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RESEARCH

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Feasibility of portable telemedicine devices for ambulance-based prehospital triage: a comparative simulation study

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Abstract

Background Video-based telemedicine can improve prehospital triage. However, it is unclear which portable device enabling a real-time specialist consultation via two-way video and audio connection in dynamic emergency medical service environments should be used. This feasibility study identified the most suitable portable telemedicine device for prehospital triage.

Methods Four simulated stroke-like scenarios were conducted with ambulance professionals and remote vascular neurologists. Three portable telemedicine devices were tested: two head-mounted assisted-reality devices (RealWear Navigator ™ 520, Vuzix M400) and a smartphone using Siilo Messenger application. Feasibility was evaluated through structured surveys from both user groups and a patient actor. Quantitative data were analysed using Multi-Criteria Decision Analysis with stakeholder-derived criterion weights to generate overall value scores and device ranking.

Results Out of 47 analysed surveys, the Vuzix head-mounted device achieved the highest overall value score (0.80), followed by Siilo Messenger smartphone application (0.77) and RealWear head-mounted device (0.73). Ambulance professionals prioritised usability, favouring the smartphone application, whereas neurologists emphasised video quality, favouring Vuzix head-mounted device. Qualitative feedback highlighted trade-offs: head-mounted devices offered hands-free use but required peripherals and hindered patient interaction, while smartphones were intuitive but limited by video quality and image stability.

Conclusions Device suitability for prehospital telemedicine depends on balancing technical performance with usability. The smartphone-based application provides practical solution for early implementation, while head-mounted devices may be preferable when hands-free operation and video quality are critical. Future research should assess their clinical and operational impact to enable safe and scalable implementation.

Keywords Telemedicine, Prehospital care, Emergency medical services, Ambulance triage, Decision support, Stroke triage, Feasibility study, Simulation study, User-centred design

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Background

Healthcare systems worldwide face increasing pressure to deliver high-quality acute care with finite resources. Ageing populations, the rising prevalence of multimorbidity, and growing demand for emergency care services have resulted in overcrowding and delays for patients with genuine emergencies [1, 2]. Such pressures may compromise the quality and timeliness of care [3, 4], underlining the urgent need for more efficient use of available resources.

Amid increasing systemic pressure, improving prehospital triage has emerged as a key strategy to optimise the use of limited acute-care resources [5, 6]. In response, health systems have begun exploring innovations that enhance care allocation without compromising patient safety. One promising approach is the integration of telemedicine in emergency medical services (EMS), enabling real-time consultation between ambulance professionals at the scene and hospital-based physicians.

The need for improved triage is particularly evident in acute stroke care. Stroke remains one of the leading causes of death and disability worldwide [7, 8]. In many EMS systems, including those with strong gatekeeping functions such as the Netherlands, all suspected stroke ("stroke code") patients are transported directly to the hospital to enable rapid treatment initiation. Yet up to 40 percent of these patients ultimately prove to have a stroke mimic, while only about 15 percent of stroke-code patients are eligible for acute interventions [9]. This approach prioritises speed but results in substantial over-triage and inefficient use of acute care resources.

Within this context, we are developing SMART Triage (Smart Medical Application for Remote Triage), a digital platform for Dutch EMS that enables secure, real-time audio–video communication and vital data sharing between ambulance professionals and hospital physicians. SMART Triage aims to optimise prehospital triage by integrating teleconsultation seamlessly into routine ambulance workflows. Stroke was selected as the initial focus because it represents a large, well-defined patient group, is one of the most validated applications of prehospital telemedicine with demonstrated safety and feasibility [10, 11], and is a diagnostic domain in which remote specialist input can add substantial value. In addition, accurate differentiation between stroke and stroke mimic requires the detection of subtle neurological deficits such as facial asymmetry and speech changes. A telemedicine device that reliably provides high-quality video and audio, enabling assessment of these subtle clinical features, may also support remote assessment in other acute prehospital presentations where specialist input is valuable. These include the assessment of older people living with frailty, for which prehospital teleconsultation has demonstrated feasibility and impact on conveyance decisions [12], paediatric emergencies, where telemedicine has been identified as a potentially valuable tool for remote specialist support, given the inherently low volume of paediatric calls in prehospital care [13], and mental health-related calls, where video-based triage has been associated with reduced ambulance dispatch compared with telephone triage alone [14].

Previous studies have used various telemedicine devices for prehospital consultation, including smartphones [15, 16], in-vehicle systems [17–20], tablets [21–23], head-mounted devices [24] and other technologies [25]. These devices differ in usability, technical performance and integration into EMS workflows. For successful implementation it is crucial to select a device that is technically reliable, compatible with ambulance operations, and supports efficient communication [26, 27]. Actively involving end users in this selection and development process is essential to ensure adoption [28].

Despite a growing body of research on prehospital telemedicine, no studies have systematically compared multiple device types within a standardised evaluation framework particularly during the development phase, when user-centred design is most critical. The aim of this study was therefore to identify the most feasible portable telemedicine device for prehospital triage, based on its performance in simulated ambulance scenarios.

Methods

Study design and setting

This feasibility pilot study was conducted within the EMS of the Hollands Midden region in the Netherlands. The service operates 31 ambulances and employs about 260 ambulance professionals, serving approximately 770,000 inhabitants. A professional actor portrayed four predefined *stroke-code* scenarios in a controlled environment. During the simulations ambulance professionals used three different portable telemedicine devices, two head-mounted device and one smartphone-based video conferencing application, to conduct real-time consultation with two hospital-based neurologists.

Stroke code scenarios

Four scenarios were developed by an experienced ambulance professional (J.B.) to represent variation in clinical presentation and complexity rather than to evaluate diagnostic accuracy: (1) stroke versus functional neurological disorder; (2) stroke versus peripheral vestibular syndrome; (3) stroke versus migraine aura; and (4) lacunar infarct versus large vessel occlusion (LVO). Figure 1 provides a sample case scenario. A complete overview of all scenarios can be found in supplementary material S1.

Case scenario #1

Setting: 'Home' (indoor with natural light)

Roles:

- Patient: 54-year-old woman (actor)
- On-site: ambulance professional
- Remote: Neurologist via video link

Vital signs: BP 190/100, HR 65, SpO2 96%, Glu 9.0 mmol/L, pupils +/+

FAST+: Balance: unsteady, needs support; Eyes: blurred vision, no diplopia; Face: symmetrical; Arms: no drift; Speech: clear, repeats sentences; Time: onset 1 h ago.

Case summary: A 54-year-old woman was found at home after reporting sudden onset of leg weakness, unsteady gait, and blurred vision while preparing lunch. She remained alert and oriented. Vital signs were within normal limits, and glucose was 9.0 mmol/L. On examination by the ambulance nurse, weakness was inconsistent and did not follow an anatomical pattern. Symptoms fluctuated during the initial assessment. RACE scale was 0. Given the acute presentation and inability to rule out stroke, the ambulance professional decided to consult a vascular neurologist via telemedicine.

Fig. 1 Example of a simulated stroke-code scenario used to evaluate portable telemedicine devices during prehospital assessment

Each scenario was performed once with each portable telemedicine device, resulting in twelve simulation runs. To approximate real-world conditions, the scenarios were conducted across four settings: indoors with natural light; indoors with backlighting; indoors with background noise; and outdoors with natural light. These conditions reflected common operational challenges, such as variable lighting and noise. After completing the initial patient assessment according to the national stroke protocol [29], including FAST and evaluation of additional focal deficits, teleconsultation with the vascular neurologist at the hospital was prompted marking the start of each scenario.

Participants

Four ambulance teams participated, each comprising one ambulance driver and one on-scene clinician (ambulance nurse or physician assistant), reflecting routine practice. Three scenarios were conducted by ambulance nurses and one by a physician assistant. Each team was assigned to one scenario, with random scenario allocation. Each scenario was subsequently performed using all three devices, resulting in twelve simulation runs. The same ambulance driver remained constant within each team, while different ambulance nurse was assigned per scenario.

Teams were briefed by the research group on the study protocol, and provided with scenario scripts and predefined vital sign details. Device vendors delivered brief hands-on training sessions to ensure correct device use. Teams were instructed to follow standard assessment protocols. Ambulance nurses, trained only in standard neurological assessment, performed extended neurological examination under the remote guidance of the neurologist via teleconsultation. Vital signs, standard neurological assessment, blood glucose levels and Rapid Arterial Occlusion Evaluation (RACE) Scale were reported, replicating current telephone-based practice.

A vascular neurologist (N.D.K.) and a neurology resident (R.C.) performed remote assessments using either a computer or smartphone, receiving live video and audio streams through the device-specific telemedicine platforms. In each scenario, one neurologist led the consultation while the other observed. Two additional vascular neurologists from different hospitals (L.M.H.K.) and (E.L.L.M.S) independently reviewed the recorded footage. All neurologists were blinded to the scripted case details.

Technology

Three portable telemedicine devices were evaluated: two head-mounted assisted-reality devices (RealWear Navigator™ 520 (RealWear, Vancouver, WA), and Vuzix M400 (Vuzix Corporation, Rochester, NY)) and a smartphone device using the Siilo Messenger application (Amsterdam, NL) for video conferencing. Technical and operational characteristics are provided in Table 1.

Table 1 Technical specifications and operational characteristics of the three evaluated telemedicine devices

Feature	RealWear Navigator™ 520	Vuzix M400	Smartphone with Siilo Messenger app
Device type	Head-mounted assisted reality	Head-mounted assisted reality	Smartphone-based video app
Display	720p HD micro-display	OLED micro-display	Integrated smartphone display
Camera	48 MP; up to 1080p video; 6 × zoom; electronic image stabilisation	12.8 MP; up to 4 K video; no zoom; electronic image stabilisation	Typically 12–48 MP (device-dependent)
Audio	Noise-cancelling microphone; speaker	Noise-cancelling microphone; speaker	Integrated microphone & speaker
Control	Voice commands	Touchpad	Touchscreen
Battery life	~ 8 h (mixed use)	2–3 h (with video), extendable with external power pack	4–6 h video calling (device-dependent)
Connectivity	Wi-Fi, Bluetooth, tethered LTE/5G via hotspot or SIM-enabled modem	Wi-Fi, Bluetooth, LTE/5G via paired phone or SIM module	Wi-Fi; Native 4G/5G (SIM)
Weight	~ 270 g	~ 180 g	~ 170–200 g (device-dependent)
Portability	Head-mounted	Head-mounted	Handheld; requires manual handling
Patient visibility of specialist	No	No	Yes
Price	~ €3,500	~ €2,100	Free app (additional organisational contract available with secure environment)
Access	User account	User account	One Time check on valid CCPS registration before access is granted

CCPS Certificate of Current Professional Status

The selected devices were identified through a pragmatic selection process combining an exploratory market search and expert input. Portable telemedicine solutions currently available and accessible within the Dutch healthcare context were first identified, after which consultation with an extended reality (XR) specialist informed the inclusion of head-mounted assisted-reality devices as a distinct category with potential advantages for hands-free use in dynamic prehospital environments. The final selection was designed to represent two relevant implementation pathways: advanced head-mounted devices and a widely available smartphone-based application reflecting a low-threshold and scalable solution. This selection was further informed by existing prehospital telemedicine initiatives in other countries.

All three devices enabled real-time, two-way audio and video communication between ambulance professionals and a remote neurologist. The head-mounted devices allowed hands-free use, but differed in specifications: the RealWear offered a higher-resolution camera with optical zoom and longer battery life, while the Vuzix had an OLED display, was lighter, and more compact but had shorter operating time unless an external power pack was attached. The smartphone configuration relied on integrated cameras and handheld operation, but it uniquely enabled the patient to see and interact directly with the neurologist.

All video connections consisted of live, real-time video streams; no patient data were recorded or stored during the study. The smartphone operated via the Siilo application, the RealWear device via RealWear Collaborate built on Microsoft Teams infrastructure hosted on Microsoft Azure, and the Vuzix device via the Rods & Cones platform. All platforms supported encrypted video transmission and complied with GDPR requirements. The Siilo and Rods & Cones platforms, as well as the Microsoft Azure infrastructure, are ISO 27001 certified. Vascular neurologists accessed the video streams on hospital computers at Leiden University Medical Center.

Data collection

To assess feasibility, data were collected using a structured survey. Drawing on desired evaluation aspects and previously described surveys from similar pilot studies [9], seven evaluation criteria were selected: *audio quality, video quality, adjustability, connectivity, usability, clinical assessment support, and decision-making support*. These were rated on a 6-point Likert scale by both professional groups (1 = very poor, 6 = excellent). Usability was rated only by ambulance professionals, as they operated the devices during the simulations. Neurologists used the associated software platforms to receive the live video and audio streams, but did not handle the devices themselves. Two open-ended questions captured qualitative feedback and willingness to adopt the device in routine practice. The full survey is available in the supplementary materials. Responses were obtained for each of the three devices across all four scenarios and completed by two ambulance professionals and two neurologists after each scenario.

In addition, qualitative feedback was obtained from the professional actor through an open-ended discussion, regarding the experience and perceptions of each device, to inform the acceptability from a patient perspective.

Data analysis

Survey responses were analysed descriptively and integrated using Multi-Criteria Decision Analysis (MCDA), a structured method that aggregates performance across multiple evaluation criteria with different levels of importance [30–32]. Participants from each role group (ambulance professionals and neurologists) ranked the seven evaluation criteria by importance for real-world implementation. To reduce conceptual overlap [32], the criteria *connectivity* and *clinical assessment support* were excluded from the main analysis, as they closely relate to *audio/video quality* and *decision-making support*.

For each role group, mean ranks were calculated and combined with equal weighting to ensure balanced influence. These combined ranks were converted into criterion weights using the Rank Order Centroid (ROC) method, which distributes weight proportionally by rank order [33]. Performance scores for the five remaining criteria were normalised to a 0–1 range using min–max transformation. The ROC-derived weights were then applied to these normalised scores to generate overall value scores and a corresponding device rankings. Missing responses were handled using an available-case approach. In scenarios where the ambulance driver assisted rather than operated the device, some items were left blank and excluded from the analysis.

To explore potential differences between professional roles, subgroup analyses were performed separately for ambulance professionals and neurologists, applying ROC-derived weights based on each group's own ranking of the five independent criteria. Two sensitivity analyses were conducted to assess robustness of the overall rankings: (1) repeating the MCDA including all seven original criteria (i.e., reintroducing *connectivity* and *clinical assessment support*), and (2) re-running the MCDA using equal (unweighted) weights.

Open-ended survey responses and qualitative reflections from the professional actor were summarised descriptively to complement the quantitative results and provide insight into device usability and acceptability.

Results

Multi-criteria decision analysis

Criteria weighting, performance scores and overall value

A total of 47 completed surveys were analysed, comprising 24 responses from ambulance professionals and 23 from neurologists (one response missing). Criteria weights ranged from 0.04 to 0.46. *Decision-making support* received the highest weight and *adjustability* received the lowest weight.

Regarding performance, the Vuzix head-mounted device outperformed the RealWear head-mounted device and the Siilo Messenger application on a smartphone in three out of five criteria: *video quality*, *adjustability* and *decision-making support*. RealWear performed best in *audio quality*, and Siilo scored highest for *usability*.

Overall, Vuzix ranked highest with a score of 0.80, followed by Siilo with 0.77 and RealWear with 0.73. The results are summarised in Table 2.

Role-specific MCDA results

Role-specific analyses (Supplementary Tables S1 and S2) showed differences between groups. Both ranked *decision-making support* as most the important criterion. However, ambulance professionals assigned relatively greater weight to *usability*, whereas neurologists prioritised *video quality*. As usability was only assessed by ambulance professionals, this comparison is based on differences in criterion weighting rather than on direct comparison of usability scores between groups. Among ambulance professionals, the Siilo Messenger smartphone application ranked highest (0.83), followed by Vuzix (0.81) and RealWear (0.79). Among neurologists,

Table 2 MCDA table with normalised performance scores, criteria weights and overall value scores

	Normalised performance scores			Criteria weight	Scores x weight		
	RealWear	Vuzix	Siilo		RealWear	Vuzix	Siilo
Audio	0.78	0.70	0.74	0.09	0.07	0.06	0.07
Video	0.70	0.83	0.76	0.26	0.18	0.21	0.19
Adjustability	0.52	0.66	0.31	0.04	0.02	0.03	0.01
Usability	0.74	0.70	0.90	0.16	0.12	0.11	0.14
Decision-making	0.75	0.86	0.78	0.46	0.34	0.39	0.36
Overall value					0.73	0.80	0.77

RealWear is RealWear head-mounted device, Vuzix is Vuzix head-mounted device, and Siilo is Siilo Messenger application

Vuzix ranked highest (0.73), followed by Siilo (0.62) and RealWear (0.61).

Sensitivity analysis

Including all seven criteria (i.e., reintroducing *connectivity* and *clinical assessment support*) resulted in scores of 0.75 for RealWear, 0.82 for Vuzix and 0.76 for Siilo. Using equal weighting resulted in scores of 0.70 for RealWear, 0.75 for Vuzix and 0.70 for Siilo. Device rankings remained consistent across the analysis. Full details are provided in Supplementary Table S3 and S4.

Open-ended responses

Participants appreciated the hands-free operation of the head-mounted devices, which allowed them to keep both hands free for patient's assessment. Several respondents reported challenges with lighting conditions, particularly backlighting, and difficulty obtaining a wide-angle patient view, since neither device offered sufficient zoom-out capability.

The RealWear device was often criticised as less intuitive due to its voice-controlled interface, which required ambulance professionals to manage both patient assessment and device operation. In contrast, the Vuzix's remote camera control (zoom and lighting) by the neurologist was well received as it reduced the ambulance professional's operational burden. However, the Vuzix device required additional peripherals, such as Bluetooth speakers, to communicate directly with the patient. The RealWear device integrated loudspeaker allowed direct patient communication without additional equipment.

The Siilo Messenger application was described as familiar, intuitive and easy to deploy within existing workflows. Reported drawbacks included lower video quality, instability of the viewing angle, and limited options for adjusting zoom or lighting during assessments.

Patient perspective

The patient actor reported clear differences in perceived professionalism and engagement between devices. Both head-mounted devices appeared more professional and inspired confidence, yet created a sense of distance when the ambulance professional primarily interacted with the remote neurologist. Using the monocular Vuzix device, which required closing one eye, was described as "unnerving".

The RealWear device was preferred for maintaining eye contact, as its display did not obstruct vision. The smartphone felt more familiar and encouraged active patient participation, though it appeared less professional and more "makeshift".

Discussion

This pilot study compared three portable telemedicine devices for prehospital stroke triage using a structured MCDA complemented by qualitative feedback. Device feasibility proved to depend on the interplay between technical performance and user experience. Among the three devices, the Vuzix head-mounted device achieved the highest overall value score, driven by superior *video quality* and *decision-making support*, while the Siilo Messenger smartphone application was favoured for *usability* and integration into existing workflows.

Device suitability appeared context-dependent and shaped by professional role. Ambulance professionals emphasised *usability*, whereas neurologists placed greater weight on *video quality*. This reflects their different interactions with the technology. Neurologists, who do not operate the devices themselves, are mainly concerned with image clarity and stability, which directly affects their ability to assess patients remotely. Ambulance professionals must operate the devices in dynamic environments, while performing multiple tasks, making ease of use and minimal interference with patient care decisive factors.

These role-specific preferences underline that successful telemedicine implementation depends on combining reliable technical performance with seamless integration into existing workflows. Previous reviews on prehospital telemedicine, including telestroke applications, consistently highlight technical reliability and usability as important determinants of adoption [10, 27, 28, 34, 35]. The preference of ambulance professionals for a smartphone-based solutions aligns with earlier work showing that intuitive use and smooth workflow integration facilitate acceptance [27, 28], while neurologists' focus on video quality reflects prior telestroke findings that high-quality video enhances diagnostic confidence [10, 34]. However, while previous studies assessed feasibility or technical performance in isolation through heterogeneous, single-system evaluations, our study applied a standardised framework to systematically compare multiple device types.

This pilot study therefore advances existing evidence by integrating quantitative MCDA weighting with qualitative user feedback to capture both professional perspectives in a single analytical design. In contrast to previous reviews with heterogeneous methods and limited stakeholder input [10, 34], this approach provides a transparent way to explain why usability and image quality are prioritised, rather than merely confirming their importance. Moreover, including both ambulance professionals and neurologists from a European EMS system where video-based telemedicine is not yet implemented offers a pre-implementation perspective rarely represented in the telemedicine literature. These methodological and contextual contributions extend existing work from feasibility assessment toward understanding contextual fit, which is crucial for sustainable telemedicine implementation.

Strengths and limitations

A key strength of this study is its structured evaluation combining quantitative weighting with qualitative insights. The MCDA framework enabled the integration of multiple, user-defined evaluation criteria, while sensitivity and subgroup analyses enhanced robustness of findings. Including both professional and patient perspectives strengthened validity and provided a more comprehensive assessment of feasibility. Another strength is the deliberate focus on neurological scenarios, which represent one of the most demanding use cases for prehospital telemedicine. Accurate neurological assessment requires both high-resolution video for subtle visual cues and clear audio for evaluating speech. Demonstrating feasibility under such conditions provides a stringent and clinically relevant test of device performance.

Several limitations should be acknowledged. First, the small sample size and simulation-based setting may not fully capture the complexity and variability of real-world EMS operations, thereby reducing generalisability. Second, the ROC-based weights were derived from expert judgement rather than formal preference elicitation, introducing potential subjectivity. Third, although overlapping criteria were excluded to reduce redundancy, independence among remaining criteria may not hold entirely in practice. Finally, all devices were tested in a fixed sequence (RealWear, Siilo, then Vuzix) for logistical reasons, which could have introduced potential learning or familiarity effects. Ideally, testing would have been conducted on different days with alternating sequences, but this was not feasible within the constraints of a single simulation session.

Implications for practice

Successful implementation of prehospital telemedicine requires close alignment between device features and the distinct needs of different user groups. Accordingly, no single device can be considered universally optimal, and implementation strategies should be tailored to operational context to ensure adoption.

Early implementation of prehospital telemedicine could start with smartphone-based applications, as their usability, familiarity and non-threatening nature for the patient enable rapid adoption with minimal training or infrastructural change. Collaboration with developers should focus on improving video quality and stability to optimise performance in prehospital environments. Where hands-free operation or superior video quality is essential, head-mounted devices may be considered as complementary options, allowing device choice to depend on situational needs. When selecting telemedicine devices, health systems should also consider practical factors including interoperability with existing IT infrastructure, data security, training requirements and patient acceptability.

Although this study focused on patients with a suspicion of stroke, we feel that the findings are transferable to other prehospital conditions where remote specialist consultation could improve triage, such as unspecified complaints, paediatric emergencies, trauma, or geriatric care. This phased and adaptive approach provides a pragmatic pathway for scaling up telemedicine across patient groups while retaining flexibility for technological refinement.

Within the SMART Triage programme, these results will inform further development and phased implementation of a digital triage platform that aims to embed teleconsultation into prehospital decision-making. More broadly, they may support the design of scalable, interoperable telemedicine solutions for other EMS regions and acute care networks.

However, these findings should be interpreted as an early step in the development process rather than a basis for immediate large-scale implementation. Successful integration of prehospital telemedicine depends on alignment across technical, organisational, financial, and regulatory domains. Evidence from systematic and scoping reviews consistently shows that robust IT infrastructure, interoperability with existing systems, workforce training, governance structures, and sustainable reimbursement models are critical preconditions for successful implementation and long-term adoption [26, 28, 35].

Conclusion

This pilot study identified the currently most feasible portable telemedicine device for prehospital triage through structured, scenario-based evaluation. The smartphone-based video application emerged as a practical and readily deployable solution compatible with existing workflows, while head-mounted devices remain promising for scenarios requiring hands-free operation or enhanced video quality. Future research should evaluate these technologies in real-world conditions and incorporate health economic analysis to evaluate their clinical, operational, and financial impact, as well as user and patient satisfaction. Broader evaluation of scalability and system-level integration will be essential to ensure sustainable adoption of telemedicine across acute care networks.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

SLK conceived the study, coordinated data collection, analysed the data, and drafted the manuscript. RC, JB, and ST contributed to study design. RC, NDK, MD, MV, LMHK, and ELLMS participated in data collection and assessment activities. GG supervised the study and contributed to data interpretation. All authors reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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Data availability

Data underlying this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study did not fall within the scope of the Dutch Medical Research Involving Human Subjects Act (WMO). Therefore, formal approval by a medical ethics committee was not required. All participating professionals provided informed consent to take part in the simulation and data collection.

Consent for publication

Not applicable. No patient data were collected.

Competing interests

The authors declare no competing interests.

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