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Optimizing Real-Time Advanced Ultrasound Supervision in a University Setting: A technical feasibility study

N. Hanger*[1], L. Johnsen[1,2], R. Stoklund Thomsen[1,3], R. Stalsberg[1]

[1]Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, Trondheim, Norway

[2]Department of Vascular Surgery, Haukeland University Hospital, Bergen, Norway

[3]Department of Rheumatology, St. Olavs Hospital, Trondheim, Norway

*Corresponding author e-mail address: nina.hanger@ntnu.no

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Abstract

Introduction: Ultrasound-based diagnosis requires great expertise for reliability and accuracy, thus practical training is vital. Digital training can offer students the possibility of practical training in their local setups. However, there are critical issues that remote educators must address, particularly in advanced ultrasound training. The present study was therefore aiming at developing a suitable technical setup for supervision and education in tele-ultrasound that can be applied to a variety of advanced diagnostic and therapeutic areas.

Methods: Using an action research approach including four cycles of action, we tested four technical setups with different software and hardware components across four ultrasound courses. Based on evaluation forms, written reflections, and two focus group interviews from the four cycles of action, respectively, we modified the setups to improve the technical solution for the next cycle.

Results: The initial set-up was using commercial video call apps via mobile phones. Although no additional equipment or expertise was required, it was precluded by the poor image quality and motion blur resulting from capturing the ultrasound image on the smartphone. Nevertheless, this solution is viable when quick clarifications are needed. Additional stabilization support in the second set-up did not provide satisfactory image quality. The best technical solution was found in the third set-up, using a frame grabber and Reacts, which allows simultaneous live streaming of the ultrasound screen image and two web cameras. However, the cumbersome software interface, the need for an expensive user license, and problems with the internet connection reduced the acceptability of this setup. The optimal setup in cycle four, was a reasonable frame grabber, and Zoom, which is free, has a simple user interface and can stream live audio-visual ultrasound data from the probe and user simultaneously. Its annotation function is also beneficial in supervision.

Conclusion: Through an action research approach including four cycles of action and thorough, subsequent evaluations, we found that a videoconferencing platform, such as Zoom, a computer, and a frame grabber connected to the ultrasound scanner was the optimal solution as this set-up is simple and affordable and is facilitating a good video-transmitted learning situation for students and supervisors. This technical set-up could therefore be suitable for a wide range of remote ultrasound courses.

Introduction

The World Health Organization (WHO) has recognized ultrasound as one of the foremost technologies of health services [1] which allows real-time meticulous tissue imaging while being portable, easily accessible, cost-effective, and without harmful ionizing radiation. The modality is highly operator dependent and requires experience and skill to ensure high-quality examination, image capturing, and interpretation [2]. Therefore, comprehensive training of a diagnostic medical sonographer is essential. Education and accreditation for sonographers vary between countries. In this study, the term 'sonographer' refers to a health professional trained to perform ultrasound exams regardless of speciality. Experience has shown that healthcare professionals applying for ultrasound courses in Norwegian universities are typically young and full-time employees with additional domestic duties, which may hinder their ability to attend university classes. Furthermore, only a limited number of institutions in Norway offers such ultrasound courses of sufficient quality, and travelling distances may be an additional barrier for sonography candidates [1]. In this regard, digital training and supervision, digital diagnostics, and reporting in the form of tele-radiology, may be a practical and useful solution.

Digital training can offer students the possibility of practical training in their local setups on their own patients using familiar ultrasound equipment, in addition to minimising travelling expenditure and the need to take leave of absence from their full-time employment and family. However, there are critical issues that remote educators must address. A major challenge in sonography training is demonstrating the dual task of manoeuvring the transducer in response to sensory stimuli from images, often referred to as psychomotor skills in ultrasonography [3]. These skills are described as ‘open’ because they involve many variations that are incurred from a core component each time the skill is executed [4-6], due to a number of patient- and sonographer-related factors, such as bodily habitus, organ orientation and position, pathology, and vascular haemodynamic [3]. In such scenarios, a sonographer’s skill set becomes extremely complex, as it involves the necessary skills of sliding, tilting, rotating, and fanning the transducer through a structure to achieve adequate visualization. Therefore, providing high-quality training of these visuomotor and visuospatial skills [3] without being physically present requires a technical setup that is feasible, accessible, and easy to use to enable the high-quality transfer of non-static ultrasound images and allow face-to-face conversation and immediate feedback. Additionally, a video display is essential for the instructor to observe the students' probe positioning and knob handling and their posture towards their patients. Furthermore, it is imperative that the involved personnel uphold respect for patient security and the right to confidentiality throughout these learning situations.

Previous studies have reported that tele-ultrasound is a viable option for both training and remote diagnosis [1, 7-11]. It was found to be comparable [7] or at least sufficiently efficient [11] to conventional teaching. However, most of these studies were conducted within a point-of-care ultrasound (POCUS) setting. POCUS is a widely used rapid diagnostic tool for multiple medical conditions, such as acute appendicitis, airway comprise, abdominal aortic aneurysm, and traumatic injury assessment [4]. In a POCUS setting, ultrasound can offer simple clarifications even with limited training, such as "is the heart beating?", or "is free fluid present in the abdomen?". In the area of more advanced ultrasound examinations such as echocardiography, vascular ultrasound, ultrasound of dialysis fistulas, and musculoskeletal ultrasound the protocols are far more technically advanced, and the image acquisition is more complex as modalities such as doppler modes are used in addition to multiple detailed measurements. Therefore, the present study aimed to develop a suitable technical setup for supervision and education in tele-ultrasound that can be applied to a variety of advanced diagnostic and therapeutic areas. We strive to establish a competent technical solution for bidirectional live sharing of real-time audio, ultrasound images, and probe orientation, as well as to provide remote supervision while performing sonography using digital communication platforms.

Materials and methods

We adopted the action research approach [12], which seeks to generate knowledge or change practice by direct involvement of the concerned actors. It is a cyclical, repetitive process of enquiry that includes gathering and analysing information and taking action [13]. This study involved lecturers and professors with experience in educational planning, teaching, and supervising students in various fields of advanced medical ultrasound. All supervisors had >10 years of clinical experience in ultrasonography, 4-10 years of experience in ultrasound student training, but no experience with tele-ultrasound and video supervision. In addition, we included 4-10 students enrolled in four different ultrasound continuing education programmes in a Norwegian university setting (2019-2022). The students had at least a health-related bachelor's degree, some professional experience and full-time employment alongside the courses. They were required to have regular access to ultrasound apparatus.

The research process moved through four cycles of action (A–D) and included testing several hardware and software for educational use in four different ultrasound continuing education programmes with durations of 1–3 semesters. Each cycle of action includes four phases: a plan, the action taken, subsequent evaluations, and continuous reflections (Fig. 1). Although there was a principal research plan for finding a suitable technical setup, the specific action plans for each cycle were based on the evaluations of the previous. **Cycle A** included the *action* of using Skype (Microsoft, Skype Technologies) for videoconferences on the participants' smartphones via a wireless hospital network or 4G mobile network. The test-out was conducted as an exam situation in a cardiovascular ultrasound course, including ten students (nine nurses and one radiographer). **Cycle B** was conducted in a vascular ultrasound course wherein the *action* involved all the four students in a vascular ultrasound course (three nurses and one radiographer) using their personal smartphones and either the FaceTime app (Apple Inc.) or the Facebook Messenger app (Meta Platforms) in individual supervision settings. All participants (students and supervisors) used their own 4G mobile networks. In **cycle C,** a more advanced technical setup was tested in a dialysis fistula ultrasound course with four students (nurses).

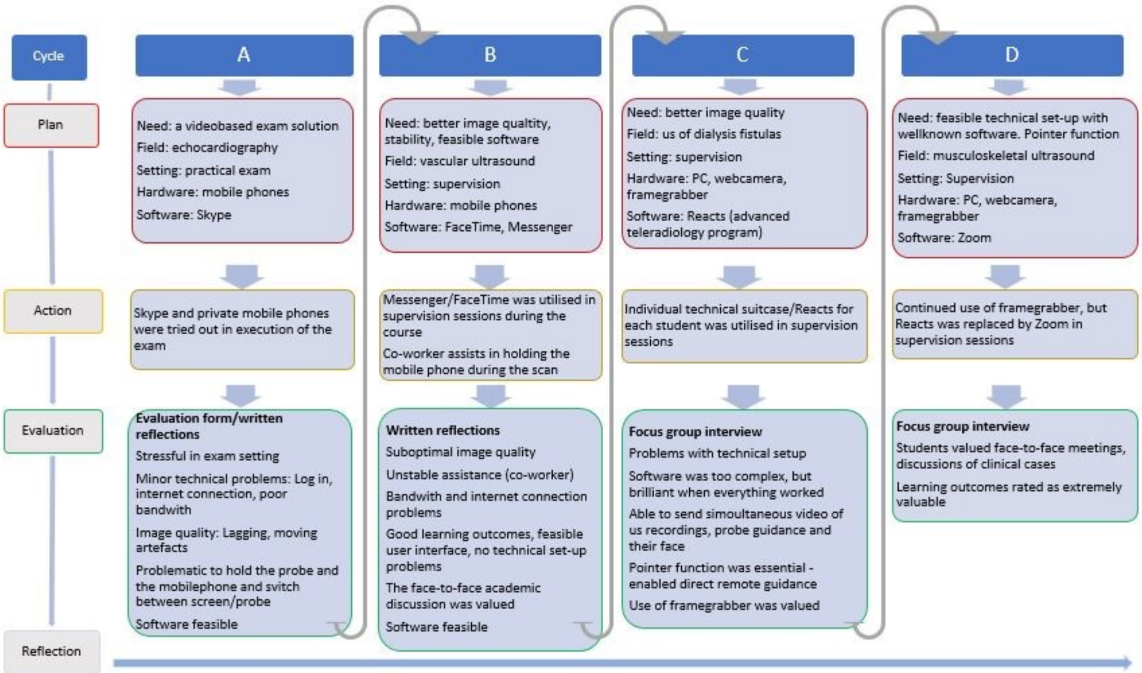

Figure 1. Conceptual framework of action research, aligned with snapshots of events that occurred during the four cycles in our study.

The main components were a frame-grabber (Epiphan DVI2USB 3.0) and the Reacts platform (Philips & Innovative Imaging Technologies) (Fig. 2). Reacts is a collaborative software platform that enables secure communication and interaction in health care – it allows simultaneous visualization of up to five counterparts, multiple cameras, and live video streams. Each student received a prepared portable suitcase that included a camera tripod, the frame-grabber, the necessary cables and adapters for connecting the student's personal ultrasound device, and a user manual.

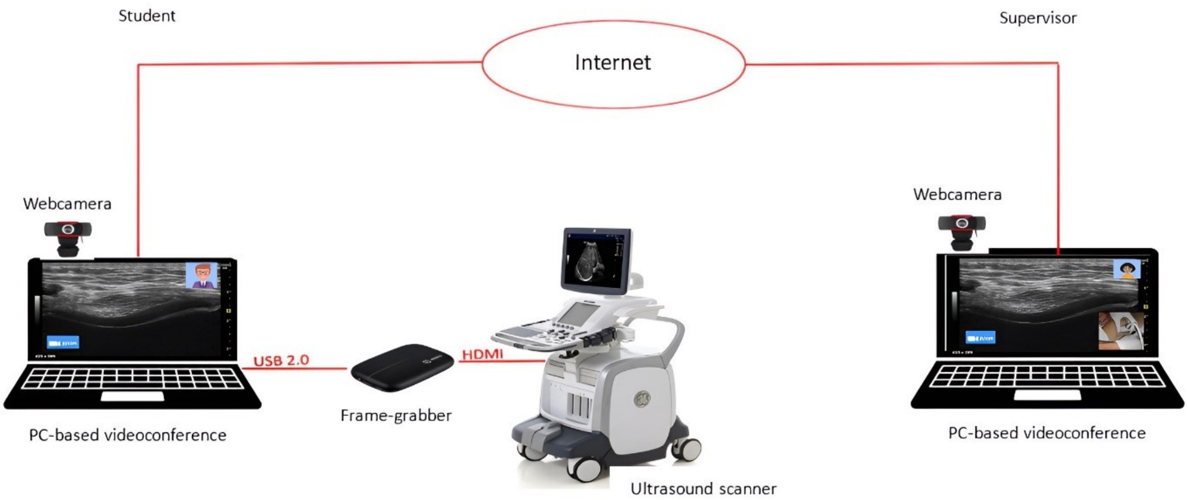

Figure 2. The technical setup in cycle C

The setting for **cycle D** was a musculoskeletal ultrasound course, where the Zoom (Zoom Video Communications, Inc) video-conference app was used for live video sharing along with the Epiphan frame-grabber hardware. Because the students in each cycle used diverse types of probes and scanners, depending on what was available at their workplace, it was a significant point that all kinds of ultrasound equipment were connectable to the videoconferencing equipment.

In total, 12 students participated in this course (3 physical therapists, 3 manual therapists and 6 chiropractors). The entire study included 6 supervisors in total: two in cycle A, one in cycle B, one in cycle C, and two in cycle D.

Each action was followed by an *evaluation*, which was used to adapt the subsequent technical setup. Apart from an evaluation form and all the supervisors' written reflections summarized after cycles A and B, two digital focus group interviews were conducted by two of the researchers for with a voluntary selection of four and three students after cycles C and D, respectively. To this end, an interview guide was prepared, and the students were encouraged to discuss their experiences with the technical setups and the supervised training. Each interview lasted approximately 1 hour and was transcribed and analysed employing the systematic text condensation approach [14] to identify themes of relevant feedback. To ensure the reliability of the results, all researchers jointly discussed all interpretations. More details of the data and analyses used for evaluation in each cycle of action are shown along the results in Table 1.

Continuous reflection

During the evaluations, all supervisors and lecturers produced written reflections about their experiences after a new technical setup was tested. These notes were discussed in research group meetings. The dialogue between the involved partners following each action cycle was used as the foundation and motivation for the next action-evaluation-reflection cycle (Fig. 1).

Ethical considerations
The study falls outside the scope of 'medical and health research', hence exempted from formal ethical approval following guidelines from the Ethical Committee for Medical and Health Research. The study protocol was approved by the National Centre for Research Data. The participants were provided written information about the study, which clearly stated that participation was voluntary, and they could withdraw from the study at any time. Those agreeing to participate provided written informed consent.

No metadata revealing patient identification was recorded or transmitted during the tele-ultrasound, so no formal consent from patients was necessary according to national legislation. Nevertheless, the patients examined during tele-ultrasound supervision and examination were informed before the session, and oral consent was obtained prior to conducting the examination. Only video frames without any metadata were transferred through the display port on the ultrasound scanner. As long as no patient ID (name, birth date, etc.) is displayed on the screen, no patient data is transferred.

Results

Skype in an exam setting: Technical problems and suboptimal image quality
Ten students completed the practical exam via Skype in cycle A (spring 2019). None of them were familiar with Skype prior to the exam; thus, training sessions, starting from logging in to using Skype, were provided one month ahead of the exam to overcome potential technical problems.

The students' evaluation revealed minor technical problems with the login, internet connection, and/or –speed, but no serious issues were reported. After the exam, one student reported that the stress from technical problems negatively affected his performance. Examiners' evaluation indicated that using Skype in an exam setting was feasible, despite suboptimal image quality due to lagging caused by poor bandwidth or internet connection. Additionally, the students reported difficulties holding their mobile phone steady during scanning, which was consistent with examiners reporting moving artefacts during the scan.

Messenger/FaceTime in supervision: Unstable assistance and suboptimal image quality
The evaluations of cycle A revealed that testing new technical solutions in an exam setting was inappropriate; accordingly, the actions in cycles B–D were carried out as supervisory sessions conducted throughout the semester. Based on the evaluations from cycle A, we allowed students to use a freely available and familiar app, Messenger or FaceTime, on their own smartphone. Additionally, the students were offered assistance from a co-worker for holding the mobile phone steady while scanning.

Four students completed tele-ultrasound supervision in this cycle (fall 2019). The subsequent evaluation showed very good learning outcomes and a feasible user interface;

there were no problems due to the technical setup. However, the suboptimal image quality of the ultrasound image was still a challenge, which was further aggravated when using colour Doppler and/or pulsed-wave Doppler. The supervisors reported distortions in colours in the colour Doppler mode and loss of detail in the spectral curves. The poor image quality was not caused by the limited resolution of the mobile camera, but rather due to light reflection from the ultrasound screen and the above-mentioned colour distortion.

Advanced teleradiology setup in supervision: Essential utilities but complex setup
Based on the experiences from cycle B, a more stable and stationary technical setup was prepared. During the Covid-19 pandemic lockdown (March 2020 and onward), we decided to try videoconferencing to overcome the problem of artefacts arising from a moving video source. After consulting experts in the field of teleradiology, we approved the use of a frame-grabber with Reacts, which is an advanced teleradiology programme with options for bidirectional audio/video communication and interactions, such as annotations in the ultrasound image, real-time ultrasound image transfer, and video showing probe movement. We created user manuals and completed multiple tests of the equipment and software.

To use the Reacts software, each supervisor required an individual licence (USD 120/year), and each user had to create a user account (free of charge). The supervisor had to manage an appointment manager to invite new users to their community, and then set up digital meetings that could invite up to five users. To receive invitations, the participants had to be on the supervisor’s contact list.

The Reacts software has a split screen solution for bidirectional sharing of ultrasound images and two video channels – one was assigned to the integrated web camera in the student’s computer and one to the tripod web-camera. This allowed the three students to transmit live both the ultrasound image and a video of their face, as well as their hand moving the probe.

Both students and supervisors perceived the Reacts’ user interface for preparing and performing these meetings as being too complex, although it was a fantastic tool when it worked.

The fact that they were able to share live videos of the ultrasound recording, probe guidance, and their faces simultaneously was highly valued by both students and supervisors. However, the most important experience from cycle C was that both the supervisor and the students had the opportunity to use a marker and point in the transmitted ultrasound image. This two-way remote annotation enabled direct guidance by pointing to the desired area in the ultrasound image and was emphasized as particularly useful.

Zoom in supervision: A simple technical setup offered the essential utilities
The evaluations from cycles B and C emphasised the value of using a rather simple technical setup, preferably a commonly used software. The transmission of ultrasound images on the supervisor's screen and the pointing function (marker) were highlighted as essential by both supervisors and students.

At this point in time (fall 2020), the digital consequences of the Covid-19 pandemic familiarised everyone with videoconferencing. After looking for software that offered the possibility of digital annotations, we found that the Zoom application provided pointer functionality. Hence, in cycle D, the use of a frame-grabber was continued, but the Reacts software was replaced by using Zoom on computer.

The three students out of 12 in total, who completed the evaluative focus group interview appreciated the face-to-face meeting with the supervisor via Zoom and the opportunity to discuss clinical cases. They also regarded the learning outcome of the tele-supervision intervention as extremely valuable, using words such as "encouraging" and "motivating". In cycle D, no problems due to the technical setup, bandwidth limitations, or poor image quality due to moving artefacts or colour distortions were reported. Table 1 elaborates and clarifies details in the methods, analyses, and results in the four cycles.

Table 1 Settings, methods of data acquisition, analyses, and main results from the four cycles of action.

Cycle	**Settings, methods, informants, and analyses**	**Thematized results, including descriptive quotes**
A	**Setting**: final practical exam (45 min/stud). Testing of the software was conducted twice before the exam. Whichever probe and scanner type the students operated at their workplaces. **Method:** evaluation form/written reflections at the end of the course: Open ended reflections on topics considered important. **Informants:** nine nurses and 1 radiographer in the 2nd year of a two-year continuing education program in echocardiography. **Analysis:** simple systematic text condensation (STC).	**Image quality:** Students: 3 out of 10 reported poor image quality. Supervisors: Both reported inadequate image quality for detailed assessment due to motion and poor colour Doppler rendering: *"The image quality was suboptimal but still usable in our situation (COVID-19) with few other alternatives"* (supervisor) **Experience with the technical setup:** One student experienced some technical problems due to the Wi-Fi connection and felt that the stress affected his performance on the exam. **Anonymization of patient data**: Both supervisors and students reported that patient anonymity was maintained in accordance with current regulations. The patients' names were never disclosed or mentioned, and their faces was not filmed.
B	**Setting:** mid-term supervision. One 60 min session/student. One-to-one student and supervisor. No testing in advance. Whichever probe and scanner type the students operated at their workplaces. **Method:** written reflections from students and supervisor after the session. Students reflected on technical quality of the video session,	**Technical issues:** One minor issue with the mobile network caused low video frame rates at times. A high-speed Wi-Fi connection might improve this. **Moving artefacts and suboptimal image quality:** Students struggled with handling the phone video recording and the ultrasound session simultaneously. Video (region of interest or screen) to be recorded came out of focus. The pausing of video recording when the student had to put down the phone made the session "stuttering". Suboptimal rendering of the

	assessed learning outcomes, and suggested improvements. The supervisor wrote a report from each of the video sessions focusing on the same subjects as the students did. **Informants:** three nurses and 1 radiographer in the 2nd year of a two-year continuing education program in vascular ultrasound. **Analysis:** STC	ultrasound screen due to reflections of light in the room. Suggestions: Use a helper to handle the phone, or a selfie-stick or other devices for placement of the phone. The idea of a head-mounted camera was also launched. **Learning outcome:** Supervisor: Despite technical challenges; gained a clear impression of each student's skill development and professional level. Valuable to observe students in their own clinical environment; found students more relaxed, enhancing performance. Students: Found teacher interaction encouraging and inspiring. Valued academic discussions and face-to-face video interaction as highlights of the supervision session
C	**Setting:** Two mid-term supervisions of 60 minutes. Groupwise (three students and two supervisors in the same session). Whichever probe and scanner type the students operated at their workplaces. **Method:** Focus group interview at the end of the semester Discussion points: Advantages/ disadvantages and prior experience with video guidance, technical quality and challenges, learning outcomes, suggestions for improvements, flexibility, videoconferencing vs. hands-on, managing video and ultrasound-recording simultaneously. **Informants:** Three nurses attending the course Ultrasound of dialysis fistulas (15 ECTs) during the COVID-19 pandemia **Analysis:** STC	**The software and technical set-up:** students reported having little knowledge of data usage in general, making the technical setup especially challenging. Both students and instructors felt that technical problems overshadowed the potential academic benefits of the mentoring sessions. Both considered Reacts to be an excellent tool when it actually worked. The image quality was assessed as good. *"The pointer is an essential feature, plus being able to see the ultrasound image and hand/probe movement simultaneously."* (supervisor) **Learning outcome:** The supervision itself was considered very useful. *'You get more one-on-one time with the instructor than when you are at school.' 'Sometimes you feel alone—there's no one to ask. No one else in the department knows ultrasound.'* The students reported that having their own clinic, familiar surroundings, personal equipment, and own patients, provided security, calmness, and less stress.
D	**Setting:** Three supervisions/student during one semester. Groupwise (one supervisor and 2-3 students in each session). 60 minutes/session. Testing of software and frame grabber in advance on campus. Whichever probe and scanner type the students operated at their workplaces. **Method:** Focus group interview the following semester. The same discussion points as in cycle C **Informants:** 6 chiropractors, 3 manual therapists and 3 physiotherapists in the 1st year of a two-year continuing education program in musculoskeletal ultrasound **Analysis:** STC	**Technical setup and software:** Some experience with videoconferencing during the pandemia. Neither supervisors nor students reported issues with connectivity/technical challenges or image quality. *"I must admit I was simultaneously excited and stressed about online guidance. However, it went very well."* (student) **Learning outcome:** Students valued face-to-face meetings. Discussion of clinical cases was reported as "*extremely valuable*". *"It's fantastic to discuss the clinical challenges we encounter. Guidance is important to me because I receive confirmation of what I'm doing well and explanations and advice on how to better acquire and improve the images I take"* (student) *"I also see the advantage of online guidance in that we got to practice on our own ultrasound machines that we will be using going forward. It helps us become more familiar with our own machines"*

Discussion

This study applied an action research approach of four cycles to find a proper method for advanced diagnostic tele-ultrasound supervision and education conducted in a university setting. We found that using Zoom video conference software with annotation functionality in combination with a frame-grabber was the best solution.

Owing to the need for advanced psychomotor skills required in diagnostic ultrasonography, proper supervised training is crucial [4]. A survey found that 56% of European ultrasound education providers included hands-on training in the curriculum [15]. Reasons for this lack of supervised training may include the time-consuming nature of such supervision and the need for extensive facilitation. Consequently, tele-ultrasound has been suggested as a potential tool for both training and remote diagnostics, particularly in POCUS [1, 7-11].

Our study showed that the easiest setup was using smartphones and commercially available videoconference applications as a low-cost method for such supervision, regardless of manufacturer and ultrasound system. However, the students reported considerable motion blur and suboptimal image quality when using a smartphone. Nevertheless, it can be a useful and simple tool for quick consultation in cases that need clarification or a second opinion. Other studies using smartphones were conducted in POCUS settings using ultrasound to answer dichotomous diagnostic questions regarding substantial pathology or in an emergency setting. In our study, students used FaceTime for digital supervision in far more complex and detailed vascular examinations involving the use of advanced Doppler measurements and analyses. These conditions necessitate a clear transmission of high-quality images involving the complex colour spectrum and the pulsed wave Doppler spectrum (in addition to the B-mode). The complexity of the ultrasound images used in our study compared to POCUS may explain the disparity between our results and those of previous studies using FaceTime.

A potential practical challenge regarding the use of smartphones and social media applications may be internet firewalls maintained to restrict staff from using social media in a hospital setting [4]. Another potential problem regarding the General Data Protection Regulation GDPR relates to third-party issues. The fact that regulations regarding telemedicine in Norway remain unclear in some areas [16] has not been addressed in the present study.

However, it is essential to emphasize that using such 'basic' software is not an adequate solution for clinical use involving the transfer of patient data. In such cases, video conferencing equipment specialized for health care services, including secure data encryption, would be required in transmitting health data.

Data transmission within tele-ultrasound is often categorized as store-and-forward or real-time [1]. A previous study stated that less than 50% of tele-ultrasound transmissions were done using the real-time method [17]. While real-time transmission offers the advantage of immediate feedback during supervision and guidance, the availability of sufficient internet bandwidth and connection and affordable software may preclude the use of this method [1]. However, the recent boost in both the speed and spread of broadband networks facilitates the use of real-time tele-ultrasound [18].

An audio-visual frame-grabber enables transmission of real-time ultrasound images with high quality without causing movement artefacts and colour distortion, as it will present the exact colour scale. The frame-grabber is a cheap and simple hardware device for direct streaming of screen sources (commonly used by gamers) that connects the ultrasound scanner to a computer. Combining the frame-grabber with a reasonably fast internet connection and a computer with suitable software allows a high-quality face-to-face video meeting with a tele-ultrasound supervisor. Such a setting allows simultaneous mirroring of the ultrasound image on the supervisor’s screen. Having access to richer information streams, such as real-time video of the ultrasound image, the patient, and the sonographer’s hand moving the probe, allows the supervisor to diligently guide the student, thereby improving the quality of the supervision. Similar benefits have been found in other studies [4]. Soni et al. mentioned several advantages of hands-on training via tele-ultrasound, such as personalized teaching, flexible scheduling of sessions, and the opportunity to troubleshoot scanning without faculty physically intervening [19]. These experiences were confirmed in the present study.

Most setups used for tele supervision are more advanced and involve more than just a simple smartphone; often, these setups include extra cameras, laptops, and more advanced equipment [20, 21]. A study using Reacts in a POCUS setting did not address technical issues using the platform [7]; however, another study using Reacts reported that this kind of software can experience glitches [19]. Results from our cycle C action demonstrated that satisfactory quality ultrasound images can be streamed via Reacts using a low-cost frame-grabber, resulting in agreeable outcomes; thus, advanced software or additional expensive hardware may not be required.

Cost is a relevant socio-economic concern regarding tele-ultrasound. To make this technology feasible, a special emphasis on affordable tele-ultrasound platforms is important. Wireless networks and smartphone access have become more prevalent, and most communication companies, such as Apple and Microsoft, provide commercially available real-time audio-visual transmission software in compliance with patient protection laws, such as the Health Insurance Portability and Accountability Act in the USA, making tele-ultrasound a feasible proposition [22]. Previous studies mainly focus on the patient’s perspective and the cost-effectiveness of tele-ultrasound regarding minimal time and travelling costs, especially in rural regions. Our technical setup used in cycle D is low-cost, commercially available, and feasible in a setting of remote digital education and supervision. By adding a frame-grabber, more advanced ultrasound scans, such as cardiovascular exams, can be suited for tele-ultrasound supervision. It may also be introduced in a clinical setting, especially where there is a need for expert guidance or second opinions, thus yielding socio-economic gains.

Strengths and limitations

This study involved only a small group of students; hence, the evaluations may not be representative of all users. However, the study encompassed four different ultrasound courses for three years (2019-2022). In addition, the fact that we tested different solutions across multiple courses increased the external validity of our results.

The digital focus group interviews were conducted via Zoom, which may have affected the experiences of the participating students. Speaking up through a screen is strenuous, and requires a different communicative arrangement compared to physical encounters. However, as the input from the focus groups concurred with the students' informal statements, they were considered reliable.

The applicability of our experience is encouraging. The setup using Zoom in combination with the frame grabber is simple and affordable. Furthermore, the user interface is intuitive and thus feasible in the settings of supervision and education. We plan to replicate the setup for future courses at our university. In addition, the setup may demonstrate external validity as it can be useful in other educational environments, such as those requiring training in psychomotor skills. There are no limitations regarding manufacturer and ultrasound system. The method may also be applied in remote regions by less experienced sonographers without a supervisor, as well as by clinicians who are inclined towards trying out newer technology to gain further supervision and second opinions.

A systematic review pointed out the limited evidence of this fairly new tele-sonography field of medical education [22]. Further research is needed with an emphasis on student satisfaction to compare the efficacy of tele-ultrasound supervision with conventional teaching. Although beforementioned literature have shown that there is extensive evidence for the use of tele-ultrasound, most examinations in those studies only used B-mode. There is a paucity of literature using real-time tele-ultrasound for triplex images (B-mode, colour Doppler, and pulsed wave Doppler), which is far more complex. Additional research on using tele-ultrasound in triplex examinations is warranted in the fields of cardiovascular, vascular, and advanced obstetric ultrasound.

Conclusion

A smartphone in combination with a commonly used commercially available app is the simplest tool for tele-ultrasound and can be suitable for clarifying simple or limited clinical issues that do not require the use of Doppler. For more complex problems where several modalities are needed, better image quality is required; in such scenarios, a frame-grabber is a suitable tool for direct streaming of the ultrasound image.

For educational training and supervision, a video conferencing tool with direct two-way communication and annotation functionality enables all participating parties to communicate and discuss the same image. The present action research shows that using a frame grabber and the commercially available Zoom platform is a feasible setup for teaching and supervising in ultrasound for a variety of diagnostic ultrasound areas, owing to its simple user interface and low cost.

Declarations

Ethics approval and consent to participate

This study was approved by [nationality] Centre for Research Data ([nationality]no. 355360).

The study falls outside the scope of 'medical and health research', hence exempted from formal ethical approval following guidelines from the Ethical Committee for Medical and Health Research. The study protocol was approved by the National Centre for Research Data. The participants were provided written information about the study, which clearly stated that participation was voluntary, and they could withdraw from the study at any time. Those agreeing to participate provided written informed consent. The patients examined during tele-ultrasound supervision and examination were informed before the session, and their consent was sought before conducting the examination. No metadata revealing patient identification was recorded or transmitted during tele-ultrasound, as the video stream displayed only the screen output.

Availability of data and materials

The datasets generated and analysed during the current stud are not publicly available but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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