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SURGICAL HELMET SYSTEMS IN TOTAL JOINT ARTHROPLASTY, HOOD STERILITY AND DONNING TECHNIQUE: REVIEW

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Abstract:
Infection that occurs deep within the body after arthroplasty is a severe and harmful complication. Registry data indicates that modern positive-pressure surgical helmet systems (SHS) may lead to a contradictory rise in infection rates, therefore creating uncertainty about their effectiveness in arthroplasty. The objective of this study was to examine the helmet systems used in total joint arthroplasty, specifically focusing on the technique for putting on the helmet and assessing the sterility of the sterile surgical helmet system (SSHS) during arthroplasty. When utilizing these helmets, it is important for the surgeon to avoid placing objects near the axillary region due to the gown's seam potentially having a reduced ability to prevent particle contamination. Surgical High Speed (SHS) is highly recommended for use in arthroplasties. It is highly advisable to securely seal the area where the gloves and gown meet, and to replace the outer gloves every hour in order to minimize the chances of contamination from SHS.

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INTRODUCTION:

During the initial stages of arthroplasty surgery, the incidence of infection was as high as 9.5%.Nevertheless, due to improvements in surgical hygiene and infection control protocols, the prevalence has been reduced to around 1% to 2%.Studies have revealed that airborne microbial contaminations are responsible for as much as 98% of infections. The main source of these contaminations in the surgical theatre is staff, especially surgeons [1,2].
A positive pressure surgical helmet system (SHS) has been created as a more straightforward substitute for the negative pressure body exhaust system (BES) in arthroplasty surgery to reduce contamination caused by surgeons [3]. While many surgeons consider SHS to be the successor of BES, their methods of action are completely opposite. SHS utilizes a ventilated helmet to introduce air into the gown and hood, generating a positive pressure. This pressure can cause particles to escape via crevices in the gown that offer little resistance [4].

The incidence of deep periprosthetic infections in patients undergoing total hip arthroplasty (THA) is approximately 1 to 2%, while for total knee arthroplasty (TKA) it is around 2 to 4% [5]. Consequently, this leads to the need for additional surgical procedures, an extended duration of hospitalization, escalated costs, and diminished functional results. To reduce the risk of joint infection, it is important to identify the potential sources of infection [6,7]. Methods to decrease the chances of infection including reducing the number of people in the operating room, using laminar flow systems, administering antibiotics before surgery, wearing face masks, utilizing body exhaust suites, and/or using sterile surgical site irrigation solutions [8,9]. The SSHS consists of a helmet that is not sterile, but is covered with a sterile visor mask hood. It is assumed to be sterile, hence there is no regular practice of changing gloves if there is contact with the SSHS.

With the annual growth in the number of hip and knee joint replacements performed in Australia [10], there is a growing concern about the impact of prosthetic joint infection (PJI) [10]. The initial Charnley whole body exhaust-ventilated suit was created with the aim of minimizing the introduction of contaminants into the surgical area with a system that utilizes negative pressure for both intake and outflow. The current surgical helmet was created to address the impracticality of the inflow-outflow tubes that are part of the exhaust-ventilated suit. These systems utilize a fan located on the top part of the helmet to intake air, which is subsequently circulated within the space formed by a disposable hood cover and the surgical gown [11].
In a significant randomized control experiment conducted in 1982, it was discovered that the utilization of body exhaust suites, in conjunction with ultraclean air ventilation systems, resulted in a 25% decrease in the occurrence of PJI [12]. Nevertheless, later investigations have challenged the outcome. An examination of the New Zealand joint registry over a span of 10 years revealed a higher incidence of early infection in patients who underwent total knee and hip replacements and used surgical helmets [13]. A comprehensive analysis has additionally shown that surgical helmets do not lead to a decrease in wound contamination [14]. Nevertheless, surgical helmets continue to be widely employed as personal protective equipment (PPE). Initiating the operation helmet's ventilation system once the surgeon has fully dressed in sterile garments and gloves could potentially decrease the likelihood of contamination [15].

Furthermore, certain studies have indicated that SHS exclusively shields surgeons and other sterilized staff members from potential fluid and bloodborne transmissions, but does not decrease the occurrence of contaminations in the operating area. The efficacy of SHS in mitigating the risk of contamination from surgeons and preventing PJI has been called into question [4].

DISCUSSION:

In recent times, there has been an increased focus on the design of contemporary, self-contained space suits. Despite being less bulky due to the absence of linked tubing, these systems employ a ventilated helmet to provide air into the hood and gown, generating positive pressure and allowing particles to escape through different holes and areas of low resistance in the gown [16]. While surgeons may believe that space suits are the heirs of body exhaust suites, it is important to note that modern space suits are primarily designed as personal protection devices against blood spatter and debris. They are not intended to assist in reducing periprosthetic joint infection [17]. An extensive analysis of the New Zealand Joint Registry, conducted by Hooper et al. [14] from 1999 to 2008, revealed that the rate of periprosthetic joint infection increased by over two-fold when modern space suits were utilized in nearly 90,000 primary hip and knee arthroplasties, as opposed to standard gowns. Nevertheless, a more recent analysis conducted from 2000 to 2014, as well as a comparable examination of a joint registry in the United States, did not demonstrate any discernible distinction [17,18].

Multiple researchers have investigated the potential causes of contamination by examining the interaction between gowns and gloves, as well as the pattern of air release when utilizing different combinations of helmet systems and gowns or togas [4]. Young et al. [20] conducted a study in which they applied fluorescent particles, similar in size to shed skin flakes, onto the hands of surgeons before they put on their gowns and gloves. The purpose of the study was to investigate the movement of these particles.

Periprosthetic joint infection (PJI) is a very destructive consequence that significantly contributes to illness, death, and expenses associated with healthcare. The release of bacteria by operating room staff has been widely acknowledged as a cause of contamination during surgery, and efforts to minimize this transmission are a key focus of quality improvement initiatives [2,21]. Frequently employed measures comprise laminar airflow, surgical caps, facemasks, sterile gowns, and body exhaust systems (BES) or surgical helmet systems (SHS). Sir John Charnley introduced the BES in the 1960s, employing a closed "negative pressure" mechanism to effectively hinder the spread of bacteria through the air [10]. There is ongoing debate on the effectiveness of modern "positive pressure" SHS or "space suits" in reducing deep infection rates because to conflicting findings. However, SHS (surgical hoods and suits) are frequently utilized in arthroplasty surgery primarily due to its significance as personal protection equipment [21].

Efforts to identify potential sources of infection during surgery have increasingly concentrated on the apparel worn in the operating room and the way it is put on. A study has been carried out to investigate different ways for putting on sterile gloves (closed, open, staff-assisted), methods for opening sterile glove packaging (direct hand off, direct drop), and gowning approaches (self-gowning, assisted-gowning) [22,23].

There is significant variation in hospital protocols regarding the utilization of SHS hoods, as well as a range of ways for putting them on. In certain establishments, a team member who is not sterile places the hood over the surgeon with the aim of maintaining the sterility of the surgeon's hands and surgical instruments. At other facilities, the surgical team collaborates to help each other put on the Surgical Headgear System (SHS). There is a potential danger of gloves becoming contaminated either by coming into contact with the unsterile plastic helmet underneath or by touching the shoulders of a colleague. Likewise, wearing a hood without directly seeing it can lead to infection from the unsterile helmet or shoulders [23].

The prevailing belief is that early prosthetic joint infection arises from contamination during surgery. Multiple studies have shown that most instances of wound infection following sterile surgery, such as total joint arthroplasty, are attributed to operating room staff [24]. Nevertheless, research has demonstrated that simple perioperative measures can significantly impact infection rates. An illustrative instance is a randomized clinical experiment conducted by Loftus et al., which included 236 adult patients. The trial revealed that implementing consistent enhancements in fundamental perioperative preventative measures resulted in a significant decrease in the transmission of S. Aureus and the occurrence of surgical site infections [25].

The role of "positive pressure" surgical hand scrub (SHS) in reducing surgical infection is still a subject of ongoing debate and agreement has not been reached [10, 13]. Nevertheless, the utilization of SHS remains prevalent within the arthroplasty community. Furthermore, there is a lack of guidance regarding the optimal approach for putting on a hood, and various methods and practices for hood usage are observed in different healthcare facilities. The findings of our study revealed a minimal level of glove contamination when using SHS under laminar airflow conditions with delayed fan activation. In addition, we found no notable disparity in sterility between these two frequently employed wearing methods.

Kang et al. conducted a study on surgical helmet and hood procedures and discovered that activating the helmet's fan system late led to minimal dispersion of UV fluorescent powder, in contrast to activating it early. In addition, they observed that the use of sticky wrist straps did not result in a reduction of powder dispersal when combined with delayed fan activation. Curiously, the authors suggested that a staff member who has not undergone scrubbing should be responsible for applying all sterile hoods [25]. In a similar vein, Hanselman et al. discovered a notable disparity in the rates at which powder is dispersed when comparing late versus early fan activation. As a result, they advised that the process of donning gowns and gloves should be finished prior to activating the SHS fan [26]. Young et al. performed a study examining the dispersion of fluorescent powder during simulated surgical gowning. The surgeons' hands were coated with luminous powder to replicate the process of skin shedding. According to their research, the presence of positive pressure from secondhand smoke

(SHS) causes particles to move from the surgeon's hands to the cuff of the gown. This requires the use of a sealant tape around the inner glove [24]. Research has also been conducted on the disparity in particle pollution between a helmet design with a single fan and one with a double fan. Vermeiren et al. observed no disparity between these two technologies, however, they emphasized that contamination at the interface between the glove and gown was evident in all experiments conducted with both systems [27]. It is crucial to emphasize that all of these investigations warn against making a direct connection between powder dispersal and PJI. They also highlight the need for future microbiological studies.

There has been a scarcity of microbiological investigations conducted in this region. Moores et al. conducted a study to investigate the impact of laminar airflow and fan activation on particle counts and rates of bacterial contamination in sterile hood systems. It was discovered that turning on the fan during scrubbing led to a considerable rise in both bacterial contamination and particle counts, with a multiplication factor of 3.7. Additionally, they proved that all the exposure plates that were left uncovered in the presence of laminar airflow showed no growth of microorganisms. As a result, they concluded that the most aseptic method of wearing a surgical hood system (SHS) is when it is done under laminar airflow. According to the authors' recommendation, it is advised to activate the fan only after the surgeon has fully dressed in a gown [28].

The investigation revealed that Bacillus species were the most commonly isolated organisms. This is consistent with other studies that assess the level of contamination in sterile materials. Bacillus species are organisms that can survive in situations with little nutrients and can function both with and without oxygen. Additionally, they have the ability to produce spores, which grants them resistance to several chemical and heat sterilizing methods [29, 30]. Kearns et al. found that the baseline contamination rate of SHS hoods was 22% (22/102) at the start of the surgery, and it climbed to 47% (48/102) by the end of the total joint arthroplasty process [31]. In a separate study conducted by Singh et al., it was discovered that 80% of the surgical handsets (SHSs) utilized in 40 arthroplasty procedures were contaminated with microorganisms by the conclusion of the operation. The study found that the rate of contamination rose at 30-minute intervals, and this rise was notably higher when non-laminar airflow theatres were exposed to SHSs [32].

The International Consensus Group recommended the utilization of SSHSs in joint arthroplasty surgery [33]. Amidst the COVID-19 pandemic, there has been a surge in curiosity about safeguarding against virus transmission and the potential use of conventional orthopaedic surgical instruments for combating respiratory viruses. In 2004, Derrick and Gomersall discovered that the Stryker T4 and Stackhouse Freedomaire helmet-hood filters, manufactured by Stryker Instruments and Stackhouse Incorporated respectively, were inadequate in preventing the transmission of SARS [34]. According to a recent study utilizing the 3 M™ Fit Test, it was found that the Stryker Flyte surgical helmet filtration system (manufactured by Stryker Corporation, located in Kalamazoo, MI, USA) was ineffective in shielding against airborne particles in the form of aerosols [35]. The demand for enhanced safety measures in the operating room, particularly during the initial phase of the COVID-19 pandemic, led to the creation of tailor-made Surgical Smoke Handling Systems (SSHSs) and subsequent advancements in filter technology. Other medical fields have employed adapted SSHSs to combat the hazards of infection, yielding satisfactory outcomes [31]. The revised respiratory system filters have the potential to offer effective filtration against aerosol and airborne infections in mechanical ventilator systems [35].

CONCLUSION:

It is beneficial for surgeons to use helmet systems as personal protection when necessary, but it is prudent to wait for further conclusive studies on how these systems may impact the risk of periprosthetic joint infection. When deciding to utilize such a system, there seems to be minimal distinction between single-fan and double-fan systems. However, the surgeon must also exercise caution about the connection between the gown and gloves, maybe securing it with sterile tape, and should never place any object in close proximity to the armpits. Enhancements to present gown designs could be made by enhancing the seals, particularly at the arm-body seam. Additionally, future stand-alone helmet designs should consider the impact of modified airflow and pressure within the suit and its surroundings. The introduction of tape at the junction between the gown and gloves did not modify the rate of contamination. The overall contamination rate was exceedingly low, and if a genuine disparity does exist, it is probable to be minimal. When deciding on the surgical clothing for total knee arthroplasty (TKA), factors such as cost, surgeon preference, and personal protection should be considered. However, there is currently little evidence to suggest that the use of surgical headwear systems (SHS) will have any impact on wound contamination or the occurrence of deep infection.

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