



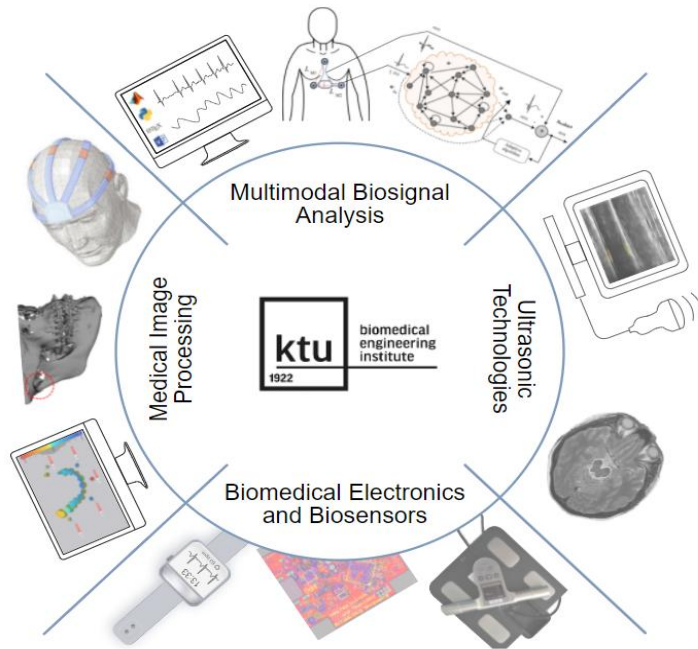
# ThrombUS+: Wearable Continuous Point-of-Care Monitoring, Risk Estimation and Prevention for Deep Vein Thrombosis

Presented by Prof. Dr. Vaidotas Marozas on behalf of ThrombUS+  
Biomedical Engineering Institute  
Kaunas University of Technology (KTU)  
Lithuania



# KTU Biomedical Engineering Institute

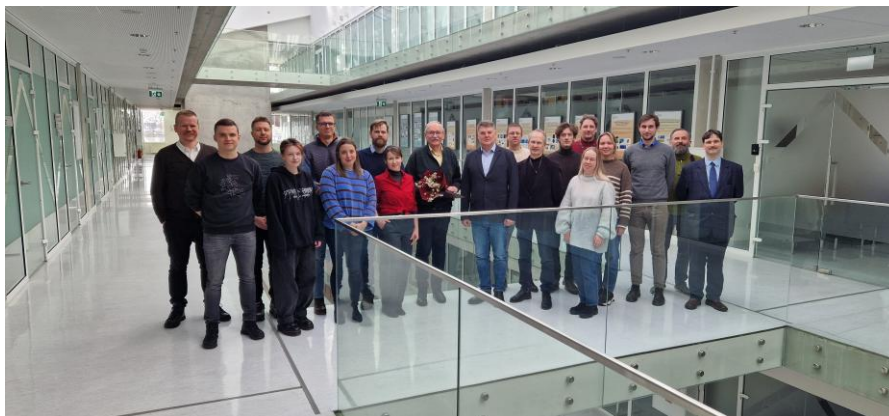
ktu



KTU Santaka Valley



KTU M-Lab

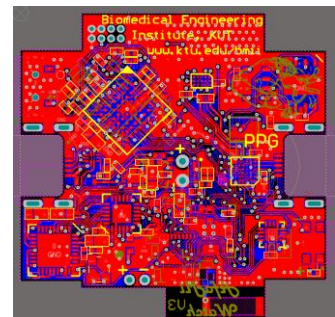


# Achievements

ktu

Photoplethysmography & 6-lead ECG-based atrial fibrillation monitoring  
Licensed to UAB Teltonika.

The smart device „TeltoHeart“ is now on the market.



## Case study: project ThrombUS<sup>+</sup>

**Call Identifier:** HORIZON-HLTH-2023-TOOL-05-05

**Call title:** Harnessing the potential of real-time data analysis and secure Point-of-Care computing for the benefit of person-centred health and care delivery

**Program:** Horizon Europe, 4. Health, 2023-2024

**Destination:** 5. Unlocking the full potential of new tools, technologies and digital solutions for a healthy society

**Proposal submitted:** 13 April 2023

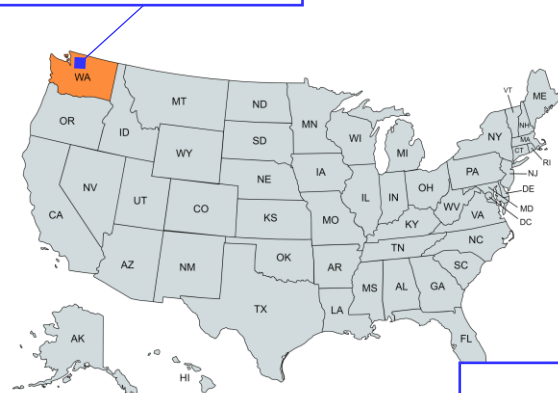
Wearable Continuous Point-of-Care Monitoring,  
Risk Estimation and Prevention for Deep Vein Thrombosis

**Project type:** IA (Innovation Action)

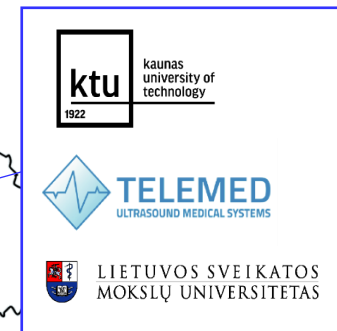
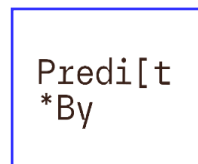
**Project Budget:** 9,565,763.75 €  
**EU funding:** 8,141,251.25 €

**Duration:** 42 months  
**Start:** 1 January 2024  
**End:** 30 June 2027

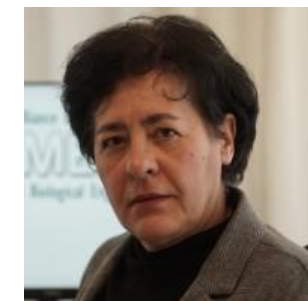
**Invited:** 04 August 2023  
**Signed:** 08 December 2023



Greece  
Lithuania  
Germany  
Italy  
France  
Finland  
Spain  
USA



Coordinator



Prof. Eleni Kaldoudi



## Research -5



## Industry -9



## Hospitals - 5

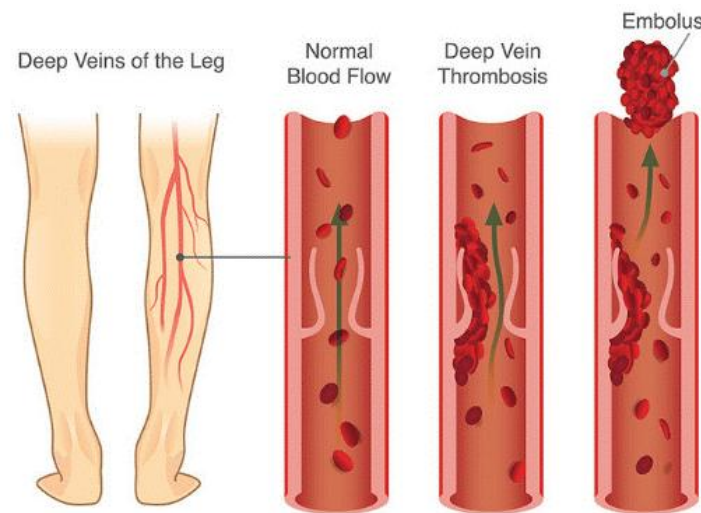


Deep Vein Thrombosis (**DVT**) is the clotting of blood in a deep vein of an extremity usually the calf or thigh.

A **clot** is mainly **composed** of **fibrin** and **red blood cells**.

A clot usually forms **around the valves** in the deep veins of the leg.

The clot might be pushed via the heart to the lungs where it can block an artery, what is know as **pulmonary embolism**, an acute, **life-threatening** event.



<https://www.usaveinclinics.com/vein-disease/deep-vein-thrombosis-dvt/>, June 2024

<https://www.cdc.gov/blood-clots/data-research/facts-stats/index.html#:~:text=The%20precise%20number%20of%20people,die%20of%20VTE%20each%20year.>, June 2024

DVT is a major **preventable cause** of morbidity and mortality worldwide.

- **3<sup>rd</sup>** most frequent **vascular diagnosis** after heart attack and stroke,
- affects more than 1,000,000 Americans per year  
affects more than 700,000 Europeans per year
- **annual** health expenditure related to DVT is **€8.5 billion in EU**

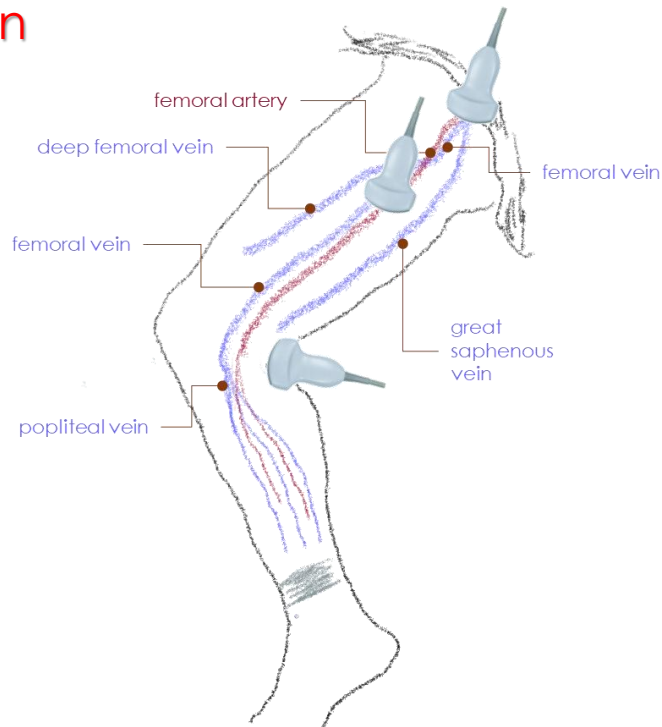
Olaf M et al. Deep Venous Thrombosis. Emerg Med Clin North Am. 2017 doi: 10.1016/j.emc.2017.06.003

Cohen AT et al. Thromb Haemost. 2007 Oct;98(4):756-64

Barco S et al. Thromb Haemost. 2016 Apr;115(4):800-8. doi: 10.1160/TH15-08-0670

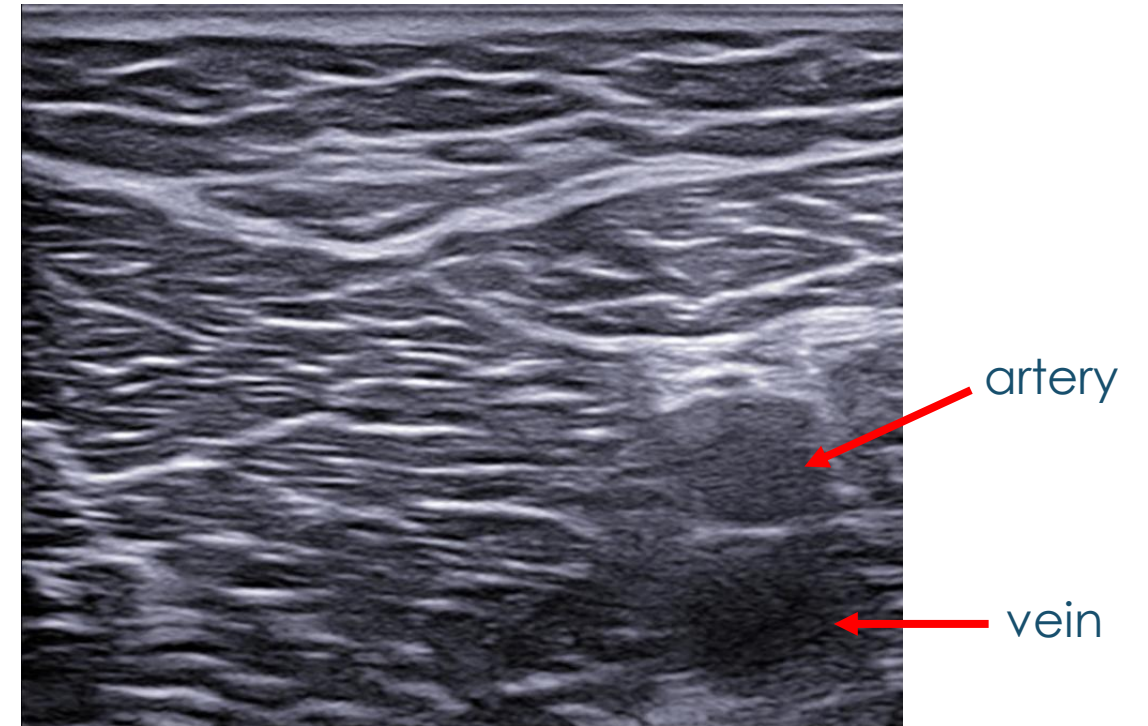
**Currently**, ultrasonography is the method of choice for DVT diagnosis

- direct visualization of the thrombus
- Doppler to assess venous flow
- **compression ultrasound**



Compression US

ThrombUS<sup>+</sup>

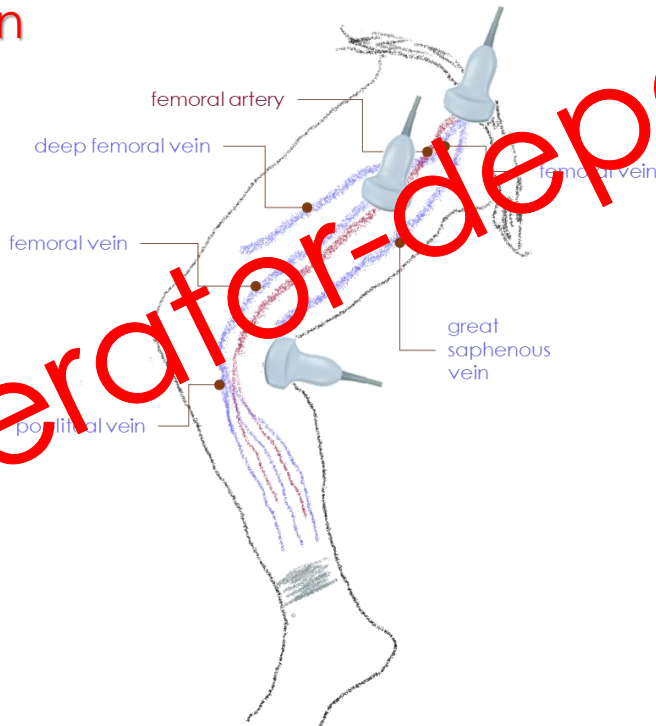


While compressing with the US probe till the artery starts to compress,

- ⇒ when **normal**, the vein fully collapses.
- ⇒ when **DVT is present**, vein does NOT collapse.

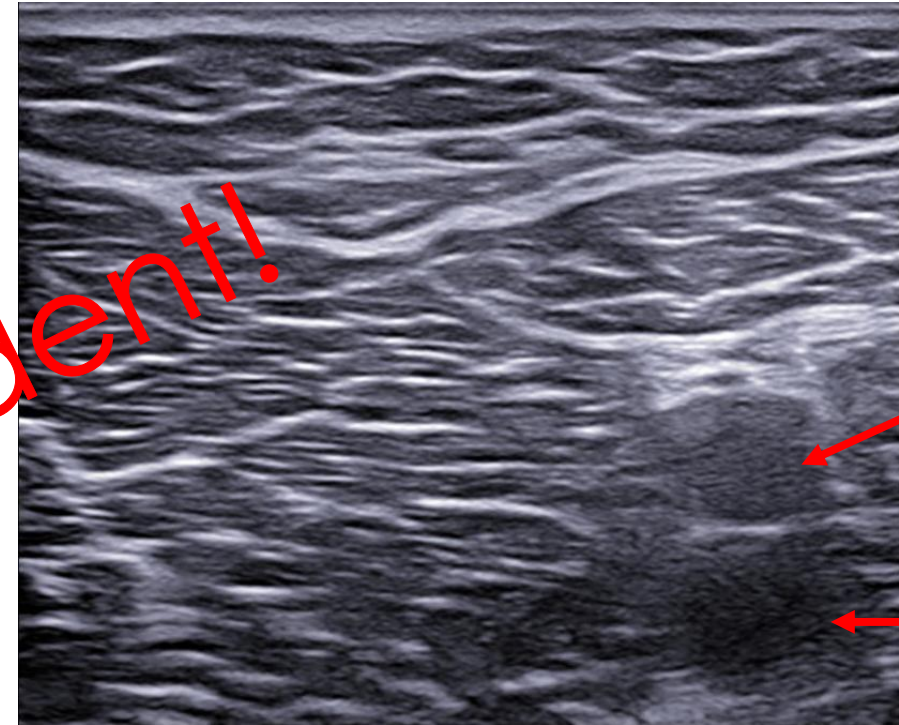
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Compression US

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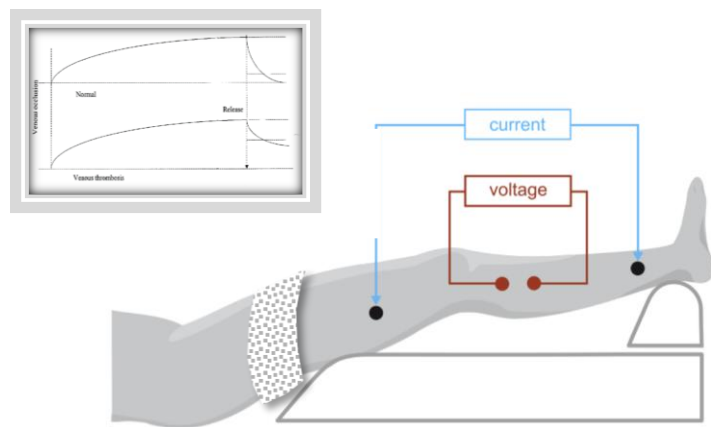
- ⇒ when **normal**, the vein fully collapses
- ⇒ when **DVT is present**, vein does NOT collapse

# Other modalities for DVT diagnosis:

## Venous Occlusion Plethysmography (VOP) methods

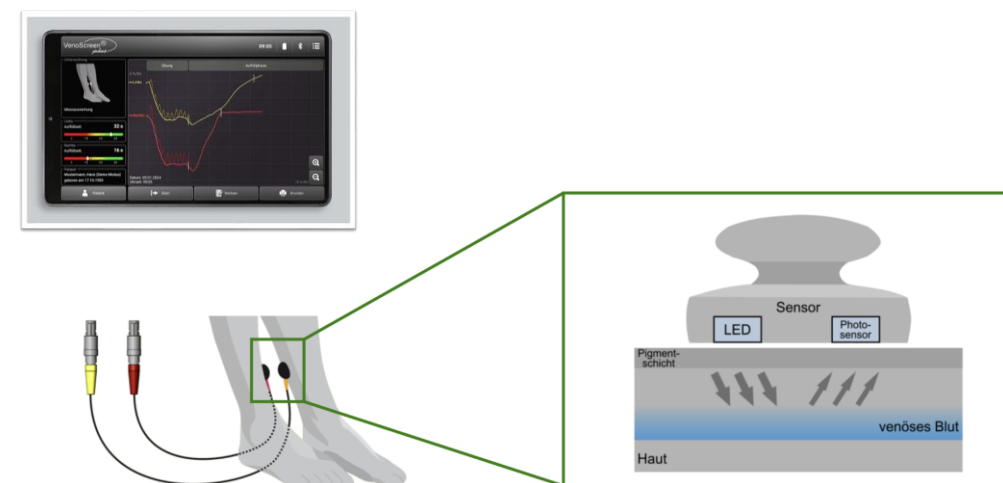
### Electrical Impedance Plethysmography

measures blood volume changes in peripheral veins via electrical impedance changes



### Light Reflection Rheography

measures blood volume changes in peripheral veins via reflection of light



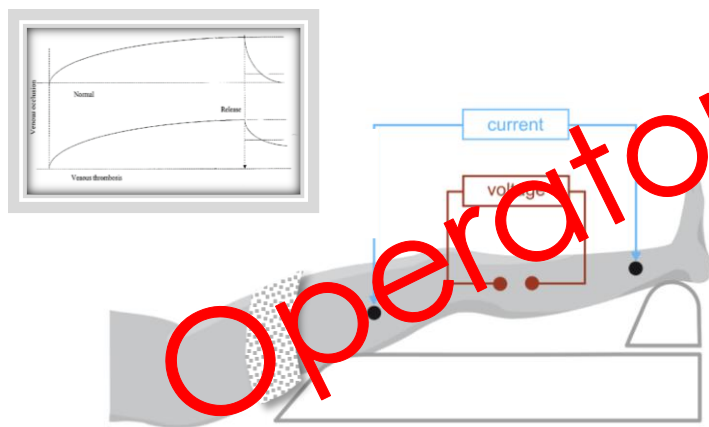
© S. Balling, medis.

## Other modalities for DVT diagnosis:

### Venous Occlusion Plethysmography (VOP) methods

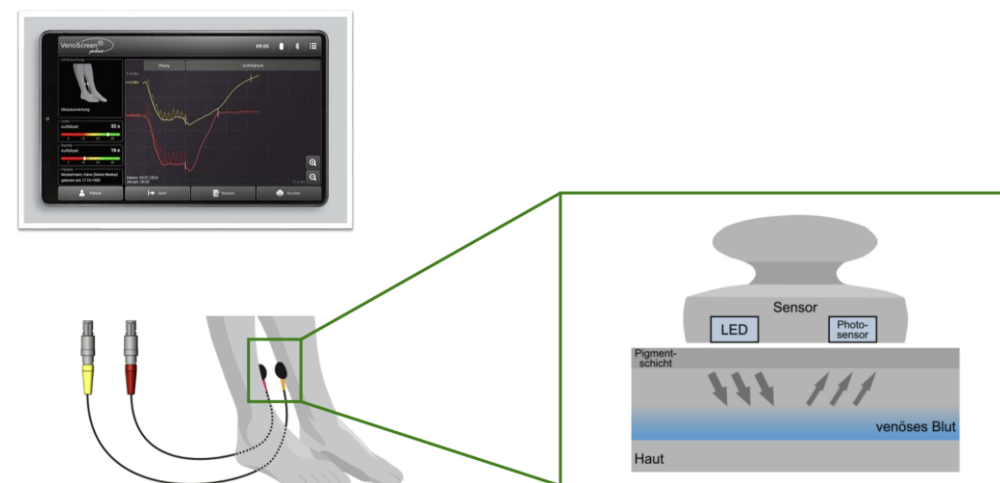
#### Electrical Impedance Plethysmography

measures blood volume changes in peripheral veins via electrical impedance changes



#### Light Reflection Rheography

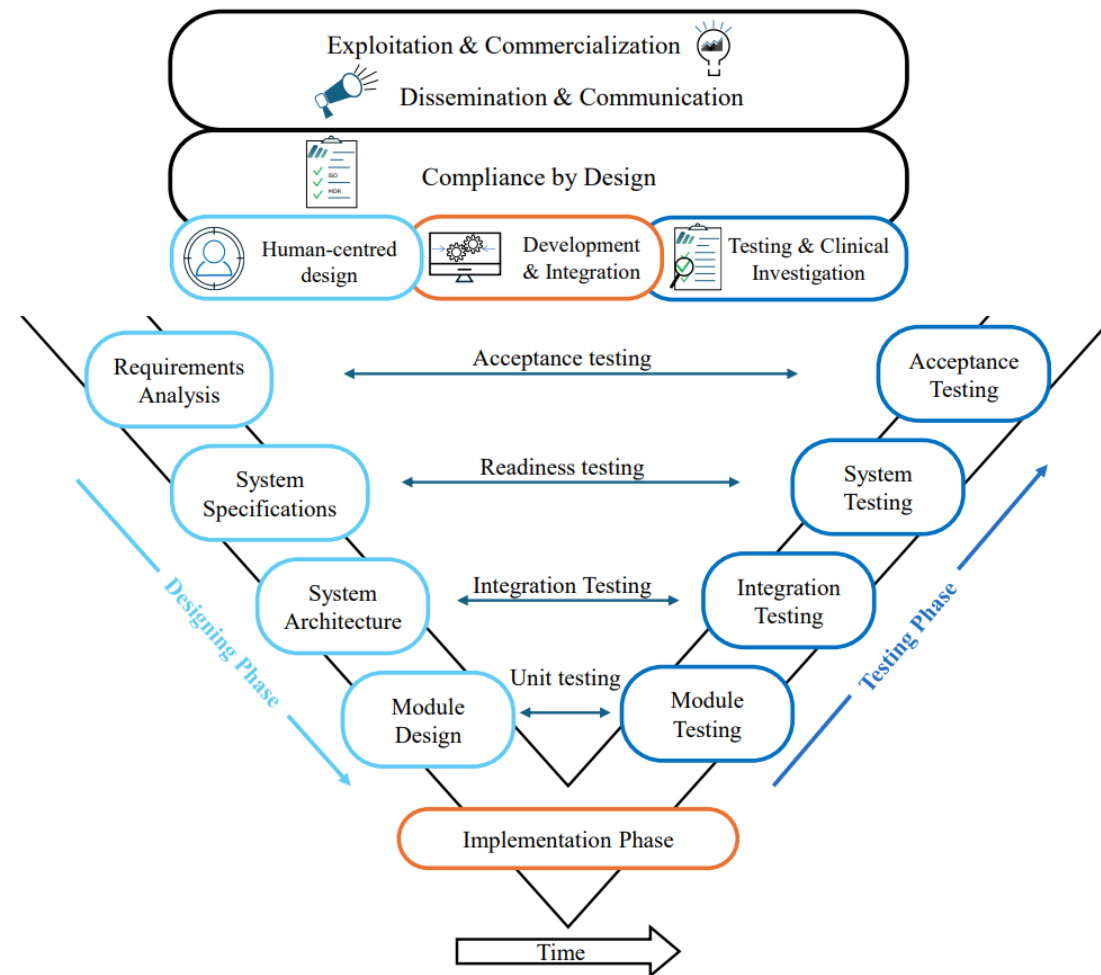
measures blood volume changes in peripheral veins via reflection of light



© S. Balling, medis.

# High-level implementation methodology of the ThrombUS+ project

The **V-model** is a graphical representation of a **systems development lifecycle**



# Shared language & understanding: definitions

- **screening** – checking for disease when there are **no symptoms**, e.g., the mammography / colonoscopy / genetic tests
- **continuous screening** - **regular monitoring** of patients **for signs, symptoms**, or changes that may indicate the development or progression of a particular condition  
eg., heart arrhythmia screening using a smartwatch
- **diagnostic (detection) tests** - for those **showing symptoms** in need of a **differential diagnosis**, eg., DVT diagnosis & thrombus identification, (FP: Baker's cysts, lymph nodes)
- **monitoring (intermittent)** – ongoing **observation** of individuals who have **already been diagnosed** with a particular health condition, e.g., DVT; thrombus features: size, strain,...
- **prevention** – the actions and strategies aimed at **reducing the incidence, prevalence, and impact** of diseases, e.g., intermittent sequential compression cuffs, exercise gamification
- **Risk assessment & monitoring** - the systematic assessment and **tracking of factors** that contribute to the likelihood of developing specific diseases or health conditions, e.g., Caprini model, Wells score,...

## Main Reference Use Cases - RUCs

RUC#1 Neurosurgery

RUC#2 Lower limb orthopaedic surgery

RUC#3 Cardiovascular surgery and risk



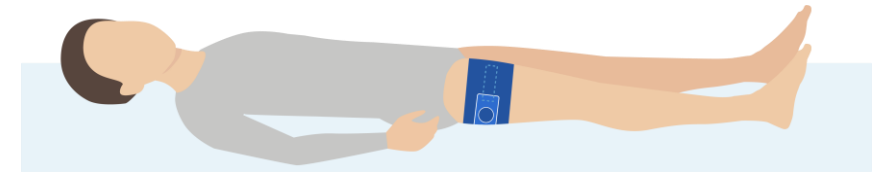
More focus on  
**post-surgical** cases

RUC#4 Pregnancy and postpartum

RUC#5 Obesity

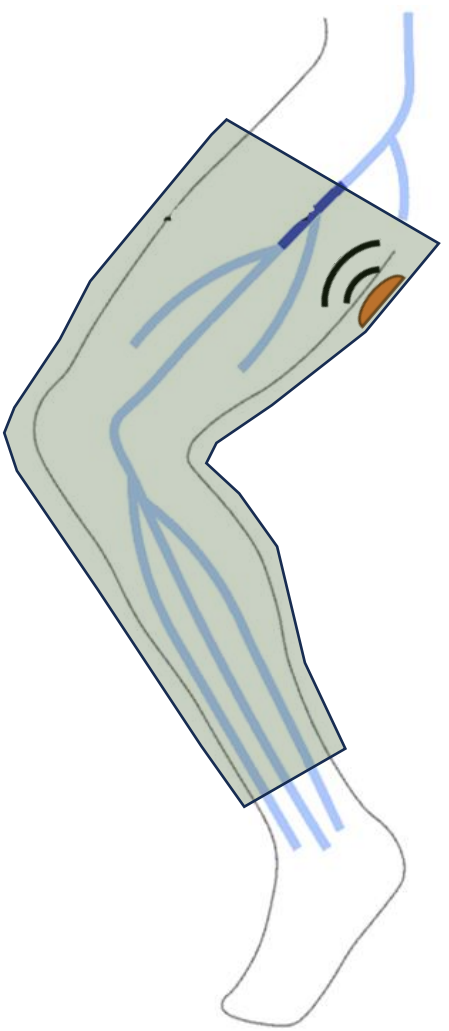
RUC#6 Cancer and oncological treatment

RUC#7 Autoimmune diseases and genetic disorders

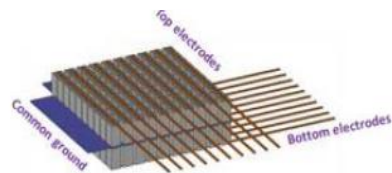


Early detection of DVT is crucial!

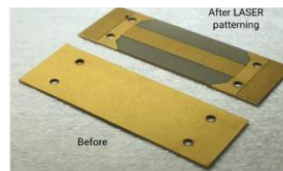




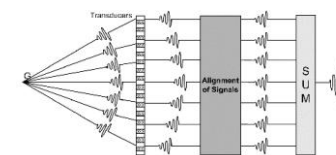
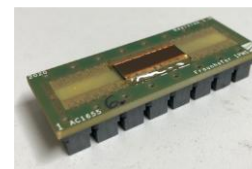
WP3



2 types of bulk technology US transducers by **VERMON**



MEMS technology US transducer by **FRAUNHOFER**

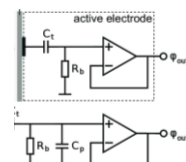


Beamforming by **TELEMED**

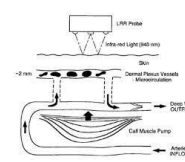
WP4



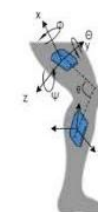
smart textile wearable by **ComTech**



electrical impedance plethysmography by **TAU**



light reflection rheography by **MEDIS**



activity sensor network by **KTU**



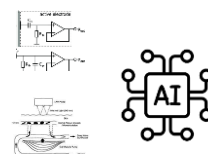
pressure micropump by **KTU**

WP3

WP5



AI based ultrasound DVT detection by **EchoNous**



AI based DVT detection based on EIP and LRR by **TAU** and **MEDIS**



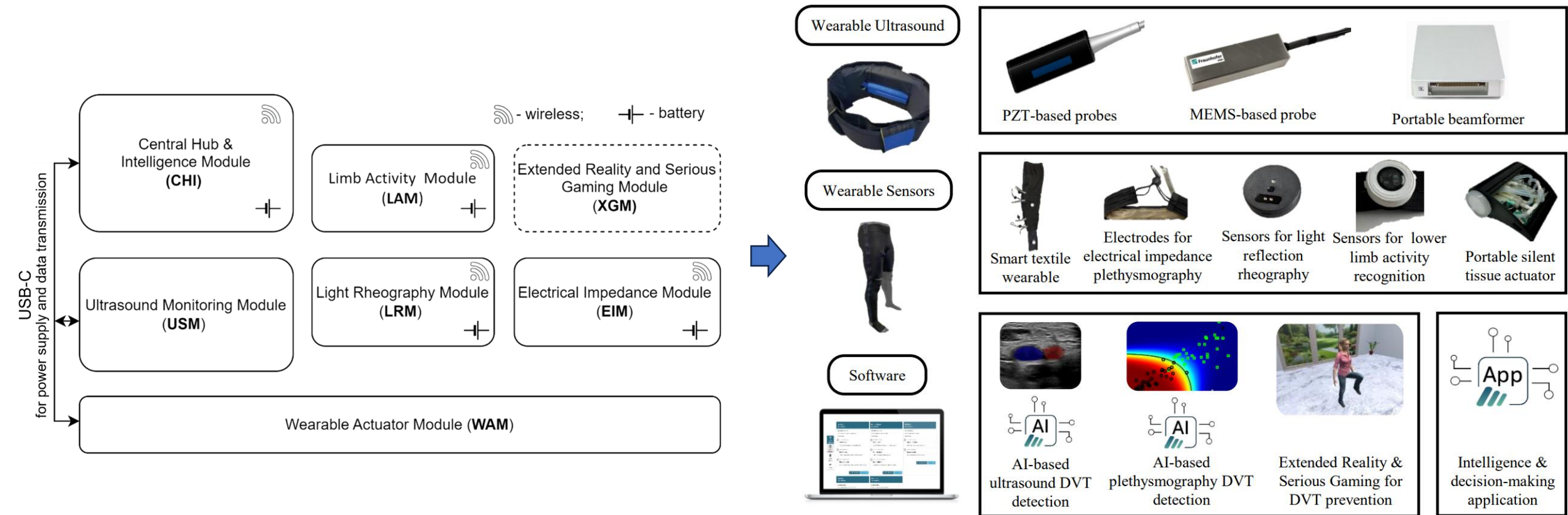
DVT risk detection, activity based serious game and extended reality by **ATHENA**

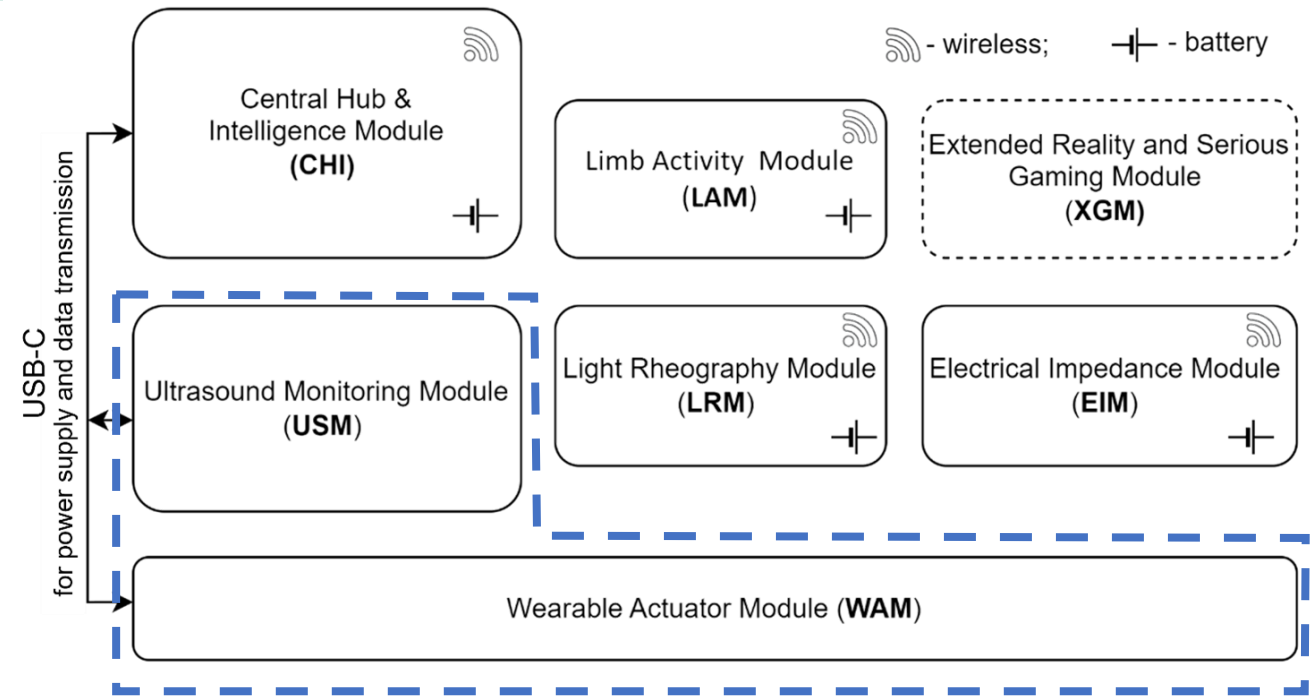


central intelligence and app by **ATHENA**

WP6

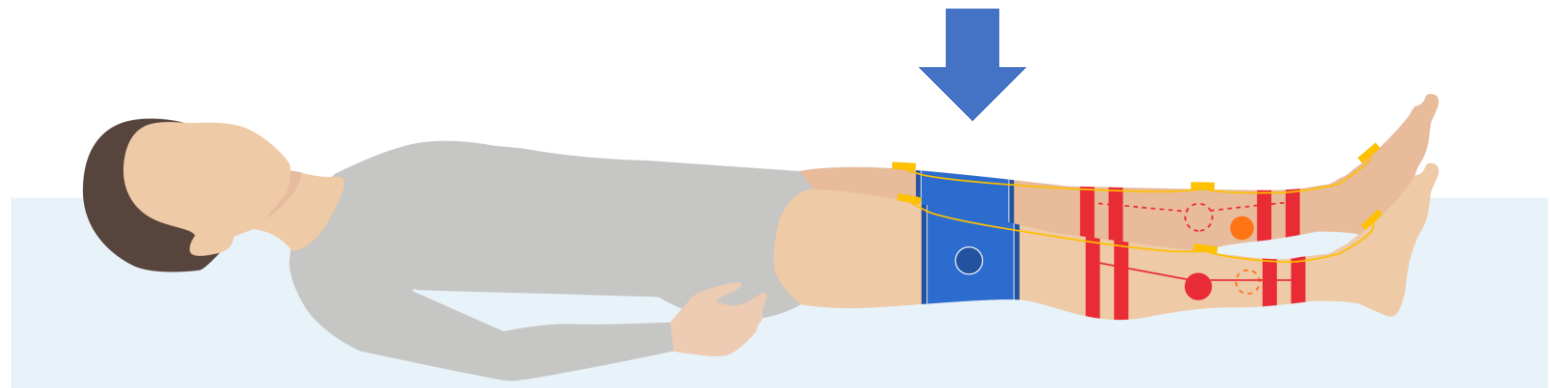
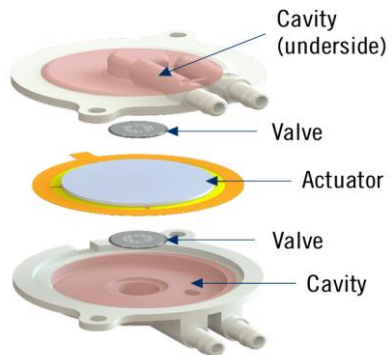
# System modules & Developed components

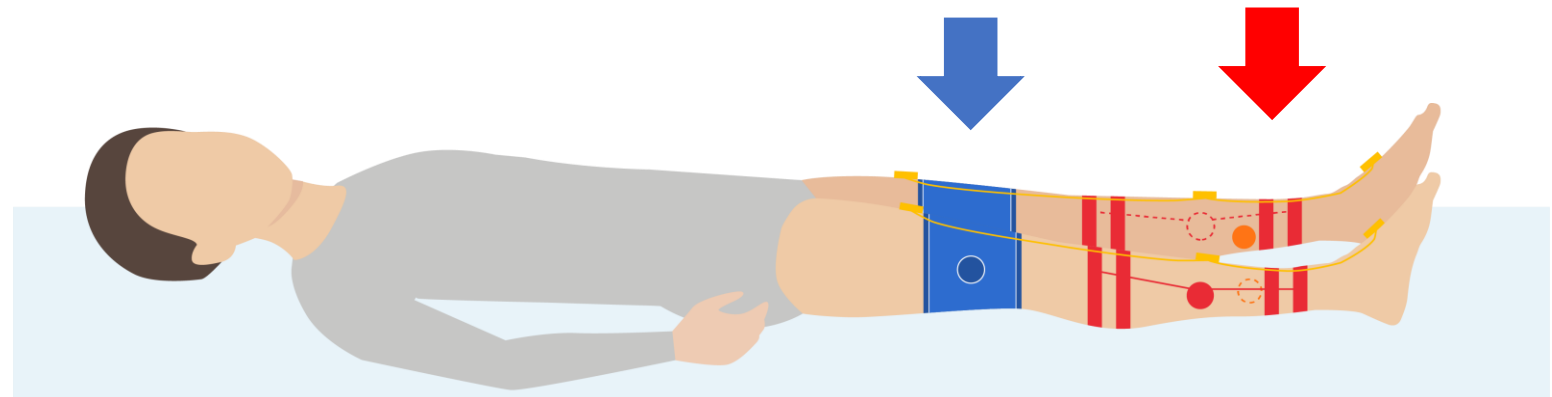
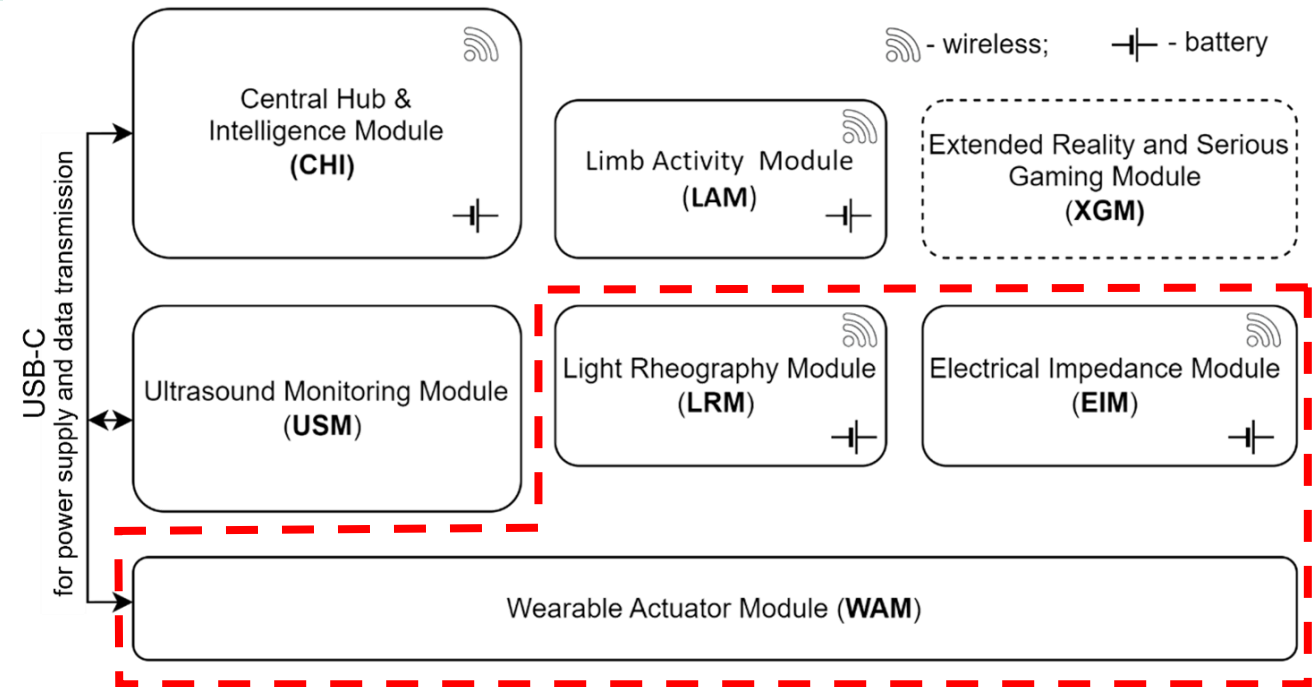




Operator-less, wearable, automated  
Compression Ultrasonography

Key component – piezoelectric pump





Operator-less, wearable, automated  
Venous Occlusion Plethysmography (VOP)

using

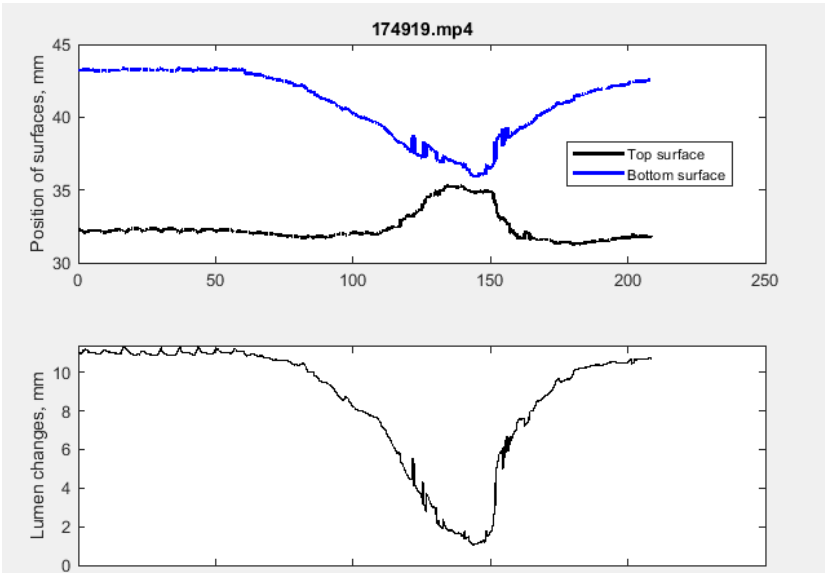
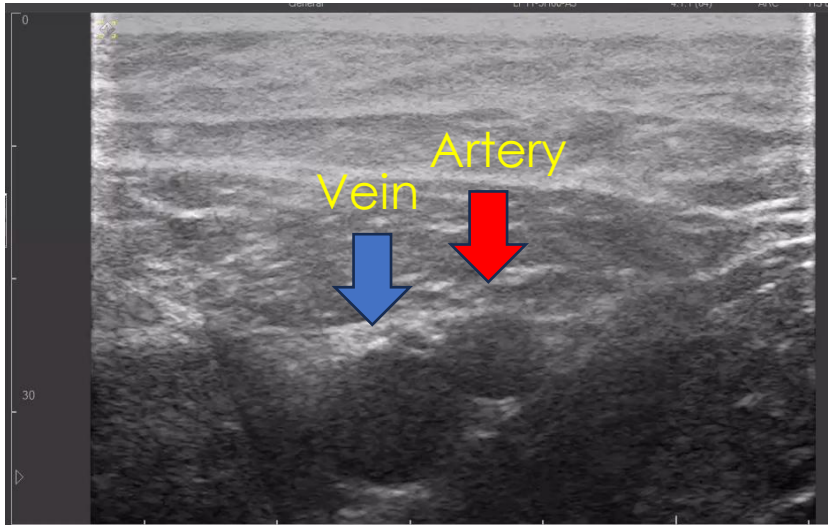
Electr. Impedance module (EIM)  
Light Rheography module (LRM)  
Wearable Actuator Module (WAM)

# Compression Ultrasound Prototype

Tissue actuator with  
US transducer

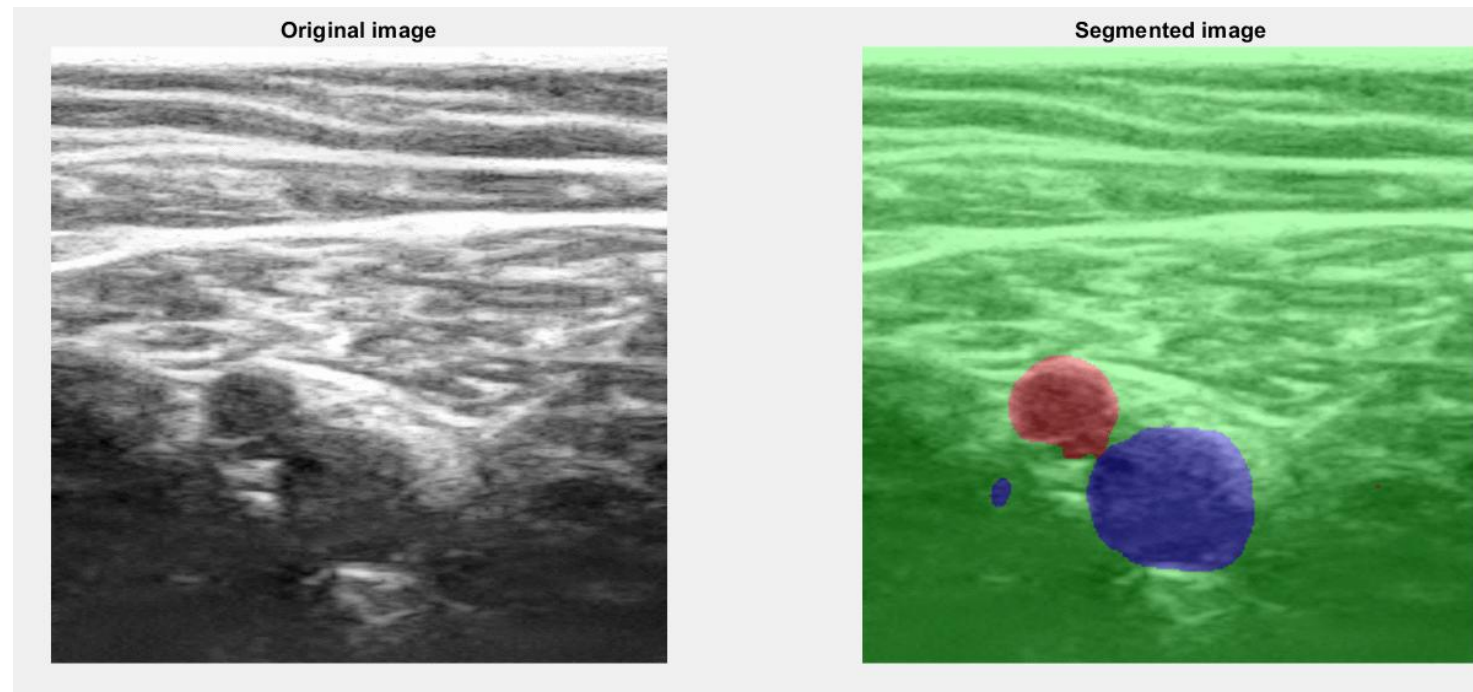


Telemed US  
beamformer



How will ThrombUS+ use **AI / ML**  
to monitor for DVT?

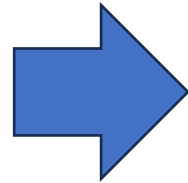
# Wearable compression ultrasonography: AI / ML- based **vessel segmentation**



(c) J. Grajauskaitė

## Challenges in US segmentation

- Low contrast and speckle noise
- Anatomical variability
- Shadowing and artifacts
- Irregular object boundaries



### 1. Preprocessing techniques

- Speckle noise reduction
- Contrast enhancement

### 2. Deep learning approaches

- U-Nets
- Attention-based networks

### 3. Incorporating domain knowledge

- Shape priors (active shape models)
- Biophysics-informed learning

### 4. Data augmentation & synthetic data

- Augmentations (rotation, flipping, deformations)
- Synthetic data generation

**A** Conventional ultrasound image set collection to create a training data set

Participants >3000

**B1** Training data set collection using the prototype wearable ultrasound to fine tune the AI model

Participants >500

**B2** Physiological signals, lower limb activity and plethysmography measurements via the ThrombUS+ prototype wearable sensor components from healthy volunteers

Participants >60

**C1** Early feasibility study of the ThrombUS+ integrated prototype in patients in the postoperative ward

Participants 25-50

**C2** Prospective, double-blinded, pilot study evaluating artificial intelligence driven automatic detection of deep vein thrombosis by the ThrombUS+ device compared to standard ultrasound imaging in patients suspected for deep vein thrombosis

Participants: 50-100

Data for training AI/ML models

# work package breakdown

- WP 1. Management
- WP 2. Requirements and product co-design
- WP 3. Ultrasound sensing
- WP 4. Plethysmography, activity sensors and wearable
- WP 5. Decision support and action intelligence
- WP 6. Integration and validation**
- WP 7. Clinical studies
- WP 8. Dissemination & Communication
- WP 9. Exploitation, and Commercialization

## T6.3 “Hardware integration”

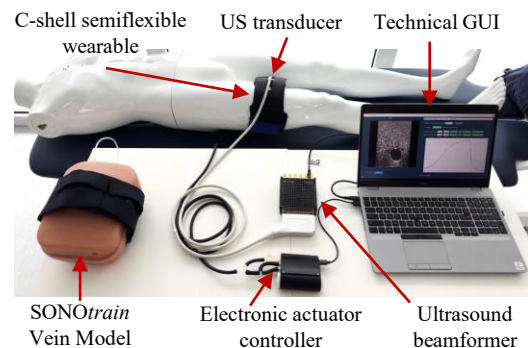


## MONITORING

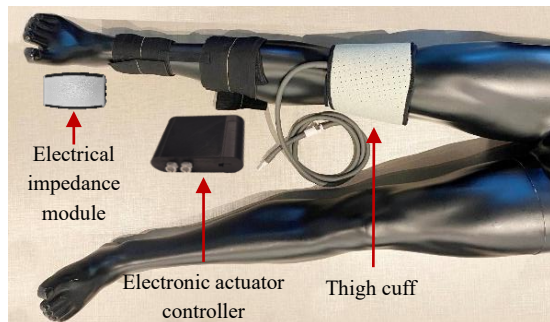
# T 6.5 “Software and hardware integration”



### Compression ultrasound



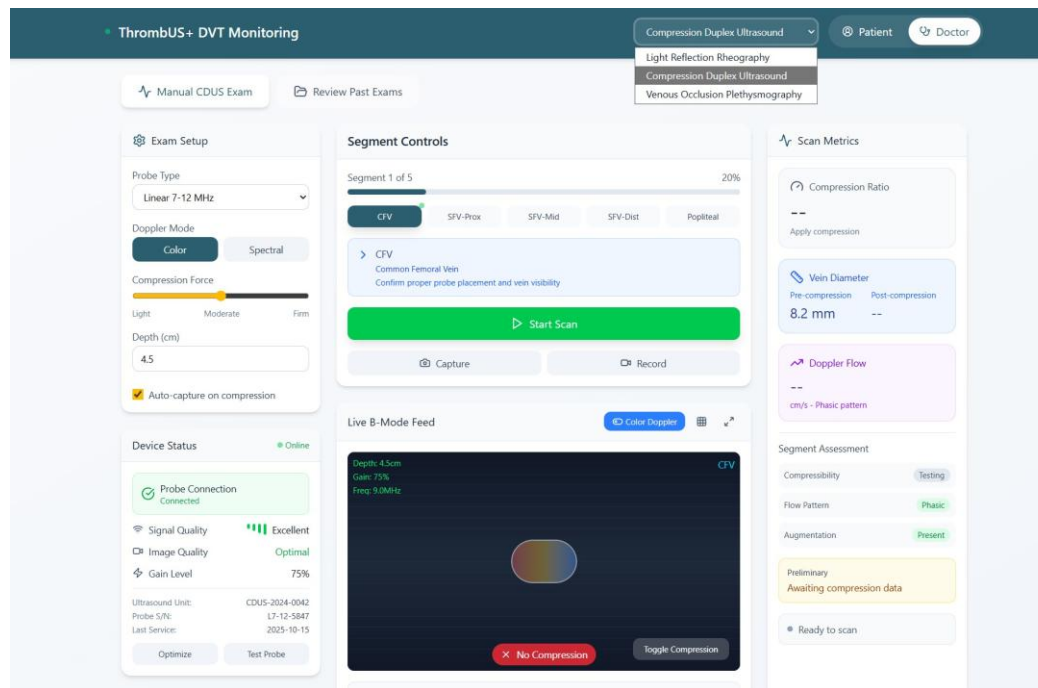
### Venous Occlusion Plethysmography



### Light Reflection Rheography



## Central Hub & Intelligence



## PREVENTION

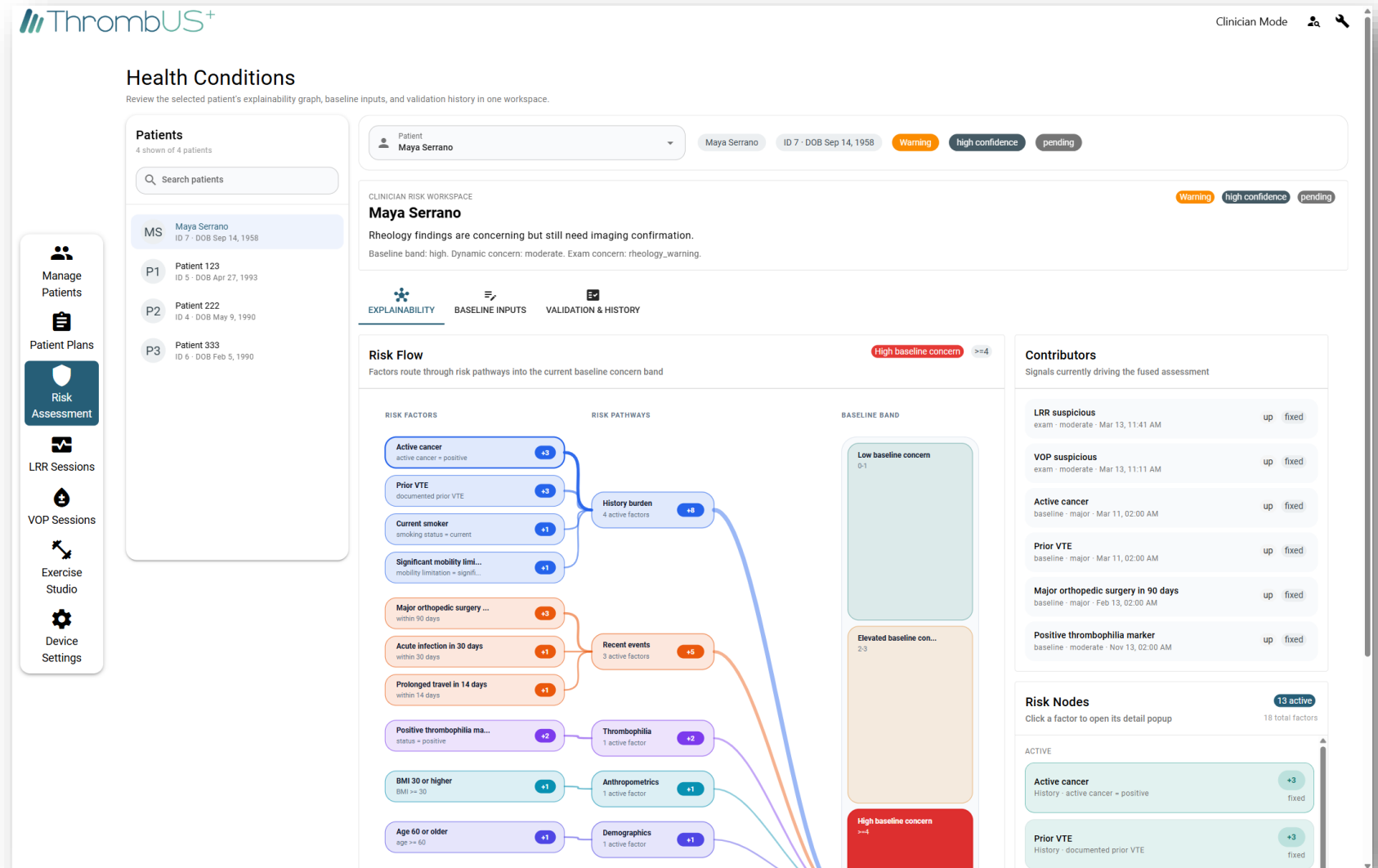


### Limb activity module

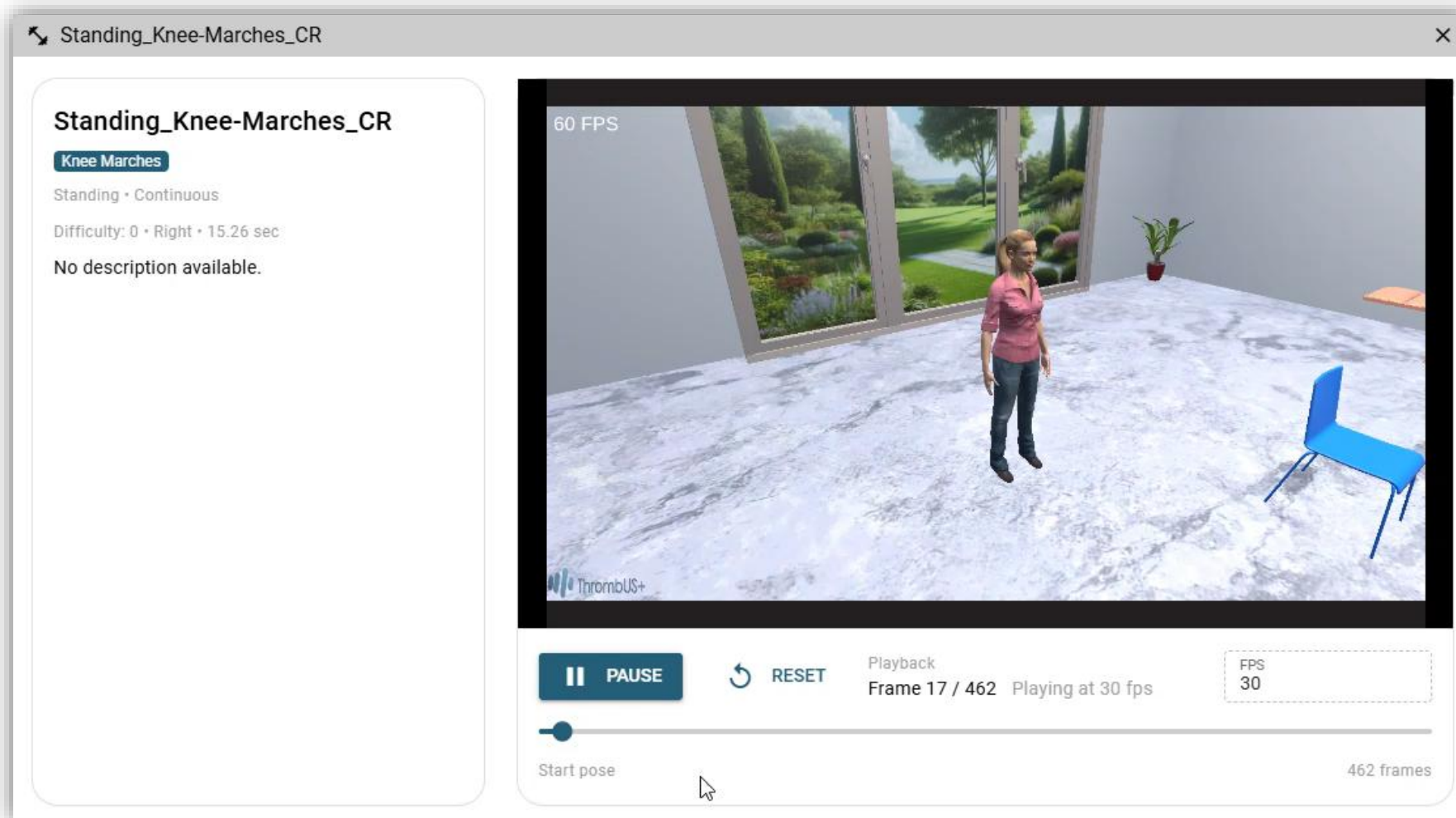


# DVT Risk Assessment: a readable summary to the clinician

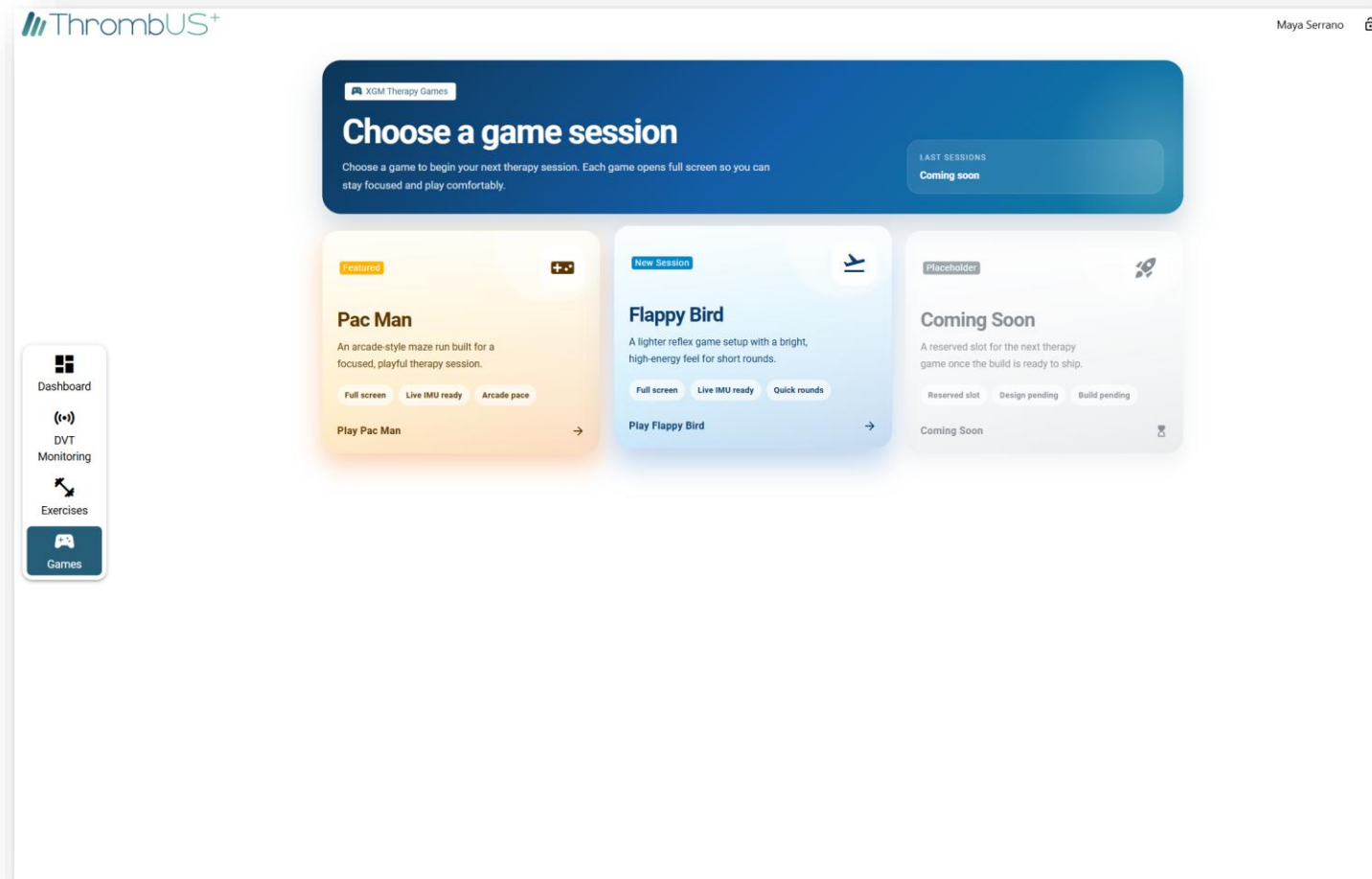
- The feature supports clinical interpretation in addition to operational use.
- The overview precedes the explainability graph and evidence tabs.
- The view summarizes current risk status for clinical review and communication.



# DVT Prevention: Exercise browsing and assignment editing



# DVT Prevention: Serious games



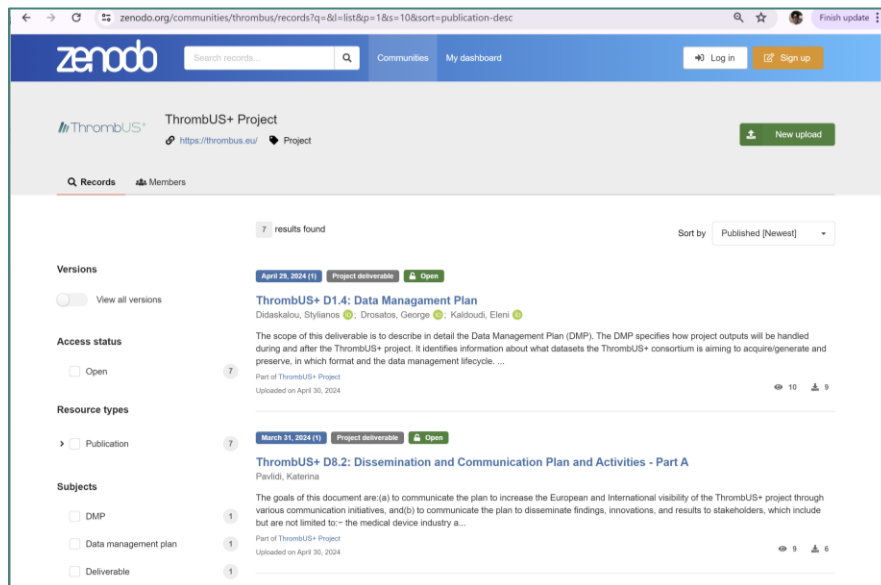
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2	D1.1	ATHENA	DEC	SEN	1	Jan 2024
3	D10.1	ATHENA	ETHICS	SEN	1	Jan 2024
4	D1.2	ATHENA	R	SEN	3	Mar 2024
5	D1.3	MEDEA	R	SEN	3	Mar 2024
6	D8.2	SciGen	R	PU	3	Mar 2024
7	D9.1	VDE	R	PU	3	Mar 2024
8	D1.4	ATHENA	DMP	PU	4	Apr 2024
9	D7.1	PHAZE	R	PU	5	May 2024
10	D2.1	PBY	R	PU	6	Jun 2024
11	D2.2	VDE	R	PU	8	Aug 2024
12	D2.3	KTU	R	PU	10	Oct 2024
13	D2.4	ComfTech	R	SEN	12	Dec 2024
14	D3.1	VERMON	DEM	SEN	12	Dec 2024
15	D3.2	FRAUNHOFER	DEM	SEN	12	Dec 2024
16	D3.3	KTU	DEM	SEN	12	Dec 2024
17	D4.1	TAU	DEM	SEN	12	Dec 2024
18	D4.2	MEDIS	DEM	SEN	12	Dec 2024
19	D4.3	KTU	DEM	SEN	12	Dec 2024
20	D7.2	PHAZE	R	PU	12	Dec 2024
21	D7.3	PHAZE	R	PU	13	Jan 2025
22	D6.1	KTU	R	PU	14	Feb 2025
23	D3.4	TELEMED	DEM	SEN	15	Mar 2025
24	D7.4	PHAZE	R	PU	15	Mar 2025
25	D4.4	ComfTech	DEM	SEN	16	Apr 2025
26	D6.2	KTU	R	PU	18	Jun 2025
27	D3.5	KTU	R	PU	19	Jul 2025
28	D4.5	KTU	R	PU	19	Jul 2025

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30	D3.6	TELEMED	DEM	SEN	21	Sep 2025
31	D4.6	ComfTech	DEM	SEN	21	Sep 2025
32	D1.5	ATHENA	DMP	PU	24	Dec 2025
33	D7.6	PHAZE	R	PU	24	Dec 2024
34	D6.3	KTU	DEM	SEN	26	Feb 2026
35	D8.3	ATHENA	DATA	PU	26	Feb 2026
36	D5.1	EchoNous	DEM	SEN	28	Apr 2026
37	D5.2	TAU	DEM	SEN	28	Apr 2026
38	D5.3	ATHENA	DEM	SEN	28	Apr 2026
39	D5.4	ATHENA	DEM	SEN	28	Apr 2026
40	D5.5	ATHENA	DEM	SEN	28	Apr 2026
41	D6.4	ATHENA	DEM	SEN	28	Apr 2026
42	D7.7	PHAZE	R	PU	29	May 2026
43	D6.5	KTU	DEM	SEN	32	Aug 2026
44	D7.8	PHAZE	R	PU	36	Dec 2026
45	D1.6	ATHENA	R	SEN	42	Jun 2027
46	D1.7	MEDEA	R	SEN	42	Jun 2027
47	D7.9	PHAZE	R	PU	42	Jun 2027
48	D8.4	SciGen	R	PU	42	Jun 2027
49	D8.5	SciGen	R	PU	42	Jun 2027
50	D9.2	VDE	R	PU	42	Jun 2027
51	D9.3	PBY	R	PU	42	Jun 2027
52	D9.4	MEDEA	R	SEN	42	Jun 2027
53	D10.5	ATHENA	ETHICS	SEN	42	Jun 2027
54	D10.2	ATHENA	ETHICS	SEN	12	Dec 2024
55	D10.3	ATHENA	ETHICS	SEN	24	Dec 2025
56	D10.4	ATHENA	ETHICS	SEN	36	Dec 2026

52 +4  
deliverables

KTU  
responsibility  
8 deliverables

Submitted public deliverables or publishable summaries can be viewed in the **project website** and in the project's community in **Zenodo**



No	Deliverable	Nature	Due	Status
DI.1	<a href="#">Management guide &amp; collaboration infrastructure</a> (file size: 683 KB) Kaldoudi E. Management Guide and Collaboration Infrastructure. Publishable Summary of Deliverable 1.1, Thrombus+ Horizon Europe Innovation Action, EC Grant Agreement No. 10107227, 31 January 2024. <a href="#">Download</a> <a href="#">View</a>	SEN	January 2024	Submitted
DI.2	<a href="#">Quality assurance and risk management plan &amp; activities – Part A</a> (file size: 527 KB) Daskalaki S, Kaldoudi E. Quality Assurance and Risk Management Plan and Activities – Part A, Publishable Summary of Deliverable 1.2, Thrombus+ Horizon Europe Innovation Action, EC Grant Agreement No. 10107227, 29 March 2024. <a href="#">Download</a> <a href="#">View</a>	SEN	March 2024	Submitted
DI.3	<a href="#">Innovation and IPR management plan and activities – Part A</a> (file size: 934 KB) Dimitrova P, and the Thrombus+ Consortium. Innovation and Intellectual Property Rights Management Plan and Activities – Part 1, Publishable Summary of Deliverable 1.3, Thrombus+ Horizon Europe Innovation Action, EC Grant Agreement No. 10107227, 31 March 2024. <a href="#">Download</a> <a href="#">View</a>	SEN	March 2024	Submitted
DI.4	<a href="#">Data management plan</a> (file size: 766 KB) Daskalaki S, Dimitrova P, Kaldoudi E, Thrombus+ Data Management Plan, Deliverable 1.4, Thrombus+ Horizon Europe Innovation Action, EC Grant Agreement No. 10107227, 30 April 2024. <a href="#">Download</a> <a href="#">View</a>	PU	April 2024	Submitted
DI.5	Data management plan – Update	PU	December 2025	
DI.6	Quality assurance and risk management plan & activities – Part B	SEN	June 2027	
DI.7	Innovation and IPR management plan and activities – Part B	SEN	June 2027	

No	Deliverable	Nature	Due	Status
D2.1	Patient-centric cases and requirements definition	PU	June 2024	
D2.2	Regulatory framework, security, safety and ethics strategy and guidelines	PU	August 2024	



<https://thrombus.eu/>



## Lessons learned

- Dedicated time for **focus groups** and structured **brainstorming sessions** with **clinicians** is essential to ensure that the **medical perspective** is adequately **integrated**.
- Clear communication and a **shared vocabulary** between technical and medical teams are essential to avoid misunderstandings and ensure efficient **collaboration**.
- **Iterative feedback loops** between developers and clinicians significantly improve the relevance and usability of the developed solutions.
- **Flexibility in project implementation** is necessary to accommodate evolving clinical insights and constraints.

# The latest article from ThrombUS+



The screenshot shows the article page for "ThrombUS+ Project: Towards Wearable Continuous Point-of-Care Monitoring for Deep Vein Thrombosis of the Lower Limb". The page is from the Computational and Structural Biotechnology Journal, a Science Partner Journal. The article is an Innovation Report, published on 12 Apr 2026, with Article ID: 0082 and DOI: 10.34133/csbj.0082. The authors listed are Vaidotas Marozas, Stylianos Didaskalou, Rimvydas Eitminavičius, Nick Portokallidis, Rytis Jurkonis, Saulius Daukantas, Mantas Jucevičius, Andrius Rapalis, Nicolas Pousset, Mathieu Legros, Sean Toffessi Sewe, Nicolas Lange, Søren Köble, Marco Kirchner, Andrius Sakalauskas, Pavlos Moustakidis, Susann Balling, Jürgen Querengässer, Lara Alessia Moltani, Jessica Cesana, Sami Maja, Roni Ahola, Andrius Macas, Neringa Balčiūnienė, Rytis Kjauskas, Adomas Aladaitis, Linas Velička, Michail Potoupnis, Elvira Grandone, Maxime Gautier, Thorsten Pirz, Sophia Zoe Narter, Pietro Dionisio, Spiros Anagnostopoulos, Lucas Javier Segal, Federico Puppo, Katerina Pavlidis, Arūnas Lukoševičius, Anni Vehkaoja, and Eleni Kaldoudi. The article has 10 downloads. The journal cover image on the right shows a DNA double helix structure.

<https://spj.science.org/doi/10.34133/csbj.0082>

**Greece, January 2024**



**Kaunas, May 2024**



**Italy, January 2025**



**Finland, June 2025**



**Spain, March 2026**





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„Wearable continuous point-of-care monitoring, risk estimation and prevention for deep vein thrombosis“, 2024-2027