addressing key challenges:

- **Algorithm Accuracy and Standardization:** While current devices show promise, variability in sensitivity and specificity for VT detection requires refinement through advanced machine learning and validation in diverse populations.
- **Regulatory and Ethical Frameworks:** Clear guidelines are needed to govern the use of consumer-derived data in clinical decision-making, ensuring accuracy, privacy, and accountability.
- **Integration into Healthcare Systems:** Seamless incorporation of wearable data into electronic health records and clinical workflows will maximize utility while minimizing clinician burden.

Future directions should prioritize multicenter studies to validate wearable performance in VT detection, develop AI-driven predictive analytics, and establish reimbursement models to ensure

equitable access. Collaborative efforts among technologists, clinicians, and policymakers will be essential to harness the full potential of these devices while mitigating risks.

The case exemplifies how smartwatch technology is redefining arrhythmia management, offering a paradigm shift toward proactive, patient-centered care. As wearable capabilities evolve, their integration into structured clinical pathways promises to enhance early diagnosis, improve outcomes, and ultimately save lives. The medical community must embrace this innovation thoughtfully, balancing enthusiasm with rigorous evidence generation to ensure safe and effective implementation.

The emergence of smartwatch technology in cardiovascular monitoring has ushered in a new era of patient-centered arrhythmia detection and management. This case of smartwatch-detected ventricular tachycardia demonstrates how wearable devices are reshaping clinical paradigms by providing continuous, real-world cardiac monitoring that complements traditional diagnostic methods. The ability to capture transient but life-threatening arrhythmias during symptomatic episodes offers clinicians' unprecedented access to data that might otherwise remain undetected, particularly in high-risk patients who may be reluctant to undergo conventional monitoring or invasive procedures.

Beyond their diagnostic utility, these devices empower patients to become active participants in their care, fostering greater engagement and adherence to treatment recommendations. The visual confirmation of arrhythmias through personal devices appears to significantly influence patient decision-making, as evidenced by this case where smartwatch data ultimately led to acceptance of critical ICD therapy. This psychological impact represents a fundamental shift in patient-provider dynamics, with technology serving as both a diagnostic tool and a catalyst for behavioral change.

Conclusions:

- However, the integration of consumer-grade wearables into clinical practice requires careful navigation of several challenges. Concerns regarding algorithm accuracy, data security, and appropriate use must be balanced against the clear benefits of enhanced arrhythmia detection. The medical community faces the dual task of embracing innovation while establishing robust frameworks to ensure these technologies meet clinical standards and ethical considerations. Future progress will depend on collaborative efforts to validate device performance, optimize data integration into healthcare systems, and develop evidence-based guidelines for implementation.
- As wearable technology continues to evolve, its potential extends beyond arrhythmia detection to broader applications in cardiovascular risk prediction and disease management. The convergence of advanced sensors, artificial intelligence, and telemedicine promises to create more proactive, personalized approaches to cardiac care. While challenges remain in standardization and accessibility, the foundational value of these devices in improving patient outcomes is undeniable. This case serves as both an illustration of current capabilities and a call to action for systematic research and thoughtful integration of wearable technology into mainstream cardiology practice. The ultimate goal remains clear: leveraging technological advancements to deliver more timely, effective, and patient-centered cardiovascular care while maintaining rigorous standards of safety and efficacy.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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Competing Interests

The authors declare no competing interests.

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Ethical Standards

The research meets all ethical guidelines, including adherence to the legal requirements of the study country.

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ECONOMIC BENEFITS FROM KAHRIZS DUE TO OPERATING COSTS

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ABSTRACT

Against the background of global climate change, anthropogenic impact on the environment, population growth, expansion of irrigated areas, development of industry, energy and other sectors of the economy, there has been a shortage of fresh water in a number of countries around the world. The earth is already experiencing a serious water problem. According to UN experts, more than 500 million people worldwide suffer from various infectious diseases due to drinking poor-quality water, and 5,000 people die daily due to lack of drinking water. River water is mainly used for drinking water supply to the population, industry and industrial areas, as well as for irrigation of agriculture. However, the water resources of the rivers are extremely limited and unevenly distributed over the territories. When using groundwater, various hydraulic engineering devices are used, including artesian and subartesian wells, horizontal and girder aquifers, spring water extraction devices, and ancient kahrizs. Among these aquifers, the ancient kahrizas are fundamentally different from other devices due to their unique design, principle of operation and lack of energy requirements.

Keywords: climate change, water problem, qanat, groundwater, irrigation of agriculture

Introduction

The earth is already experiencing a serious water problem. According to UN experts, more than 500 million people worldwide suffer from various infectious diseases due to drinking poor-quality water, and 5,000 people die daily due to lack of drinking water. River water is mainly used to supply the population, industry and industrial areas with drinking water, as well as to provide agriculture with irrigation water. However, the water resources of the rivers are extremely limited and unevenly distributed over the territories. Compared to the neighboring republics of the South Caucasus, Azerbaijan ranks last in terms of local water reserves. River water reserves per capita in our country are 8.3 times less than in Georgia, and 12 times less than in Russia. 60-70% of the water resources of rivers are formed due to runoff from neighboring countries. Therefore, there is a need to use additional water sources, especially groundwater.

When using groundwater, various hydraulic engineering devices are used, including artesian and sub artesian wells, horizontal and girder aquifers, spring water extraction devices, and ancient Kahriz. Among these aquifers, the ancient Qanat are fundamentally different from other devices

due to their unique design, principle of operation and lack of energy requirements. Many of the ancient Qanat, which are over 3,000 years old, still function over 3,000 years old, still function effectively today. It is no coincidence, the ancient Qanat were included in the UNESCO World Heritage List. However, the Kahriz historical monuments and unique water supply facilities are gradually being forgotten and are falling into disrepair for one reason or another.

Various scientific research institutes, government agencies and water management organizations are engaged in the study and determination of water reserves and resources. The determination of water reserves and resources, the analysis and systematization of observation materials for them, and at the same time the results of specific studies are reflected in the reports of various organizations and scientific papers of research institutions [1,2,3]. This generalization of Azerbaijan's water resources was carried out on the basis of literary data, funds, information materials, reference books and encyclopedic data.

It should also be noted that Qanat as an independent research object has been studied very little both in Azerbaijan and in other countries of the world. Therefore, the study of the structural structure and the principle of operation of Qanat, their current state and construction technology, their restoration and creation of a new generation, as well as their preservation and development as historical monuments are among the most important tasks facing science today.

Resources of river waters. 8350 rivers have been registered in the territory of Azerbaijan, most of which dry up during the summer season [3]. The resource of river waters in Azerbaijan is formed depending on the amount of atmospheric precipitation. According to meteorological data, the total flow consumption of rivers flowing in the country in the wettest years is 1200-1800 m³/sec, and the reserves of river waters are 37.84-56.76 billion m³. The flow consumption of all rivers in the average wet years is 1024 m³ / sec, and the total flow volume is 32.3 billion m³ [4.5]. In temperate years, the flow consumption of Rivers is 882 m³/sec, and the total flow volume is 27.8 billion m³ [6]. In the years of severe drought, the flow consumption of rivers decreases to 736 m³/sec, and the total volume of flows decreases to 23.2 billion m³. During the years of extreme drought, the reserves of river waters decreased to 20-22 billion m³ [7.8]. The average long-term reserve of river waters is 26.8 billion m³, and their use is carried out according to this volume. About 60-70% of the flow of Rivers is formed due to inflows from neighboring countries-Turkey, Georgia, Iran, Armenia and Russia. While the total flow volume of rivers in a 50% secured year is 32.3 billion m³, 21.97 billion m³ of them enter the Republic through transit through neighboring territories (table.1). At this time, the Inland Water Resource of the rivers is about 10 billion m³, which testifies to the extremely limited and uneven distribution of the water resources of the inland rivers in our country.

Table 1. River resources at home and abroad, thousand m³ / year.

Revers	General resours	Resources included from outside	Lacal resours
Kura River (up to the confluence of the Araz)	19630	13552	6078
River (at the confluence of the Kura)	10001	7424	2577
Alazan (Ganih)	5238	3109	2129
İori (Gibirri)	819	805	14
Khrami	1849	1849	-
İntcha su	28	25	5
Dashsalahlı	9	6	3

Agstafachay	410	350	60
Akhincachay	158	131	27
Tchanakhtitchay	27	17	10
Bagirsaqdara	8	8	-
Arpatchay	687	625	62
Khatchintchay	66	61	5
Okhtchutchay	315	299	16
Bazartchay	690	629	61
Iranian rivers forming the right tributaries of the Araz	1106	1106	-
Samur	2362	850	-
Bolqartchay	65	32	33
Astaratchay	218	109	109
Kur and Araz's rivers together	29631	20976	8655
Total for the Republic	32276	21,967	10309

Global climate changes in recent years, especially warming and uneven drop in atmospheric precipitation across the regions have led to a decrease in river water resources and environmental problems [8,9]. According to meteorological observations and data provided by researchers, global warming is observed in almost all regions of the Earth [10,11]. The average annual temperature in our country in 1991-2006 increased by 0.6⁰C, in 2007-2014-by 0.8⁰C, and in 2010-2012-by 1.3⁰C, which led to anomalous precipitation [12.13].

Resources and resources of groundwater. It should be noted that the reserves of groundwater are divided into two parts – static and dynamic reserves [14,15]. The amount of water located in water-bearing layers in underground water bodies is called static reserves, and the amount of water entering water-bearing horizons in natural and artificial cases is called dynamic reserves. In recent years, static resources have been called Natural Resources, and dynamic resources are called Natural Resources [16]. Groundwater is considered an important source of water to make up for the lack of water balance. Groundwater is less exposed to pollution than surface water. Having high qualities, little depends on the juiciness of the year. Groundwater can be obtained directly on plantations or in areas close to them. Groundwater is concentrated in mountainous, foothills, sloping Plains and artesian water bodies [17]. Fresh and weakly mineralized groundwater found Development in the fissured parent rocks of the mountainous zones of the Quaternary sediments of the foothill zones and in the porous layers of the intermontane depressions. The reserve of groundwater located in porous strata has been studied in more detail [18]. In mountainous zones with undisturbed natural conditions, groundwater is formed due to atmospheric precipitation. 10-90% of precipitation in this zone is involved in the formation of groundwater. Underground streams move from mountainous areas to river valleys, and in the feeding zone, their degree of mineralization is less than 1 g/l. Groundwater is formed in the foothill zones due to atmospheric precipitation, condensation waters and seepage losses from rivers. Because natural conditions in the foothill zones are partially disturbed, underground flows have a moderate nature in this zone, their mineralization rate is 1-3 gr/l [19].

2.The purpose of the study. The purpose of the work is to provide proposals for the restoration of ancient Qanat, the technology of their construction and restoration, improvement and efficiency improvement on a scientific and practical basis, as well as the creation of new Qanat.

3.Research methods.

This article [20] describes the importance of groundwater. Qanat is a local technology that has played a fundamental role in urban and rural development in arid and semi-arid regions. Severe drought and increased demand for water in recent decades have led to excessive abstraction of water from wells rather than from ropes, which undermines the country's environmental, economic and social sustainability. This study identified thirteen economic, nine social, and eight environmental components that manifest themselves in rope regeneration. These components were determined based on prevailing conditions in the study area, expert surveys, and previous research, and then prioritized using the WASPAS entropy method. The results show that an increase in the amount of water resources, increased participation of the population and incomes of the region's residents are the most important and expected results of the Qanats revival in the area under study. Indeed, the revival of Qanats on the plain is an important step towards achieving sustainable development, as it not only maintains ecological balance, but also strengthens socioeconomic sustainability by increasing income and promoting greater human participation. Finally, proposals were presented to accelerate the revitalization of the Fariman-Torbat Jam Qanats, including the creation of associations and unions to improve social interaction, provide low-interest loans to users, and encourage private sector participation in Qanats revitalization initiatives. In this article, [21] the author conducts research on the importance of groundwater. Groundwater is a vital resource for many industries, but overexploitation has led to a significant decrease in groundwater levels in many regions. Accurate prediction of groundwater levels is essential for effective planning and management. However, the presence of non-stationarity in the time series of groundwater data, such as trends and fluctuations, can lead to a decrease in the effectiveness of forecasting. This study proposes a new hybrid approach combining long-term short-term memory (LSTM) models with empirical mode decomposition (EMD) and wavelet transform (WT) to solve these problems. Non-stationary data from three wells in San Bernardino County, California, collected over a five-year period (2017-2022), was used to train and test the models. The time series data was pre-processed using EMD and WT to break down complex patterns into simpler components, which were then introduced into LSTM models to improve prediction accuracy. Our results show that the EMD-LSTM model is significantly superior to both wavelet-LSTM and traditional single LSTM models when the error is related to the trend factor. According to the RMS error indicator (RMSE), EMD-LSTM reduced forecasting errors to 19% and 78% for wells W0804 and W0904, respectively. In contrast, for well 4905, WT and EMD were unable to improve the accuracy of the LSTM when fluctuations occurred randomly. These results demonstrate that the EMD-LSTM model is a powerful tool for predicting groundwater levels, especially in cases where instability prevails. This approach can be applied to improve groundwater management strategies, helping decision-makers ensure sustainable water resource planning, especially in regions facing unsustainable groundwater abstraction. However, the authors express their research generically. In this article, [22] the author conducts research on the importance of Qanat. The Qanat water systems (QWSs), the ancient water engineering systems in Iran belonging to the very distant past, have harvested groundwater from drainages to convey it toward the surface with no use of energy. The present article highlights the socio-economic aspects of the sustainability of the QWSs and gives a satisfactory explanation of why the QWSs should be restored. In doing so, we subscribe to the view that indigenous and scientific knowledge should be incorporated. The former serves to tackle the restoration of the QWSs, the latter contributes to the distribution of water into the farmlands as efficiently as possible. Measured by (a) resilience, (b) reliability, (c) vulnerability,

and (d) sustainability, the GIS technique made clear the performance of the QWSs has, therefore, the worst condition observed in terms of resiliency; the best condition observed concerning the vulnerability. Moreover, the QWSs have intermediate performance in terms of reliability. Finally, the sustainability index (SI) classifies the QWSs into different bands, which provide explicit support to take priority of the selection of the QWSs for restoration. In conclusion, a theoretical framework has been drawn to keep the QWSs sustainable. In this article, [24] the author conducts research on the importance of irrigation. Since agriculture is the major water consumer, web services have been developed to provide farmers with considerate irrigation suggestions. This study improves an existing irrigation web service, based on the IRRINET model, by describing a protocol for the field implementation of a fully automated irrigation system. We demonstrate a Fuzzy Decision Support System to improve the irrigation, given the information on the crop and site characteristics. It combines a predictive model of soil moisture and an inference system computing the most appropriate irrigation action to keep this above a prescribed “safe” level. In this article [25], the author conducts research on the importance of Qanat. As declared by UNESCO, Qanats are considered as a great human heritage. For many centuries, they presented a rational way of groundwater management in arid rural areas. This paper aims at revisiting this ancient water supply system reviewing its structure and characteristics including construction and operational issues. On that basis, we highlight some key sustainability perspectives related to this ancient water supply practice. We advocate that this ancient technology should not only be protected as a great human heritage but also be reconsidered as a sustainable way of groundwater management in arid/semi-arid regions.

4. Research results

4.1. Economic benefits from Qanat due to operating costs;

During the use of Qanats, the costs of their operation are spent only on control and periodic inspections (inspection of the condition of Qanat facilities). Very rarely do they need current repairs. However, considerable resources are required for the operation of modern water intake facilities, for example, sub artesian Wells. The net income from the use of Qanat according to operating costs can be determined as follows according to regulatory documents:

$$X_g = \dot{I}_q - \dot{I}_k \quad (1)$$

here

\dot{I}_q – costs incurred for the operation of a comparable waterworks in one year, man;

\dot{I}_k – the costs incurred in a year for the operation of the Qanat, man.

Sub artesian wells, which are currently being operated in the Ganja-Gazakh region, can be considered as a comparison device. According to the annual reports of the Shamkir Sub artesian well Operation Department, the operating cost of one sub artesian well with a productivity of 20-44 l/sec is 11084 man.

Operating costs are formed from the funds spent on electricity (10319 man), current repair of plunger pumps (508 man), current repair of Wells (210 man), Service and transport (114 man). Qanat do not work with electricity, their water is supplied to the consumer by its own stream. If we take the funds spent on the current repair of Qanat (508 man), Service and transport (114 man), as in the maintenance department, then the annual operating costs of one Qanat will be 622

man. According to the statement (2) and actual data, the net income from the use of Qanat for operating costs is $X_g = 11084 - 622 = 10462$ man.

4.2. Economic benefits achieved by reducing the cost of water

Modern water intake devices, such as horizontal, vertical and beam water in-take devices, deliver water to the consumer through pumping stations or submersible pumps. And the Qanat supply the water to the demanding ones with their own flow. In the first, the cost of water is much higher, and in the second-less. In this case, the net income (X_g) obtained is calculated by the following expression:

$$X_g = (D_1 - D_2) V \quad (2)$$

here

D_1 – cost of water produced by the comparable unit, man/m^3 ;

D_2 – the cost of water produced by Qanat, man/m^3 ;

V – is the volume of water produced, m^3 .

The volume of water produced by both devices is taken equal to each other. The cost of one m^3 of water is determined according to the operating costs by the following formula:

$$D = \frac{\dot{I}_x}{V} \quad (3)$$

here

D – the cost of one m^3 of water, man/m^3 ;

V – the amount of water produced during the year, m^3 ;

\dot{I}_x – operating costs, man .

Annual operating costs of a pumping station or a sub artesian well with a productivity of 100 l/sec ($8640 \text{ m}^3/\text{day}$) and a working period of 150 days per year vary from 11 to 15 thousand AZN. The volume of water pumped during the year by the pumping station

$$V = 8640 \cdot 150 = 1,296 \cdot 10^6 \text{ m}^3.$$

The operating costs of one Qanat are 622 AZN per year. According to these prices, the cost of one m^3 of water pumped by pumps is based on the expression (formula 3).

$$D_1 = \frac{11 \cdot 10^3}{1,296 \cdot 10^6} = 0,0085 \text{ man}$$

The cost of one m^3 of water produced by Qanat is

$$D_2 = \frac{622}{1,296 \cdot 10^6} = 0,0005 \text{ man.}$$

Thus, the economic benefits obtained due to the reduction of the cost of water produced are in the form of net income according to the formula (2).

$$X_g = (0,0085 - 0,0005) 1,29 \cdot 10^6 = 10368 \text{ man}$$

The benefit of Qanat in terms of Ecology and environmental protection is greater. In areas where Qanat are located, the possibility of depletion or reduction of groundwater does not occur. They feed on atmospheric precipitation and condensation waters and constantly regulate the balance

and level of groundwater. Qanat provide the population and agriculture with cleaner and cleaner water.

Conclusion

Along with the restoration of the ancient Qanat, attention should be paid to the issues of creating a new modern Qanat. There are quite favourable hydro-geological conditions for the creation of a new Qanat in our country. In modern conditions, a new Qanat can be built and put into operation in a short period of time, not manually, as before, but by mechanized method with the help of modern drilling tools and devices. Modern Qanat can be built in both pipe (gallery) type. It is considered more expedient to build a tubular Qanat.

All work related to the construction of Qanats in the new technology should be carried out in parallel and sequentially, the excavation of Qanat should be carried out not from the source to the mouth, but from the mouth to the source.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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Competing Interests

The authors declare no competing interests.

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Ethical Standards

The research meets all ethical guidelines, including adherence to the legal requirements of the study country.

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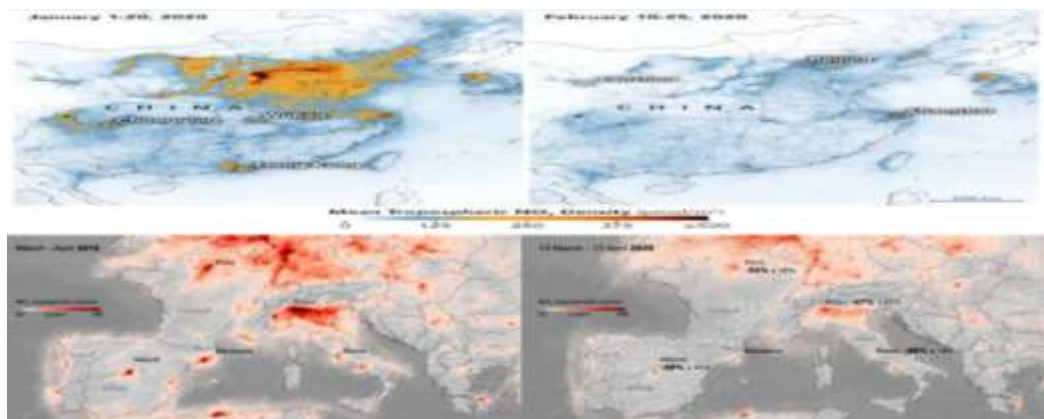


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6. M. Ahmad, “Importance of Modeling and Simulation of Materials in Research”, J. Mod. Sim. Mater., vol. 1, no. 1, pp. 1-2, Jan. 2018. DOI: <https://doi.org/10.21467/jmsm.1.1.1-2>

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