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Point-of-Care Ultrasound in Aus- und Weiterbildung in der Frauenheilkunde

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Die folgenden aufgelisteten Orginalarbeiten und Reviews liegen der kumulativen Habilitationsschrift zu Grunde, welche die wesentlichen Ergebnisse der Publikationen zusammenfasst und diskutiert:

- Recker F*, Barth G*, Lo H, Haverkamp N, Nürnberg D, Kravchenko D, Raupach T, Schäfer VS. Students' perspectives on curricular ultrasound education at German medical schools. Front Med (Lausanne). 2021 Nov 25;8:758255. doi: 10.3389/fmed.2021.758255. PMID: 34901071; PMCID: PMC8655332.
- Dietrich CF, Hoffmann B, Abramowicz J, Badea R, Braden B, Cantisani V, Chammas MC, Cui XW, Dong Y, Gilja OH, Hari R, Nisenbaum H, Nicholls D, Nolsøe CP, Nürnberg D, Prosch H, Radzina M, Recker F, Sachs A, Saftoiu A, Serra A, Sweet L, Vinayak S, Westerway S, Chou YH, Blaivas M. Medical student ultrasound education: A WFUMB position paper, Part I. Ultrasound Med Biol. 2019 Feb;45(2):271-281. doi: 10.1016/j.ultrasmedbio.2018.09.017. Epub 2018 Nov 27. PMID: 30497768
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- Grobelski J*, Recker F*, Wilsmann-Theis D, Hartung W, Karakostas P, Brossart P, Schäfer VS. Establishment and validation of a didactic musculoskeletal ultrasound course for dermatologists using an innovative handheld ultrasound system - the MUDE study (Musculoskeletal Ultrasound in Dermatology). J Dtsch Dermatol Ges. 2021 Dec;19(12):1753-1759. doi: 10.1111/ddg.14614.
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Abkürzungsverzeichnis

ACGME	Accreditation Council for Graduate Medical Education
AIUM	American Institute for Ultrasound in Medicine
DEGUM	Deutsche Gesellschaft für Ultraschall in der Medizin
EBCOG	European Board & College of Obstetrics and Gynecology
EFSUMB	European Federation of Societies for Ultrasound in Medicine and Biology
ISOUG	International Society of Ultrasound in Obstetrics and Gynecology
MSUS	Musculosceletal Ultrasound
OBGYN	Obstetrics and Gynecology
ÖGUM	Österreichische Gesellschaft für Ultraschall in der Medizin
OSCE	Objective Structured Clinical Examination
POC-US	Point-of-Care-Ultrasound
SGUM	Schweizerische Gesellschaft für Ultraschall in der Medizin
US	Ultraschall
USMed	Ultrasound Medical Education
WFUMB	World Federation of Societies for Ultrasound in Medicine and Biology

Einleitung

Point-of-Care-Ultraschall: Definition und Applikation in der Frauenheilkunde

Point-of Care Ultraschall (POC-US) gilt als neue Untersuchungsmethode in der klinischen Diagnostik, bei der Ultraschall zum Patienten gebracht und als Erweiterung der körperlichen Untersuchung angesehen wird. So können Echtzeitsonogramme überall sofort mit den Patientensymptomen korreliert werden. Auch Veränderungen eines (zeitkritischen) Patientenzustandes lassen sich mit diesem Vorgehen schnell erkennen. Zudem können zeitnah Therapieverläufe und -ergebnisse situativ und in ihrer Dynamik beobachtet werden. Dabei wird POC-US von verschiedenen Fachrichtungen in unterschiedlichen Situationen eingesetzt, kann jedoch grundsätzlich in drei Hauptaspekte unterteilt werden: interventionelle, diagnostische und Screening-Anwendungen [2-4]. POC-US unterscheidet sich dabei vom konventionellen Ultraschall: es handelt sich um eine schnelle, begrenzte Untersuchung am Krankenbett, die zu einem bestimmten diagnostischen oder therapeutischen Zweck durchgeführt wird. Die Untersuchung wird in der Regel von demselben Kliniker durchgeführt, der die Behandlungsentscheidungen trifft, und hat somit den Vorteil, dass er Hintergrund und Symptome des Patienten kennt [5]. POC-US-Sonogramme können schnell und in Echtzeit gewonnen werden, was eine direkte Korrelation der Ultraschallbefunde mit den vorliegenden Symptomen des Patienten ermöglicht und jederzeit wiederholt werden kann, wenn sich der Zustand des Patienten dramatisch verändert. Somit kann POC-US die Zeit bis zur Diagnose verkürzen und eine schnelle Einleitung der notwendigen Behandlung im klinischen Umfeld ermöglichen [6]. POC-US kann nachweislich als präzises diagnostisches Hilfsmittel dienen [7], kann die körperliche Untersuchung erweitern und die Diagnostik von klinisch wichtigen Entscheidungen verkürzen [8]. Diese zeitkritische Sofortdiagnose ist besonders in der Geburtshilfe und Gynäkologie (OBGYN) wichtig, da eine verzögerte Diagnose geburtshilflicher oder gynäkologischer Komplikationen zu kritischen Folgen für die Mutter und den Fetus führen kann [9]. Dabei stellt POC-US jedoch keinen Ersatz für eine eingehende pränatale oder diagnostische Ultraschalluntersuchung dar.

Ultraschall in der Aus- und Weiterbildung

Das Interesse am Unterricht von Ultraschallanwendungen ist seit 30 Jahren zunehmend. Was im Studienjahr 1981/82 mit dem freiwillig angebotenen Kurs «Anatomie am Lebenden» an der Medizinischen Hochschule Hannover seinen Anfang nahm, steht heute dank zahlreicher und erfolgreicher lokaler Projekte in Bonn, Frankfurt, Heidelberg, Wien, Zürich und anderen europäischen Städten auf breiteren Beinen. Überraschenderweise gibt es aber bis dato im deutschsprachigen Raum keine übergreifenden nationalen Konzepte. Dies liegt u.a. an den Spezifika der Aus- und Weiterbildung zugrundeliegenden Gesundheitssysteme [16, 17].

Sowohl die strukturellen als auch die finanziellen und erst recht die personellen Rahmenbedingungen des föderal aufgebauten deutschen Universitätssystems zeichnen sich dafür verantwortlich. Von besonderer Bedeutung bei der Weitergabe sonografischer Techniken und Wissens ist das Ineinandergreifen theoretischer Grundlagen mit primär praktischen Fähigkeiten. Insbesondere Letzteres stimuliert Studierende zur Eigeninitiative. Das führte schließlich zur Etablierung vieler lokaler Initiativen, mit oder auch ohne organisatorische Einbindung in den offiziellen Lehrkörper.

Die jeweiligen Ultraschallgesellschaften – DEGUM (Deutschland), SGUM (Schweiz) und ÖGUM (Österreich) – bieten zwar notwendige Grundlagen für übergeordnete Lösungen, aber es bedarf deren universitären Umsetzung. Dabei könnten die vorgeschlagenen Kursabläufe und Lehrinhalte von den bereits etablierten wie bewährten Kursen ärztlicher Aus- und Weiterbildung der Ultraschallgesellschaften abgeleitet werden.

Ein Blick in die USA zeigt, dass dort auch die Implementierung von POC-US in klinische Fächer, die auch den notfallmäßigen Bereich abdecken, einen erheblichen Aufschwung erlebt. Dadurch macht die in den angloamerikanischen Ländern radiologisch dominierte Sonografie auch in der Aus- und Weiterbildung einen Wandel durch. Der Einsatz der Sonografie erfolgt dabei im Kontext lösungsorientierter Konzeptionen. Erkenntlich wird dies auch an der Gründung der SUSME (Society of Ultrasound in Medical Education), einer Fachgesellschaft, die erfolgreich weltweit anerkannte Kongresse organisiert. Hilfreich ist der Blick in die USA auch deshalb, da so aktuelle Entwicklungen besser verständlich werden. Hervorzuheben ist bezüglich der generellen Ausbildung von Studierenden in der Sonografie die University of South Carolina [18, 19].

In den USA wird in der Radiologie eher auf die systematische Lehre gesetzt, während in klinischen Fächern POC-US bevorzugt wird, um so die Ultraschalltechnik in den klinischen Alltag fest zu integrieren und breit zu nutzen.
Im Rahmen lehrdidaktischer Konzepte ist der klassische Frontalunterricht als Unterrichtstechnik in den Hintergrund getreten. Es sind vorwiegend die praktischen Übungen am Probanden, die als motivierendes Instrumentarium an Bedeutung gewinnen, wobei ein minimales Verhältnis von 1:4 bzw. 1:5 gewahrt werden sollte. Dies gilt im besonderen Maße für die Ultraschallausbildung.
Auch Peer Teaching hat mittlerweile an einigen deutschsprachigen Universitäten große Bedeutung erlangt. Es handelt sich dabei um ein Treffen hoch motivierter Studierender, die nicht nur mit, sondern auch ganz ohne Hilfe des Lehrapparates effektive Trainingseinheiten aufbauen. Problematisch ist dabei insbesondere die Wahrung der Kontinuität, da es eine mitunter hohe Fluktuation der Teilnehmer gibt, vor allem aber der hochmotivierten Leader, die sich nach der eigenen Ausbildung in den klinischen Alltag eingliedern. Der jeweilige Nachfolger ist vielleicht nicht mehr so motiviert oder steht nur eingeschränkt zur Verfügung.
Wiewohl Simulatoren gerade im Bereich der Vermittlung sonographischer Kenntnisse und Fertigkeiten höchst bedeutsam sind, stehen in praxi die hiermit verbundenen Kosten derzeit ihrem breiten Einsatz entgegen.
Eine Möglichkeit könnte die Vermittlung sonographischer Inhalte über soziale Medien sein. Zudem sollten die Optimierung psychomotorischer Bewegungsabläufe sowie die Nutzung neuer Techniken im Bereich der Telemedizin und des 3D-Drucks in der medizinischen Lehre beachtet werden.

Ultraschall in Aus-und Weiterbildung in der Frauenheilkunde

Mehr als bei allen anderen bildgebenden Verfahren sind die medizinische Verwendung und die Ergebnisse von Ultraschall in hohem Maße vom Bediener abhängig. Das Potenzial für Diagnosefehler wird durch die fortlaufende Entwicklung immer ausgefeilterer Geräte mit erweiterten Anwendungsmöglichkeiten vergrößert. Während viele Geburtshelfer und Gynäkologen in der Ausbildung Kurse besuchen, die sich mit den Feinheiten z. B. der fetalen Echokardiographie, der fetalen Neurosonographie oder der dreidimensionalen Darstellung des Endometriums befassen, sind relativ wenige bereit, Kurse über grundlegende theoretische und praktische

Ultraschalltechniken zu besuchen. Es gibt einige wenige Ausnahmen, zum Beispiel in Skandinavien, wo Grundkurse obligatorisch sind. So gibt es international nur eine relativ kleine Zahl erfahrener Ultraschallärzte, die ihre Fähigkeiten immer weiter verfeinern, während vielen durchaus kompetenten Klinikern immer noch die Grundlagen im Bereich der sonographischen Diagnostik fehlen. Gleichzeitig wird die Ultraschalldiagnostik nicht nur in der Geburtshilfe und der Gynäkologie sondern mittlerweile in fast allen Fachbereichen immer wichtiger. Diagnostische Fehler können nur durch eine angemessene Ausbildung verhindert werden, die sowohl die Grenzen als auch das Potenzial der Ultraschallgeräte kennt.

Das European Board and College of Obstetrics and Gynaecology (EBCOG) hat für die Grundausbildung in der Geburtshilfe und Gynäkologie Leitlinien entwickelt. Für die Ultraschalldiagnostik sind die grundlegenden Kompetenzstufen darin nur in groben Zügen definiert. Im Bereich des geburtshilflichen Ultraschalls sollte der Auszubildende "über detaillierte theoretische Kenntnisse der normalen und anomalen Anatomie des Fetus, der Plazenta und des Fruchtwasserkompartiments, der Bestimmung des Gestationsalters, der fetalen Biometrie, des fetalen Wachstums und Verhaltens [und] der Bewertung des fetalen und utero-plazentaren Blutflusses" verfügen. Im Bereich des gynäkologischen Ultraschalls sollte der Auszubildende "detaillierte theoretische Kenntnisse über die Ultraschallaspekte der normalen Beckenanatomie, gynäkologische Erkrankungen, Unfruchtbarkeit und ultraschallgestützte invasive Verfahren" haben. Darüber hinaus sollte jeder Auszubildende über ein Logbuch verfügen, in dem 200 pränatale geburtshilfliche Untersuchungen und 100 gynäkologische Untersuchungen aufgeführt sind. Mehr ins Detail geht die European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) in ihren Mindestausbildungsempfehlungen für die Ausübung des medizinischen Ultraschalls. Für die Stufe 1 (Basiskompetenz) im gynäkologischen Ultraschall empfiehlt die EFSUMB, dass die Auszubildenden mindestens 300 Untersuchungen unter Aufsicht durchführen und ein Logbuch mit 20 dokumentierten Fällen führen sollten. Sie sollten mindestens 20 Stunden theoretischen Unterricht erhalten, vorzugsweise zu Beginn der Ausbildungszeit. Für die Stufe 1 des geburtshilflichen Ultraschalls wird empfohlen, dass Auszubildende mindestens 500 Untersuchungen unter Aufsicht durchführen, ein Logbuch mit einer Auflistung der Untersuchungsarten führen und 30 Stunden theoretischen Unterricht erhalten. In Deutschland stellt die Deutsche Gesellschaft für

Ultraschall in der Medizin (DEGUM) die Voraussetzungen für die einzelnen Stufenzertifizierungen im Bereich der Weiterbildung.
Die Indikation für Ultraschalluntersuchungen, die sonographische Darstellung der normalen Anatomie in den Standardebenen, die korrekte Einstellung eines Ultraschallsystems sowie Sicherheitsaspekte können auf konventionellem Wege (Vorlesungen, Bücher, Videos) leicht vermittelt werden, aber die praktische Anwendung eines Ultraschallsystems und insbesondere die Handhabung der Ultraschallsonden (Positionierung, Insonationswinkel) und die Anpassung an fetale Bewegungen und Lageveränderungen müssen individuell vermittelt werden. Sobald diese grundlegenden Fähigkeiten beherrscht werden, gibt es jedoch einige andere potenziell nützliche Ausbildungsinstrumente, wie z.B. digitale online Vorträge. Die ISUOG zum Beispiel bietet die Inhalte mehrerer Ultraschallkurse, die sowohl geburtshilfliche als auch gynäkologische Themen abdecken, in Form von Audio- und Videodateien an. Viele dieser Vorträge befassen sich mit fortgeschrittenen Themen, einige auch mit grundlegenden Konzepten wie der fetalen Herzuntersuchung. Diese Vorträge sind für alle Mitglieder auf der ISUOG-Website verfügbar (www.isuog.org). Multimedia-basiertes Selbststudium ist dabei in den letzten Jahren immer wichtiger geworden. So bietet die ISUOG gemeinsam mit der The Fetal Medicine Foundation, London, auch Lehrvideos an.
Eine weitere Methodik der sonographischen Ausbildung ist die Nutzung von Ultraschallsimulatoren für die geburtshilfliche und gynäkologische Basisausbildung. Derzeit sind die Anschaffungskosten sehr hoch, bei nur geringen Optionen der Variierung. So können digital vorbereitete Pathologien sowohl in der Grundausbildung als auch in der Fortbildung eine Rolle spielen, jedoch fehlt meistens der realitätsnahe haptische Effekt bei den Simulatoren.
Die Schwierigkeit, in ganz Europa einheitliche Ausbildungsstandards zu schaffen, hat dazu geführt, dass in den einzelnen Ländern getrennte und eigenständige Ausbildungskonzepte für Ultraschall entwickelt wurden. Meist werden die theoretischen Kenntnisse in den Grund- und Fortgeschrittenenkursen vermittelt. Einige Länder prüfen die theoretischen Kenntnisse einheitlich ab. Im Vereinigten Königreich wird für die Mitgliedschaft im Royal College of Obstetricians and Gynaecologists (MRCOG) eine "Gesamtprüfung" verlangt, die alle Fachgebiete umfasst, von denen nur ein kleiner Teil die Ultraschalluntersuchung beinhaltet. In einigen Ländern werden die theoretischen Kenntnisse der Auszubildenden überhaupt nicht geprüft. Während

die meisten Systeme einen formalisierten theoretischen Unterricht vorschreiben, ist die praktische Schulung kaum formalisiert. Dabei ist dies der wichtigste Aspekt der Grundausbildung. Die meisten praktischen Supervisionen für Auszubildende erfolgen wahrscheinlich ad hoc in einer opportunistischen, unstrukturierten Art und Weise in Kliniken und auf Stationen, anstatt im Voraus mit klaren Ausbildungszielen vereinbart zu werden. Häufig werden Logbücher und Checklisten verwendet, um eine bestimmte Anzahl von Scans zu dokumentieren; die Qualität der Bilder kann von einem Supervisor überprüft werden. Allerdings reicht das Erreichen einer bestimmten Anzahl von Scans nicht aus, um ein bestimmtes Kompetenzniveau zu erlangen.

So ergeben sich aus den obenstehenden Ausführungen die folgenden Fragestellungen:

- Wie sollte die sonographische Ausbildung in der Zukunft im Fachgebiet der Frauenheilkunde erfolgen und wie ist der Stand bei den zukünftigen KollegenInnen hierzu?
- Welche Anwendungen und Einsatzmöglichkeiten von Point-of-Care-Sonographie gibt es im Fachgebiet der Frauenheilkunde?
- Kann durch strukturierte innerklinische Ultraschallausbildung das Ausbildungskonzept verbessert werden?
- Können neue Technologien die Ausbildung in der Point-of-Care-Sonographie praktisch fördern und neue Optionen für die Aus- und Weiterbildung darstellen?

Ergebnisteil

Recker F*, Barth G*, Lo H, Haverkamp N, Nürnberg D, Kravchenko D, Raupach T, Schäfer VS (2021). Students' Perspectives on Curricular Ultrasound Education at German Medical Schools. Front Med (Lausanne), 8:758255. doi: 10.3389/fmed.2021.758255

Hintergrund:
Obwohl Ultraschall ein fester Bestandteil der medizinischen Ausbildung ist, haben nur wenige deutsche medizinische Fakultäten ein umfassendes Ultraschall-Curriculum eingerichtet. Ziel dieser Studie war es, die Sichtweise von Medizinstudenten auf Ultraschall in der medizinischen Ausbildung (USMed) zu untersuchen.
Ergebnisse:
Zwischen dem 1. Januar 2019 und dem 30. Juni 2019 wurde eine Online-Befragung unter deutschen Medizinstudierenden über die Studierendenvertretungen und ihre jeweiligen Lehreinrichtungen durchgeführt. Die Umfrage bestand aus 17 Items zum Thema USMed. Die Aussagen wurden auf einer 4-Punkte-Likert-Skala für die Zustimmung bewertet. Insgesamt nahmen 1040 Studierende aus 31 deutschen medizinischen Fakultäten teilgenommen. Die Mehrheit (1021, 98,2%) gab ein sehr hohes bis hohes Interesse am Curriculum USMed an. Die Studierenden stimmten der Aussage zu (n = 945, 90,9%), dass USMed während ihres gesamten Medizinstudiums hilfreich sein würde. Bei der Wahl des besten Einstiegszeitpunktes für USMed, gingen die Meinungen der deutschen Medizinstudierenden auseinander: Studierende, die ein Modellcurriculum studieren, bevorzugten einen Einstieg im zweiten Studienjahr (40,7 %), 49 % der Studierenden, die ein traditionelles Curriculum studieren, einen Beginn im dritten Jahr ($p \leq 0{,}001$). Ein unzureichendes Zeitkontingent für USMed im geplanten Studienplan (675, 65 %) und ein Mangel an Kursen, die von medizinischen Fakultäten angeboten werden (305, 29,4 %), wurden als wesentliche Hindernisse für die Teilnahme an USMed genannt. Peer Teaching wurde von 731 (70,3 %) Studierenden als effektive Methode zur Umsetzung von USMed angesehen.
Schlussfolgerung:
Die deutschen Medizinstudierenden sind sehr interessiert und bereit, an USMed teilzunehmen. Es scheint eine hohe Nachfrage nach US-Kursen zu geben, die von medizinischen Fakultäten angeboten werden.

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Students' Perspectives on Curricular Ultrasound Education at German Medical Schools

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Background: Despite ultrasound being an inherent part of medical education, only a few German medical schools have established a comprehensive ultrasound curriculum. This study aimed to explore medical students' perspectives on ultrasound in medical education (USMed).

Results: Between January 1st, 2019 und June 30th, 2019, an online survey was conducted among German medical students via the students' associations and their respective teaching facilities. The survey consisted of 17 items regarding USMed. Statements were rated on a 4-point Likert scale for agreement. In total, 1040 students from 31 German medical faculties participated. The majority (1021, 98.2%) reported a very high to high interest in curricular USMed. Students agreed ($n = 945$, 90.9%) that USMed would be helpful along their entire course of medical studies. Considering the best starting time for USMed, the opinions of German medical students diverged: students studying in a model curriculum preferred to start in the second year (40.7%) while 49% of the students studying in a traditional curriculum preferred to start in the third year ($p \leq 0.001$). An insufficient allotment of time for USMed in the planned curriculum (675, 65%) and a lack of courses run by medical faculty (305, 29.4%) were listed as perceived significant barriers to the participation in USMed. Peer teaching was regarded as an effective method in realizing USMed by 731 (70.3%) students.

Conclusion: German medical students are very interested and willing to participate in USMed. There appears to be a high demand for US courses offered by medical schools.

Keywords: ultrasound, ultrasound education, medical education, curriculum development, peer-teaching, medical student

INTRODUCTION

For a long time, ultrasound (US) was a skill learned by physicians during their residency rather than during their studies. But in recent decades, ultrasound in medical education (USMed) has become increasingly important during medical school. In Germany, USMed as a curricular component was first introduced within the National Competency Based Catalog of Learning Objectives for

Undergraduate Medical Education (NKLM) in 2015. The catalog requires students to "[be able to] use US to support basic clinical examinations according to the situation" (1) and integrates US into the curriculum in the last semesters and the practical year. However, many authors (2–5) have described that US is not just limited to diagnostic imaging, but can be used in teaching and is considered a useful additional tool for understanding complex anatomical structures and processes. In 1996, Teichgraeber et al. (6) already outlined the educational benefits of US in teaching anatomy within the preclinical curriculum. Thus, the inclusion of ultrasound in the curriculum is not only useful in terms of learning the diagnostic skill, but apparently can be supportive in other ways, such as teaching anatomy. Due to the benefits of USMed in terms of diagnostics as well as didactic support and technological advancements such as portable handheld US devices, many medical schools have started to establish USMed courses. In Germany, it is mostly offered in the form of lectures, seminars, and practical training, both on a curricular and extracurricular basis (7–9). The recently published paper from Wolf et al. (7) showed that undergraduate US courses offered at German medical schools are heterogeneous in their content and are mainly designed for advanced students. There are some medical schools that, based on many years of experience, have already realized extensive programs at both the early and advanced levels of study. There is a growing trend toward greater integration of ultrasound into medical curricula. The Universities of Erlangen-Nuremberg, Düsseldorf, and Münster offer curricular USMed for all medical students with practical training sessions over several weeks in small groups consisting of three to five medical students per tutor (10, 11). The medical faculty of the Ulm University has implemented an US course into its medical curriculum in the fifth and sixth semesters, which consists of seminars and practical training. Successful completion of a basic US course is a requirement for participation in further courses, culminating in a multiple-choice examination. Seminars are held continuously over 13 sessions covering basic subjects such as fundamentals of physics, basics of abdominal US and thyroid US, as well as more advanced subjects such as contrast-enhanced US and echocardiography. Teaching is primarily carried out by experienced specialists in internal medicine with support of student tutors (8)**.** The Medical School Brandenburg Theodor Fontane, as one of the youngest medical schools, has integrated a curriculum for longitudinal US learning, starting in the first year of study (9). During the past years, the German Society of Ultrasound in Medicine (DEGUM) has also tried to support the integration of USMed into medical curricula. Within these efforts, a DEGUM certificate for endorsed students' education was established in 2010. It becomes apparent that there are multiple efforts to integrate USMed into medical curricula in Germany in different ways. Although there is a difference between students' perceptions of what is useful and what has proven to be beneficial to the learning process, it seems to be important to include students' perceptions in the development of medical curricula.

There is a lack of data on how beneficial the integration of ultrasound into the curriculum is perceived by students in Germany and what barriers they see regarding USMed during their studies. This study aimed to gather information on the current use and students' opinions on different points of discussion on USMed at German medical schools. Moreover, we wanted to explore the extent and type of integration USMed students consider optimal, and the barriers students perceive in learning ultrasound basic principles at their home universities.

METHODS

Questionnaire and Distribution

An anonymous, voluntary online survey was developed to collect information regarding student opinions on USMed (see **Attachment 1**). Participation was possible between January 1st, 2019 and June 30th, 2019. The survey was distributed using the online platform Survio (http://www.survio.com/de/), starting with a cover letter, sent by email, including a brief description of the objectives and the purpose of the survey in cooperation with the working group of students in the German ultrasound society. The link was distributed among the local German Medical Student Councils and respective teaching facilities (skills labs) via email. Furthermore, Facebook was used to remind students via medical student groups to complete the survey. We kept track of IP addresses to prevent multiple participations. No financial reimbursement was provided.

The survey consisted of 17 questions, structured into three sections. We collected baseline characteristics, including the respective medical school, the type of medical degree program (traditional or model curriculum), and academic year in the first part of the survey. The second part consisted of six statements regarding USMed, which were to be rated on a four-point Likert scale. These included statements regarding the benefits of USMed on their medical education, and the benefits for learning and understanding physiology and spatial anatomy. In the third section, we designed multiple-choice questions with the additional option of entering a free-text answer, focusing on various aspects such as the best time to start with USMed, opinions on adequate teachers, and barriers to curricular USMed.

Participants

At the beginning of the study in January 2019, there were 37 fully accredited German state-funded medical schools among 35 universities (12, 13). In addition, various non-governmental medical schools had been founded (for example Witten/Herdecke University, Medical School Brandenburg Theodor Fontane). To take part, participants had to study at a German medical school at the time of the survey and were requested to return a completed questionnaire.

Data

Raw data were exported from the online platform as a Microsoft Excel Spreadsheet. Statistical analysis was performed using the software package "IBM SPSS® statistical software", version 25.00. For each individual item we presented percentages and total number (n) of selections from all participants. The data consisted of 1040 completed questionnaires. To compare groups of students from studying in traditional and model curricula, respectively, we performed a Chi-square test to explore statistical significance. To determine the effect sizes of significant comparisons, Cramer's Phi was calculated for 2 × 2-tables and Cramer's V for all other tables.

RESULTS

In total, 1040 questionnaires from 31 medical schools were completed. **Table 1** depicts the distribution of the number of students at each medical school. We had to exclude 28 questionnaires because of incomprehensible answers. In winter term 2018/2019, a total of 96.115 medical students were enrolled in Germany (14). Thus, 1.1% of all German medical students completed the questionnaire. Students from all academic years were represented in the questionnaire. The majority of participants were in their 3rd to 5th year of medical studies. Furthermore, 336 participants (32.3%) studied in a model curriculum, while 704 (67.7%) studied in a traditional curriculum.

The table shows the characteristics of the participating medical students and breaks this down into the specific degree programmes, the year of study and the individual medical school. Numbers are given in total and percentage (* including students who exceed the prescribed period of study or with leave of absence).

The second part of the questionnaire was designed to evaluate the participant's opinions on possible advantages of USMed and its implementation in their curricula. To explore whether students are interested in USMed, the participant's general interest in offered curricular USMed was determined (Item 5, **Attachment 1**). The results showed a clear tendency in favor of USMed, as 846 (81.4%) participants responded as having a very high or 175 (16.8%) high interest. To evaluate whether students would accept an increased workload, we asked for consent regarding the introduction of USMed as a compulsory course (Item 16, **Attachment 1**). Despite the already densely packed medical curricula, 773 participants (74.3%) stated that they strongly agree and 209 (20.1%) that they agree with the introduction of compulsory USMed into their schedules.

Regarding the participant's opinion on whether USMed would be helpful in their medical studies, 792 (76.2%) participants ticked a one (strongly agree) on a four-point Likert scale (LS) while 153 (14.7%) responded with a two (agree). Furthermore, an overwhelming majority either strongly agreed (640 or 61.5%) or agreed (319 or 30.7%) that USMed would support their understanding of anatomy and physiology (Item 8, **Attachment 1**) (**Figure 1**).

As previously described, the last part of the survey consisted of multiple-choice questions with the possibility of free-text answers. When questioned about appropriate teachers for curricular USMed, 930 (89.4%) students believed residents and attending specialists make adequate tutors, while 731 (70.3%) found student tutors with advanced US skills just as appropriate.

The perceived ideal point in time to start USMed is displayed in **Figure 2**. The opinions differed between participants studying in a model curriculum and those studying in a traditional curriculum ($p < 0.001$, $V = 0.242$). While participants studying in a model curriculum considered the second year of study to be the most appropriate (134 or 40.7%), respondents studying in a traditional curriculum preferred the third year (340 or 49%).

In addition, we tried to identify perceived problems regarding the use of USMed according to individual needs or barriers that affect participation in existing USMed at medical schools (Item

TABLE 1 | Baseline characteristics.

Characteristics	Number of participants (%)
Medical program type	
Model curriculum	336 (32.31%)
Traditional curriculum	704 (67.69%)
Academic year	
1	70 (6.92%)
2	130 (12.85%)
3	210 (20.75%)
4	233 (23.02%)
5	225 (22.23%)
6	119 (11.76%)
>7*	25 (2.48%)
Medical school of	
Philipps University Marburg	158 (15.19%)
Westfälische-Wilhelms University Münster	119 (11.44%)
Technical University Dresden	92 (8.85%)
Brandenburg Medical School Theodor Fontane	85 (8.17%)
Hannover Medical School	77 (7.4%)
Charité Medical University of Berlin	59 (5.67%)
Otto-von-Guericke University Magdeburg	48 (4.62%)
Justus-Liebig University Gießen	46 (4.42%)
Eberhard-Karls University Tübingen	37 (3.56%)
Rheinische-Friedrich-Wilhelms University Bonn	37 (3.56%)
University of Cologne	35 (3.37%)
University of Leipzig	27 (2.6%)
Carl-von-Ossietzky University Oldenburg	26 (2.5%)
University of Ulm	25 (2.4%)
University of Hamburg / UKE	25 (2.4%)
Martin-Luther University Halle-Wittenberg	25 (2.4%)
Heidelberg, Ruprecht-Karls University Heidelberg	23 (2.2%)
Mannheim, Ruprecht-Karls University Heidelberg	16 (1.5%)
Friedrich-Alexander University Erlangen-Nuremberg	15 (1.44%)
Ernst-Moritz-Arndt University Greifswald	15 (1.44%)
Albert-Ludwigs University Freiburg	11 (1.06%)
Ruhr-University Bochum	10 (0.96%)
Johannes-Gutenberg University Mainz	6 (0.58%)
University of Rostock	5 (0.48%)
Johann-Wolfgang Goethe University Frankfurt am Main	5 (0.48%)
RWTH Aachen University	4 (0.38%)
Friedrich-Schiller University Jena	3 (0.29%)
University of Regensburg	2 (0.19%)
Georg-August University Göttingen	2 (0.19%)
University of Lübeck	1 (0.1%)
University of Duisburg-Essen	1 (0.1%)

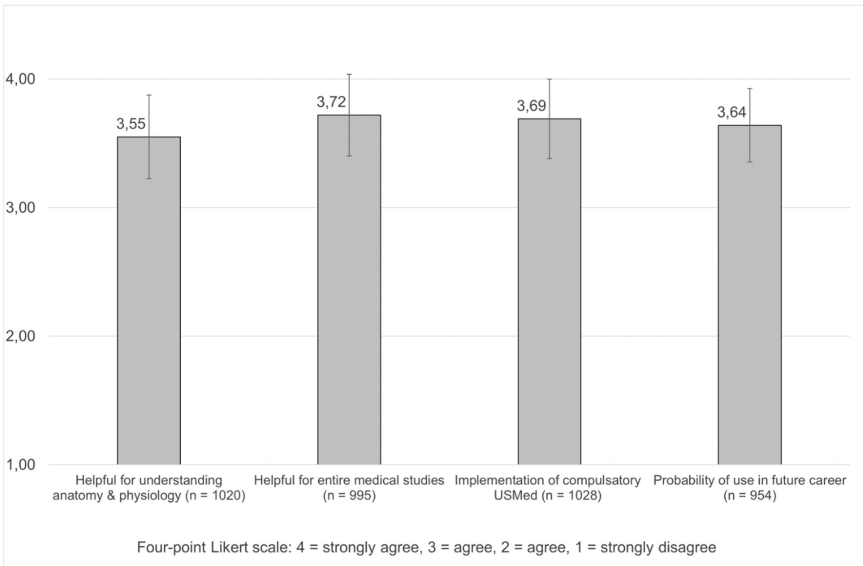

FIGURE 1 | Summary of average agreement on how ultrasound in medical education (USMed) impacts medical students. Numbers are given as mean values.

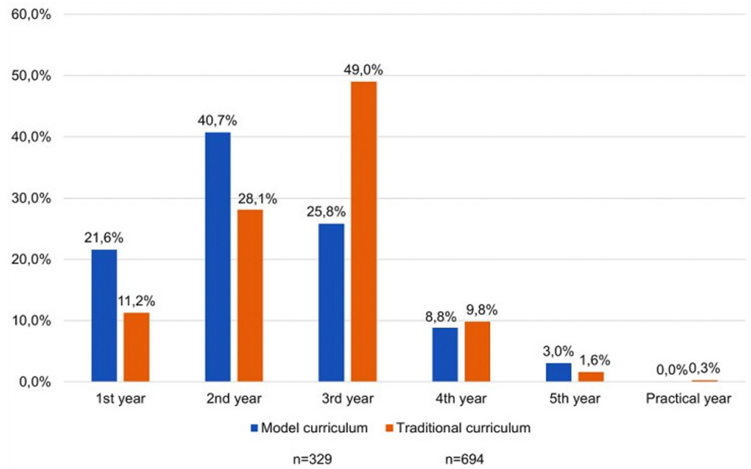

FIGURE 2 | Graph depicting the best starting time for curricular ultrasound courses depending on the medical program type. Numbers are given as percentage.

14, **Attachment 1**). Results are summarized in **Figure 3**. In total, 675 (65%) participants felt there was not enough time allotted for USMed in their curricula while 305 (29.4%) noted, that their medical faculty did not offer any USMed at all. The third most commonly listed perceived barrier (n = 198, 19.1%) was an overlap of offered USMed with other university courses.

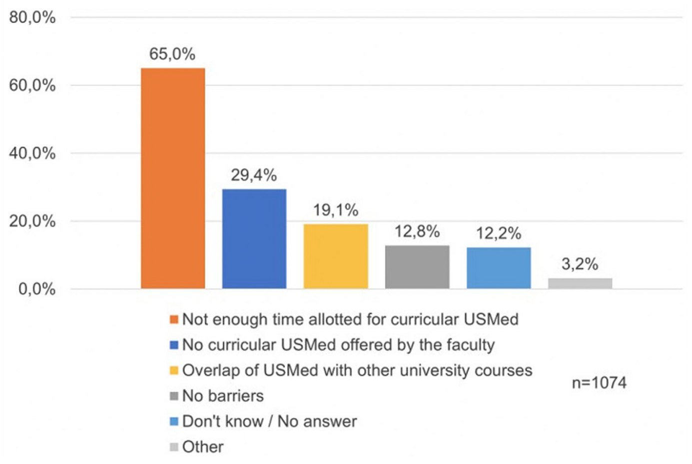

FIGURE 3 | Perceived barriers for ultrasound in medical education at German medical faculties. Numbers are given as percentage.

DISCUSSION

This is the first study focusing on students' perspectives on USMed in Germany. Collectively, we were able to survey over 1% of German medical students as only students from medical schools were targeted.

A recent Carnegie Foundation Report, "Educating Physicians: A Call for Reform of Medical School and Residency," (15) stressed, that the initial years of medical education should be supported by incorporating more clinical experiences, such as anamnesis and physical examination skills. However, implementation or extension of curricular USMed results in a higher workload for students within an already highly demanding medical curriculum. Since regular use leads to an improvement of skills, it seems useful to equip students with the basic knowledge of standard US examinations as early as possible. Longitudinal curricular USMed provides a continuous transfer of knowledge and skills. As already investigated in a study by Prats et al. (16), curricular USMed seems to diminish the threshold for utilizing US examinations and shows higher rates of ultrasound use in clinical practice in residency. Further studies must assess the impact of USMed and define a reasonable extent of USMed during medical studies.

A recent systematic literature review on the value of ultrasound in undergraduate medical education revealed that there is considerable evidence that students can gain US knowledge and abilities in medical school and that they like and desire US instruction (17).

A critical question among medical students pertains to when USMed should start. Opinions differed between students studying according to the German model curriculum and the traditional degree program. Within the model curriculum, we observed a clear tendency for early integration of USMed, preferably during the second year of medical studies. This tendency could be explained by the more practical nature of this study program. Participants at the Medical School Brandenburg Theodor Fontane were the only students studying in a model curriculum who clearly preferred the first year of medical school as an ideal starting point for USMed, as this rather young university offers a practice-oriented curriculum with an early integration of clinical and imaging skills.

In contrast to the participants' opinions, many other authors have already shown, that implementation of USMed seems to be useful in a preclinical context to support learning processes and visualization of complex contents (4, 10). Hofer et al. (11) implemented USMed in their medical curriculum at the university of Düsseldorf in 1996. They reported on the usefulness of implementing USMed in preclinical semesters and described, that reasonable integration of USMed in the curriculum can lead to optimization of teaching and skills.

The WFUMB has already published its position paper on this topic and described critical components of the integration of US into medical curricula (18). Germany however, still lacks concrete national learning objectives that can provide medical schools with guidance on what is expected from students in terms of US skills. The current learning objectives are only vague and do not meet the requirements for precise training in sonography with a focus on the abdomen in the current version of the national competence curriculum.

Numerous participants indicated concerns regarding the sparsely offered US courses in their curricula. In addition, the majority described a lack of allotted time for additional US courses due to collisions with other curricular activities (**Figure 3**). Participants often reported limited availability of course placements due to high demand. Although there appears to be a consensus among students that there is a wish for integration of US into the medical curriculum, there are clear delineated barriers that currently limit further adoption. However, in order to create a learner-friendly atmosphere and to enable students to get the most benefits out of an US course, it is necessary to design US courses in a way that students can use them according to their needs. As shown in other studies (11, 19), it is possible to design high-quality USMed despite high demand and additional costs. Wolf et al. (7) suggested that one possibility would be to use peer tutors. The majority of participants (731 or 70.3%) stated that student US tutors with advanced US skills are suitable alternatives to residents or specialists. In regard, the use of peer tutors in ultrasound education is demonstrated in numerous studies (7, 20–24). Peer-teaching seems to be a widely accepted method by medical students with the advantage of knowledge transfer at the same level and highly motivated teachers, enabling exercises in small groups rather than fully packed courses (25, 26). Student tutors can of course not replace the lecturing and supervision of an experienced physician, but rather complement them (27). At present, the training of US tutors at German medical schools is heterogeneous with several different existing approaches for US tutor training (28). But in order to establish minimum USMed standards to guarantee a certain quality of teaching throughout Germany, specific learning objectives should be integrated and added to the upcoming NKLM in this effort to provide in-depth ultrasound education nationally. These will enable medical schools to develop their specific USMed programs and to demonstrate and evaluate the effectiveness of these programs with validated test methods based on the achievement of standardized learning objectives.

USMed has been proven to be a feasible and well-accepted goal by medical students. In a recently published study, authors showed, that after only five hours of instruction, it has the ability to assist medical students gain basic competency in abdominal ultrasound examination (29). Many studies (30–32) have looked at the use of the Objective Structured Clinical Examination (OSCE), with Todsen et al. (31) demonstrating strong reliability and evidence of construct validity of the OSAUS scale in an educational setting. The question on whether to start a longitudinal ultrasound curriculum in a preclinical or clinical section of the medical curriculum remains to be answered.

One of the limitations of this study is the possibility of a non-response bias and a self-selection bias due to voluntary participation. Only about one percent of all medical students participated in the survey which limits our ability to draw conclusions. Since the survey was accessible to everyone via an internet link, we cannot guarantee that only medical students participated in the survey. Another limitation is the positive response in such studies from students who strongly favor current and practical topics. However, it is often overlooked that there must also be examinations for all compulsory courses and that in most cases other parts must be deleted from the curriculum. Furthermore, it is possible that participants completed more than one survey from different computers. We tried to reduce this problem by limiting the number of participations per IP address.

In summary, medical students are in favor of an integration and intensification of USMed offerings, which are considered useful throughout their studies. The ideal point in time to introduce USMed should be determined from a didactical point of view, taking into account the specifics of the curriculum of each faculty. There is a need for the development of national standards in order to facilitate widespread adoption of US education in German medical curricula. Current barriers to the use of USMed are mainly seen in the insufficient curricular time allotted for US courses and the general lack of courses and course placements.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Medical Faculty of the Rheinische Friedrich-Wilhelms-Universität Bonn.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by GB, FR, and NH. The first draft of the manuscript was written by GB, FR, and VS and all authors commented on previous versions of the manuscript. HL, DN, DK, and TR helped by manuscript editing. All authors read and approved the final manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2021.758255/full#supplementary-material

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Die Einführung des Ultraschalls in die Ausbildung von Medizinstudenten ist an vielen Orten auf der ganzen Welt bereits weit fortgeschritten, während sie in anderen Ländern noch in den Kinderschuhen steckt oder erst noch eingeführt werden muss. Die ordnungsgemäße Einbindung der Ultraschallausbildung in die medizinische Ausbildung erfordert Planung und Ressourcen, Kapital und Personal. In diesem Artikel erörtern wir den Stand der Technik des Ultraschalls in der medizinischen Ausbildung in der ganzen Welt sowie verschiedene Methoden, die Ausbildung der Studenten zu verbessern und den Ultraschall in alle Bereiche der Ausbildung einzubeziehen. Erfahrungen aus verschiedenen Bildungssystemen und verfügbare Erkenntnisse über die Auswirkungen der Ultraschallausbildung werden zusammengefasst. Moderne, bereits etablierte und neue Ausbildungsstrukturen sowie unterschiedliche erfolgreiche Vorgehensweisen werden von Vertretern verschiedener Gesellschaften und Fachrichtungen aus der ganzen Welt diskutiert.

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● *Review Article*

MEDICAL STUDENT ULTRASOUND EDUCATION: A WFUMB POSITION PAPER, PART I

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Abstract—The introduction of ultrasound into medical student education is well underway in many locations around the world, but is still in its infancy or has yet to begin in others. Proper incorporation of ultrasound education into medical training requires planning and resources, both capital and human. In this article, we discuss the state of the art of ultrasound in medical education throughout the world, as well as various methodologies utilized to improve student education and to incorporate ultrasound into every facet of training. Experiences from various educational systems and available evidence regarding the impact of ultrasound education are summarized. Representing multiple societies and specialties throughout the world, we discuss established modern as well as novel education structures and different successful approaches. (E-mail: Christoph.dietrich@ckbm.de) © 2018 World Federation for Ultrasound in Medicine & Biology. All rights reserved.

Key Words: **Ultrasound, Education, Point of care, Medical students, Knobology.**

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INTRODUCTION

Ultrasound is recognized as an effective first-line imaging modality for a wide range of indications. Furthermore, ultrasound appears to facilitate an interdisciplinary imaging approach and may increase interspecialty collaboration (Herrmann et al. 2015). Lack of ionizing radiation, low cost, high portability and its non-invasive nature have made ultrasound a very attractive tool for medical student education. Ultrasound also has a unique ability to connect basic science with clinical applications and enhance direct student−teacher interactions (Baltarowich et al. 2014; Hempel et al. 2016b). The aim of this position paper is to present the history of ultrasound in medical education and discuss its current status, future needs and various approaches taken throughout the world.

CONVENTIONAL ULTRASOUND AND POINT-OF-CARE-ULTRASOUND

Ultrasound use in medicine typically follows one of two general paths, as a standard comprehensive approach by traditional imagers or as point-of-care-ultrasound (POCUS) at the bedside by clinicians. The role ultrasound plays in patient care varies with region, health care system and setting type. Such diversity in application has arisen secondary to political, economic, regulatory, technological and other factors.

The use of ultrasound in medical education will depend on the type of ultrasound equipment available, selected educational approach and faculty skill sets. These will determine the type and quality of training delivered to students. Technological advancements have made ultrasound equipment more accessible and include development of hand-held ultrasound devices using personal smartphones (Barreiros et al. 2014; Gilja et al. 2014; Mirabel et al. 2015). These types of ultrasound devices are easily incorporated into student education and are an optimal form for carrying on clinical rotations (Gilja et al. 2003).

Typically, three levels of ultrasound equipment are used in student education:

- Level 1: hand-held devices, the size of mobile phones or tablets that are tailored to answer focused clinical questions.
- Level 2: point-of-care-ultrasound cart-based systems, with expanded capability compared with level 1 devices.
- Level 3: larger and more expensive, high-resolution ultrasound systems with advanced capabilities, enabling comprehensive patient evaluation (Gilja et al. 2003; Piscaglia et al. 2013).

Conventional ultrasound

For many clinical indications, ultrasound is the established first-line imaging modality worldwide. Conventional ultrasound (CUS) has been performed across multiple specialties for more than four decades. CUS equipment is generally more expensive and uses a broader variety of transducers across a wide range of imaging applications. Such systems are usually found in dedicated scanning rooms with the patients transported to the room for scanning. In a handful of countries, CUS education has long been incorporated into basic graduate medical education and postgraduate programs (Angtuaco et al. 2007; Bahner and Royall 2013; Cantisani et al. 2016; Prosch et al. 2015).

Point-of-Care Ultrasound

Point-of-care ultrasound can be performed using conventional ultrasound equipment or portable or handheld devices. Although first- and second-generation devices offered highly limited imaging capabilities, handheld scanners are rapidly improving in resolution, offering adjunct imaging capabilities and becoming increasingly comparable to modern cart-based systems. Current gaps in capabilities between hand-held and larger cart-based systems are likely to continue to narrow and one day disappear altogether.

POCUS using conventional ultrasound equipment. Conventional ultrasound equipment is frequently used for POCUS by providers with extensive imaging experience, including clinicians, radiologists and sonographers. Limitations of conventional ultrasound imaging systems generally include prolonged boot-up time, poor battery life and limited mobility.

POCUS using mobile ultrasound equipment. Point-of-care-ultrasound studies are performed at the patient's bedside by the treating clinician. Ultrasound devices may have to fit into narrow spaces and require extended battery life. The range of examinations performed is broad and can span from ocular to cardiac, from musculoskeletal to pelvic or interventional (Dietrich et al. 2015a, 2015b, 2017). Typical settings include the emergency department (ED), the intensive care unit (ICU), hospital wards and outpatient clinical and even pre-hospital settings.

POCUS using small handheld devices. Hand-held ultrasound devices have the potential to extend the physical examination with focused *ad hoc* imaging, and can guide the selection of further investigations in real time (Hussain 2015).

A variety of terms have been created to describe such ultraportable ultrasound devices, including echoscopes (Barreiros et al. 2014; Dietrich et al. 2012, 2015a, 2015b, 2017; Gilja et al. 2014; Piscaglia et al. 2013), visual stethoscopes (Gillman and Kirkpatrick 2012) and sonoscopes (Greenbaum 2003; Hoffmann 2003).

The ability of POCUS to provide real-time visual, anatomic and functional information at the patient's bedside is perhaps its greatest value in medical education. Abundant information, such as cardiac contractility, intestinal motility, and presence of a pneumothorax in a patient with chest trauma can be obtained rapidly, efficiently and with high accuracy (Bahner et al. 2008; Dietrich et al. 2015a). Real-time evaluation of anatomy and topographic areas allows the student to perform a virtual "*in vivo* dissection," improving understanding of anatomic relationships and physiology. A World Federation for Ultrasound in Medicine and Biology (WFUMB) position paper on POCUS expanding on this topic in greater detail has recently been published (Dietrich et al. 2017).

HISTORICAL PERSPECTIVE

Many advocates of ultrasound in medical education are surprised to discover how long ultrasound has been incorporated into medical curricula in some countries. "Anatomie am Lebenden" (which loosely translates to "hands-on," "peer to peer" teaching of anatomy") was an anatomy teaching experiment using ultrasound that was initiated more than 30 y ago at the Hannover Medical School (MHH, Hannover, Germany). In this program, selected medical students participated as subjects and peer teachers. Research revealed this to be an effective approach that led to improved student motivation and facilitated learning anatomy (Brown et al. 2012; Wicke et al. 2003). Several other German medical schools later adopted this approach, but hands-on exposure was limited to a narrow range of applications (Arger et al. 2005; Barloon et al. 1998; Brunner et al. 1995; Decara et al. 2005; Kobal et al. 2004, 2005; Shapiro et al. 2002; Teichgraber et al. 1996; Tshibwabwa and Groves 2005; Wicke et al. 2003; Wittich et al. 2002; Yoo et al. 2004).

Ultrasound in medical education outside of Europe has spread significantly and dates back nearly 20 y in some locations (Angtuaco et al. 2007; Fernandez-Frackelton et al. 2007; Gogalniceanu et al. 2010; Rao et al. 2008; Syperda et al. 2008; Tshibwabwa et al. 2007; Wright and Bell 2008). Standardization has been made particularly difficult, at least in part because of varied regulatory bodies (Dietrich 2012; Dietrich and Riemer-Hommel 2012). However, there is a global movement underway for adoption of ultrasound curricula in medical schools, as well as modernization and standardization led by the current evidence-based consensus conference organized by the Society of Ultrasound in Medical Education (SUSME) and World Interactive Network Focused on Critical Ultrasound (WINFOCUS) (Cantisani et al. 2016; Hussain 2015).

Perhaps the most comprehensive documentation of full ultrasound integration into a medical school curriculum came from arguably the most advanced ultrasound medical school program in the world, when in 2011 the University of South Carolina School of Medicine reported their experience in integrating an ultrasound curriculum for all students, across all 4 y of medical school (Hoppmann et al. 2011). The curriculum was based on a point-of-care ''focused'' ultrasound program that was originally developed for local postgraduate emergency medicine physicians and rotating medical students (Cook et al. 2007; Hoppmann et al. 2015).

KEY COMPONENTS OF ULTRASOUND INTEGRATION INTO MEDICAL STUDENT EDUCATION

There are several key considerations in any attempt to integrate ultrasound into medical education that deserve specific discussion. These include:

- Motivating students to perform ultrasound
- Setting appropriate goals
- How should ultrasound be taught and by whom?
- What should be part of an ultrasound curriculum?
- Educational media, material and assessment
- Support of deans
- Support of module leaders
- Hands-on teachers
- Space
- Budget (US equipment, server to save images for each student, simulation)
- Funding

Motivation

Experience has indicated that ultrasound is a considerable motivating factor for medical students when introduced into the medical curriculum. The wide use of digital tablets, smartphones, computers and online resources has readied today's students to comfortably consume visual information and adapt to learning *via* visual and auditory media.

In addition, the process of scanning can be viewed similarly to palpation during patient examination. Students typically covet any increase in hands-on patient contact experiences, and POCUS satisfies this demand by increasing clinician–patient interaction and contact time. The real-time visual information provided by ultrasound opens a new horizon for students regarding

Peer teaching. Practical skills are best learned during hands-on exercises taught in small, closely supervised groups. However, this makes training students to perform and interpret ultrasound both labor- and time-intensive (Heinzow et al. 2013). Teaching faculty may not have the time to accommodate a new commitment when ultrasound is introduced into the curriculum. The problem may be overcome by choosing teaching formats that have a multiplier effect, such as having senior staff train peer tutors who, in turn, teach peers practical ultrasound skills (Hoppmann et al. 2011).

The efficacy of peer teaching has been compared with that of traditional faculty teaching in several randomized controlled trials by assessing the post-training performance on objective structured clinical examinations (OSCEs). Performance among peer-tutored students was not inferior to that of students taught by a traditional faculty approach (Celebi et al. 2012; Kaine et al. 2016; Knobe et al. 2010), indicating that both formats are suitable for teaching basic ultrasound techniques (Celebi et al. 2012). Students might also connect more easily with their peers, creating a better working atmosphere (Garcia-Casasola et al. 2016). Peer tutors may benefit from peer teaching by improving their own knowledge and skills (Knobe et al. 2010). Training high-quality peer tutors requires an ongoing effort with regular teaching opportunities (Ahn et al. 2014).

Examples of peer teaching initiatives. In 2007, a pioneering project began at the University of Vienna: the students' initiative "sono4 you." In sono4 you, students organized themselves to provide basic training in ultrasound of the abdomen, head and neck, heart, emergency applications, musculoskeletal system and simulation of US-guided interventions to peers (Prosch et al. 2015). Peer teachers received regular training from faculty to maintain and expand their skills. Similar initiatives were later introduced at other German-speaking medical schools. Peer teaching offers opportunities to involve highly motivated trainees and should be guided by faculty to guarantee high-quality instruction (DesJardin et al. 2017).

A section of the Swiss Society of Ultrasound in Medicine (SGUM) called the "Young Sonographers" collaborated with local student groups and the Institute of Primary Health Care in Bern to develop a national curriculum for teaching basic ultrasound skills to medical students. The curriculum used blended learning, consisting of five 1-h e-learning modules and 3 h of peer-taught practical lessons per module. Student progress was assessed with a final examination conducted by SGUM ultrasound experts.

In summary, peer teaching as an avenue for making undergraduate ultrasound training available to a broad base of students is well established and tested. It is essential that students be encouraged to create initiatives for close collaboration with local experts, faculty and national ultrasound societies, to expand learning opportunities. Additionally, ultrasound societies should oversee and guide educational content, teaching format and skill assessment to guarantee high-quality ultrasound education.

Teaching the teachers. The "teach-the-teacher" approach can be very helpful when there is a lack of educational resources in a busy clinical setting. Experienced clinical faculty are recruited to learn ultrasound relevant to their settings and improve existing ultrasound skill and, in turn, provide education to students. "Teach the teachers" often focuses on improving existing ultrasound skills, but some educators are taught from scratch. Blended learning methods have proven highly effective in ultrasound education (Gogalniceanu et al. 2010; Hempel et al. 2016a) and are especially well adapted for busy faculty who are volunteering to learn ultrasound. It must be noted that not every clinical faculty or ultrasound practitioner makes a good teacher. Potential teachers require good ultrasound technique as well as good communication skills and the willingness to teach.

What should be part of an ultrasound curriculum?

Ultrasound education should begin with classic ultrasound basics such as physics, knobology, image optimization and safety. Examination techniques, along with anatomy, physiology and important pathologies, follow naturally within the curriculum. Preclinical ultrasound teaching should be introduced into anatomy and physiology courses, as this allows students to learn sonographic anatomy and improves their understanding of live human anatomy and physiology. Because ultrasound relies on practical skills, e-learning platforms and high-fidelity simulators are playing an ever-increasing role in student education. Initial studies have shown good results for e-learning and high-fidelity ultrasound simulator platforms. Simulation-based point-of-care ultrasound training is a matter of competency rather than volume.

Anatomy, physiology. Ultrasound may improve students' acquisition of anatomic knowledge (Mouratev et al. 2013; Tarique et al. 2018). Students are able to better understand the topography, function, relations of adjacent organs and their real-time movements when examining using ultrasound. Similarly, anatomy and physiology instructors have found ultrasound to be an exciting addition to their teaching armamentarium and have recognized its value in reaching the modern medical student. Anatomy and physiology ultrasound education should be presented to the students in a tailored way that relates to topics being covered in the course and should, whenever possible, be related to basic clinical scenarios.

Examination technique. Examination techniques should be well defined and scaffolded (from simple to complex and then to more focused) so that students are able to adapt to different scanning settings such as a primary care office setting versus scanning a critically ill patient in the resuscitation bay. Patient positioning (and any necessary changes in position), transducer placement and manipulation and machine operation should all be covered as part of examination techniques. However, this prefacing knowledge should not be taught at the same time as the psychomotor skills that are required to perform the scan. This is because there is limited literature to suggest that adopting this instructional practice may place the learner into cognitive overload. Working memory has a finite and limited capacity. Therefore, it is important not to teach multiple skills at the same time, for example, demonstrating how to scan the thyroid, performing image optimization and instrumentation and how to use color Doppler imaging (Nicholls et al. 2016a). Doing so would overload the finite capacity of the working memory. Therefore, it is suggested when teaching multipart, or complex, skills that the educator should first break down the task into subparts, and then teach each subpart. Whole-task practice is achieved when the skill subparts are reconstructed and practiced with the correct sequencing and timing. Students should attain a good understanding of standard orientation and movements of the transducer. Standard image orientation and any measurement norms should be followed.

Introduction to "knobology". *Knobology* refers to machine operations and controls. These controls, conceptually similar from one machine to another, are designed to achieve the same image modification and activation of adjunct ultrasound techniques, such as color Doppler activation. However, in practice, keyboards and instrument interfaces can differ greatly from one machine to another in location and actual functionality and, on some machines, do not exist.

Examination-dependent pre-sets are integrated into most machines and provided by the vendor to simplify technical adjustments. Similarly, there are essential buttons for image acquisition that exist in every machine and need to be identified. Ideally, students would become acquainted with a variety of ultrasound machine types, making it easier for them to adjust to different equipment in future educational and practice settings.

Terminology. Knowledge of standard ultrasound terminology is important to allow communication between students and teachers, as well as colleagues in clinical practice. Additionally, students should be able to read scholarly articles and understand ultrasound terminology used in diagnostic reports.

Safety. Sonographic applications are considered safe according to the guidelines of the British Medical Ultrasound Society (BMUS), European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) and WFUMB. However, depending on application and device, thermal effects could theoretically occur in the tissues being scanned, particularly in the case of Doppler ultrasound (BMUS 2016). Ultrasound education should include discussion of possible effects of ultrasound on human tissue, mainly through thermal and non-thermal (or mechanical) mechanisms (ter Haar et al. 1989). These relate to tissue heating, cavitation and mechanical overload (O'Brien 2007). The as low as reasonably achievable (ALARA) principle (Fowlkes et al. 2008), potential thermal effect as described by the thermal index (TI) and mechanical effect by the mechanical index (MI) can be included as part of safety in ultrasound student education (Nelson et al. 2009).

Relevant pathology. The clinical practice situation and setting dictate the likely pathology that will be encountered by an operator. Relevant pathologic states that apply to point-of-care ultrasound and the binary nature of decision making regarding these pathologies have been codified (Dietrich et al. 2017). Medical students should be familiar with a breadth of pathologies, reflective of their general knowledge, not of future specialty choices (Dinh et al. 2016a, 2016b). Important pathologies introduced should be curriculum driven and include findings related to trauma and surgical specialties, as well as medical diseases and emergencies.

From the teachers and students' perspective it is fundamental to understand which common pathologies can be identified by ultrasound and which require additional investigation. The early introduction of extensive repositories of pathologies risks overextending student's learning capacities. Ultrasound educators should present an overview of common pathologies and then prioritize them based on clinical situation and setting. To prepare students for their first contact with difficult or emergent clinical situations, basic emergency pathologies should be emphasized to enable adequate emergency treatment and to understand the diagnostic and therapeutic power ultrasound brings to those clinical situations.

Educational media, material and assessment

Ideally, educational tools for ultrasound should be easily accessible, standardized, systematic, easily reproducible, and transparent for structured teaching and learning purposes. Educational media and material include course books (dedicated to students), e-books, apps, interactive e-learning tools, examination technique videos, webinars and case repositories (atlas) with examples of very important pathologies (VIPs).

Hands-on ultrasound education. Hands-on education is a critical component of ultrasound training in medical school. Not only does it increase students' motivation as they perform scans on simulated or real patients, appreciating anatomy and physiology in real time, but it is also important for developing spatial coordination required for scanning. However, most importantly, hands-on training is the most vital factor in becoming a skilled doctor that is familiar with the scanner and accurate in ultrasound diagnostics.

There are no conclusive published data on the optimal tutor/trainee ratio for hands-on ultrasound training sessions. The logical answer would always be that during a 1/1 training session, the one trainee has the undivided attention of the tutor and the most intense and effective learning. However, currently there is no generally accepted recommendation on the teacher-to-student ratio during the ultrasound education process. We propose a ratio of 1/4 as a generally accepted rule of thumb that has been working well in various hands-on courses around the world for basic training. This allows for greatest efficiency in using human resources, balanced against quality instruction. In the clinical setting later on in the educational process, one-to-one shadowing with hands-on time for the trainee is suggested until it changes to the fully supervised, then partially supervised and finally independent stage.

Currently there is no generally accepted recommendation on the minimum time for trainees having the transducer in their hand before training is completed. The European Common Course (ECC) for abdominal ultrasound asks for 21 h of basic training, and 14 of the 21 h are spent on practical training with the ultrasound machine. Further research is needed to determine minimal training and hands-on exposure milestones for medical students.

Simulators. The use of low- and high-fidelity ultrasound simulation has found to be a useful tool for ultrasound education, mainly *via* improvement in trainee competence in post-course-simulated environments and improved skill in post-training assessments (Lewiss et al. 2014). For instance, learning ultrasound through the use of simulators was evaluated in a pilot study with 240 medical students at the University of Münster (Metzger and Flanagin 2011). The study reported significant improvement in students' technical knowledge and confidence post-simulation. Investigators found that pre- and post-course assessments when using ultrasound simulation are crucial to improving knowledge, motivation and skill retention (Kromann et al. 2009; Todsen et al. 2015). Research has also indicated that simulator-based ultrasound training in pairs ("dyad practice") is effective in the transfer of specific skills (Tolsgaard et al. 2015).

Ultrasound simulators using real ultrasound data are being used with increasing frequency, making the assessment of simulation-based training a crucial component of some training programs. The use of OSCE stations with a clear grading scale has been reported to reduce subjectivity in those training sessions (Konge et al. 2014; Swannick 2010). One disadvantage of ultrasound simulators is that virtual-reality sonography simulators can become an expensive educational tool; some purchase prices can go well above USD 100,000 and the lower end of pricing being 2.500−20.00, not including the costs associated with maintenance, software updates and tutor training (Konge et al. 2014; Lewiss et al. 2014). However, given the increasing use of this technology and associated costs, studies reporting the translation of ultrasound simulation training into a significant clinical benefit and improved clinical outcomes are still needed.

The traditional methods of ultrasound training are still not completely standardized, especially in departments with large numbers of trainees and practitioners. A simulator-enriched curriculum may allow for greater standardization in early training and permit objective comparison of trainees as well as tutors. Additionally, high-fidelity simulators can offer exposure to ultrasound cases that are rarely encountered by students or are difficult to expose students to, such as cardiac arrests and critical ultrasound-guided procedures. Incorporating an assessment tool into the program would provide an objective measure of competency. To this end, many simulation companies are pursuing development of built-in competency assessment tools to aid educators in assessing progress made by their students. One potential disadvantage is that funding for simulation equipment might compete with funding for traditional hands-on tutors, potentially limiting student exposure to this additional teaching tool.

E-learning, interactive teaching methods. E-learning can be a solution for training in areas with limited educational resources. E-learning often takes the form of video lectures, teleconferences and webinars. Other e-learning tools, such as webcasts and e-books, represent a cheaper solution for teaching ultrasound. The advantages of e-learning include students' ability to tailor their learning pace, duration and location. Because ultrasound expertise is highly dependent on pattern recognition, easily accessible image archives are important. Such e-learning resources are offered by WFUMB and multiple national and regional societies among others.

Massive open online course (MOOC) is an open-access online teaching approach allowing for unlimited trainee participation while providing interaction among students and faculty. It has been successfully applied in a wide variety of disciplines and is currently a focus in education research. The MOOC may also be integrated into a medical student ultrasound educational program (Tolks et al. 2016).

Webinars. The use of web-based seminars or "webinars" can help disseminate information and illustrate practical applications when no direct supervision is possible. Using web conferencing technology overcomes geographic isolation and decreases costs (Metzger and Flanagin 2011). This format allows live and interactive presentations by experts that can be accessed online from any location with an internet connection. Webinars accelerate the learning process by increasing communication with experts and by using text chats and voting and drawing tools and sharing comments and contributions (Chiswell et al. 2018).

Social media. Social media such as YouTube, Facebook and Twitter can support dissemination of knowledge but also allow interactive communication *via* chats and private messaging in defined groups. Students already use these social platforms on a daily basis for educational purposes such as in anatomy (Barry et al. 2016; Hempel et al. 2016b). Lack of quality control and significant potential for misinformation are an ongoing concern with social media as well as some other online educational modalities.

Need for standardized assessment. There is a growing demand to standardize ultrasound training, establish structured clinical courses and assess competency according to well-defined and reproducible criteria. The goal is a widely applicable approach to enhance local initiatives and standardize quality as well as predictability of outcomes across all educational programs. Training programs should follow quality assurance standards and develop criteria for centers of excellence, in which effective high-quality ultrasound is performed and also high-quality teaching is provided.

Assessment of ultrasound competency can be performed using different methods (Todsen et al. 2015), including written exams, clinical observation, video review or clinical simulation. Regular direct observation of procedural skills (DOPS) with formal feedback can be documented in the trainee's portfolio. Unstructured observations have inter-observer variability and are less reliable. To overcome this issue, structured observation of technical skills and performance using checklists or global rating scales have been introduced (Martin et al. 1997; Nielsen et al. 2013).

Ideally, a series of DOPS and other structured appraisal forms would present a summary of the trainee's progress before a final assessment and document the trainee's competence in each domain of ultrasound education. Although suboptimal for numerous reasons, until competency assessment for ultrasound procedures becomes adequate, it may be necessary to suggest threshold numbers of procedures that must be performed to obtain competency, although a logbook cannot guarantee quality of performance or safety. National training databases can produce valuable information for setting such threshold numbers (Ward et al. 2017). Simulator developers are also providing solutions to competency assessment using artificial intelligence or other tools to intricately assess a student's performance while scanning or performing procedures on a simulator. Some of these systems can also test how the students integrate findings into clinical decision making. These tools are likely to be of greater utility in the future.

Development of psychomotor skills in ultrasound performance. The competent performance of an ultrasound examination requires the user to have a broad range of knowledge and skills, including both communication and psychomotor. These skills are acquired through practical learning opportunities. Skill practice is required to develop the visuomotor and visuospatial skills that enable the learner to perform the exam in the correct planes, to obtain the diagnostic information. Many of the skills that are used to perform a focused or long ultrasound examination are complex. A complex skill is multidimensional and comprises many subparts. Therefore, the small and nuanced motor movements that are required to perform the task may not be noticed and appreciated by the learner; they are often evident only through clinical skill demonstration (Nicholls et al. 2014, 2016a, 2016b) and the use of physical guidance. The core skills needed to perform an ultrasound examination must be learned over time through supported clinical and then independent practice. The objective is to be able to execute the skill to a pre-determined or demonstrated standard. End-task and limited in-task feedback is essential to develop the foundation scanning skills required for clinical practice. Using an instructional approach that is evidence-based and aligned with the precepts of the motor learning domain is suggested when teaching a complex psychomotor skill (Nicholls et al. 2016a, 2016b).

ULTRASOUND CURRICULA INTEGRATION

Ultrasound education for medical students is among the most recently introduced subjects in medical curricula (Fodor et al. 2012). Ultrasound can be effectively used to teach clinical applications and augment physical examination skills, as well as improve anatomy and physiology knowledge (Arger et al. 2005; Bahner and Royall 2013; Bahner et al. 2013; Griksaitis et al. 2014; Hoppmann et al. 2011; Metzger and Flanagin 2011; Swamy and Searle 2012). The implementation of curricula depends on multiple factors including regulations, resources and other setting-specific factors. Traditional methods followed a siloed, organ- and topic-based approach, for example, musculoskeletal, cardiovascular, respiratory and gastrointestinal (Dahle et al. 2002; Dochy et al. 2003; Frank et al. 2010; Schmidt et al. 1996).

At the time of this article's writing, an international consensus guidelines process was underway on ultrasound in medical education. The process, organized by SUSME and WINFOCUS, is a rigorous evidence-based approach using GRADE (Grading of Recommendation, Assessment, Development and Evaluation) and modified Delphi technique to establish recommendations on ultrasound in medical education curriculum. It includes approximately 60 voting panel members from multiple specialties and more than 150 consultant advisors with expertise in ultrasound in medical education. Modern curricula of ultrasound education should meet established criteria on ultrasound education standards (Garcia-Casasola et al. 2015; Hempel et al. 2014; Kondrashov et al. 2015). Curricula incorporating medical ultrasound education also need to satisfy regulatory bodies.

Complete integration of ultrasound throughout (both vertically and horizontally) a medical education curriculum has been documented in a number of locations as proof of concept. Typically, in the pre-clinical portion, ultrasound is used to enhance student understanding of anatomy, physiology and pathophysiology. Ultrasound is also ideally taught as part of the physical assessment. In the clinical portion, students learn how to use ultrasound effectively as a problem-solving tool to diagnose a disease and pathology. Optimally, topics are related between courses, and ultrasound is used to reinforce what is learned from one course to the next. The horizontal and vertical integration of ultrasound into courses and rotations cannot be accomplished without a multidisciplinary approach. The vertical approach was characterized by assigning specific hours to ultrasound imaging for didactic sessions and workshops to cover the complete pre-clinical curriculum (Bahner and Royall 2013; Baltarowich et al. 2014; Brunner 1966; Chiem et al. 2016; Dinh et al. 2016a, 2016b; Flick 2016; Gillman and Kirkpatrick 2012; Hussain 2015; Millington et al. 2016; Prats et al. 2016; Smalley et al. 2016).

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Hintergrund

Die rasante technische Entwicklung und die Tragbarkeit von Ultraschallsystemen in den letzten Jahren haben sich tiefgreifend auf den Bereich des Point-of-Care-Ultraschalls (POC-US) ausgewirkt, sowohl in der Allgemeinmedizin als auch in der Geburtshilfe und Gynäkologie.

Der Einsatz von POC-US ermöglicht es dem Arzt, die Ultraschalluntersuchung entweder in der Arztpraxis oder am Krankenbett durchzuführen und als Erweiterung der körperlichen Untersuchung zu nutzen. Die Echtzeit-Bilder können sofort mit den Symptomen des Patienten korreliert und Veränderungen im Zustand eines (kritischen) Patienten schneller erkannt werden.

POC-US in Gynäkologie und Geburtshilfe eignet sich auch für zeitkritische Szenarien; je nach Situation und Dynamik können der Verlauf und die Ergebnisse einer Therapie in Echtzeit beobachtet werden.

POC-US sollte als routinemäßige Erweiterung der körperlichen Untersuchung angesehen werden, da sie sofortige Antworten auf möglicherweise lebensbedrohliche Situationen für die Mutter und/oder das Kind geben kann.

Aufgrund seiner erwiesenen Nützlichkeit sollten die Anwendungen und der Einsatz von POC-US in die Lehrprogramme in die Ausbildung von Medizinstudenten, Gynäkologen und Notärzten aufgenommen werden.

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REVIEW

Point-of-care ultrasound in obstetrics and gynecology

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Abstract

Background The rapid technical development and portability of ultrasound systems over recent years has had a profound impact on the area of point-of-care-ultrasound (POCUS), both in general medicine and in obstetrics and gynecology. The use of POCUS enables the clinician to perform the ultrasound scan either at the medical office or the patient's bedside and used as an extension of the physical examination. Real-time images can immediately be correlated with the patient's symptoms, and any changes in a (critical) patient's condition can be more rapidly detected.

POCUS in OBGYN POCUS is also suitable for time-critical scenarios, and depending on the situation and its dynamics, the course and results of any therapy may be observed in real time. POCUS should be considered to be a routine extension of practice for most OB/GYN clinicians as it can give immediate answers to what could be life-threatening situations for the mother and/or baby. With its proven usefulness, the applications and use of POCUS should be incorporated in teaching programs for medical students, OBGYN residents and emergency physicians.

Keywords Point-of-care ultrasound (POCUS) · Gynecology · Obstetrics · Imaging

What is POCUS?

POCUS is an examination method in which ultrasound is brought to the patient and used as an extension of the physical examination and the real-time images may immediately be correlated with the patient's symptoms [1]. It is used by various specialties in multiple situations and can be divided into three major aspects: interventional, diagnostic, and screening applications [2–4]. POCUS is different from conventional ultrasound: it is a rapid, limited study performed at the bedside for a specific diagnostic or therapeutic purpose. The study is normally performed by the same clinician who makes the treatment decisions and who has the advantage of knowing the patient's background and symptoms [5].

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POCUS images can be rapidly obtained in real time, which allows the direct correlation of ultrasound findings with the patient's presenting symptoms and can be repeated if the patient's condition changes dramatically. Thus, POCUS can reduce the time to diagnosis and allows a faster initiation of necessary treatment in the clinical setting [6]. It has been shown that POCUS can serve as an accurate diagnostic adjunct [7] and can support physical examinations with the potential to augment the detection of clinically important entities [8].

This immediate diagnosis is particularly relevant in obstetrics and gynecology (OBGYN), when delayed diagnosis of obstetrical or gynecological complications lead to critical outcomes for the mother and the fetus [9]. POCUS is, however, not a substitute for an in-depth prenatal or diagnostic ultrasound scan.

What is PUM?

Currently one of the limitations of POCUS is the lack of ultrasound equipment that is easy to move around and allows clinicians to truly bring ultrasound to the patient, instead of bringing the patient to the ultrasound machine. The introduction of portable (and more affordable) ultrasound machines (PUMs) allows for access of this imaging modality to more obstetric departments and potentially even in remote and rural regions of the world.

Modern PUMs manly consist of transducers that can be connected to a smart-phone or tablet.

Publications on POCUS in OBGYN show that diagnostic findings obtained with PUMs are similar to those generated with advanced, specialized ultrasound machines [10]. These studies overlap with various studies in other medical field such as cardiology, internal medicine and emergency medicine where PUMs have shown to be of high clinical value [10]. In 2018, the World Federation of Ultrasound in Medicine and Biology (WFUMB) published a position paper in which the key fundamentals such as definitions, possible applications and safety considerations of POCUS were discussed [11].

However, there is a still great need for a comprehensive version of the application of PUMs in OBGYN to expand and improve management decisions in labor wards, primary care and in low resourced countries [12–16]. A WFUMB project showed that training midwives in performing routine and focused prenatal scans was a convenient way to cope with the small number of trained sonographers or obstetricians in low-resource countries [17].

Ultrasound is an operator-dependent imaging technology which has major implications on education and ultrasound training [11]. The literature shows that training of physicians or sonographer/midwives in the use of basic ultrasound can be effectively achieved if those chosen for training have a positive attitude [18].

With the use of telemedicine, the transmission of ultrasound images between remote regions and ultrasound centers can be simple and fast. Rapid technical development has been a leading point in recent years, especially improving medical care in remote regions. [19]. In many low-resource countries, ultrasound is mainly available in the most highly populated and developed areas, whereas the majority of the population tends to live in poorer regions and usually have little or no access to health care. Thus, it may involve long journeys to the required medical centers for the patients and the required costs for the corresponding medical examinations can be very high. Introducing the use of solar-powered and robust ultrasound devices for POCUS into the more remote areas may reduce these costs but will only be useful if it generates a good outcome for the patient at low cost.

POCUS applications in OBGYN

POCUS in OBGYN is particularly useful in emergency situations. The literature describes high specificity and sensitivity of POCUS in OBGYN [20], but one has to keep in mind that obtaining relevant and diagnostic results is always user dependent.

In obstetrics, ultrasound is used to monitor the course of any pregnancy from 5 weeks of gestation to term. Midwives and obstetricians may use POCUS to confirm an intrauterine pregnancy, fetal viability, number of fetuses (twins/triplets) and gestational age. Furthermore, they can monitor the pregnancy in the second and third trimesters to assess fetal lie, fetal growth and fetal well-being as well as the placental position, measure the cervical length (Fig. 1) and determine the level of amniotic fluid that can indicate various pathological circumstances of the fetus.

Protocols for the performance of an obstetrical ultrasound depend on the qualification of the practitioner, the local legal and ethical conditions and also on the costs incurred in the examination.

Abdominal pain in any woman with a positive pregnancy test may be caused by an ectopic or extra-uterine pregnancy. A well-performed POCUS examination may detect a missing intrauterine gestational sac, the presence of a tubal sac or free intraperitoneal fluid due to a rupture of the fallopian tubes [21]. Findings that are relatively easy to assess include the presence and location of a gestational sac, the measurement of the crown–rump length in the first trimester (Fig. 2), fetal viability (Fig. 3), multiple pregnancy (Fig. 4), any pathological placental location such as placenta previa, abnormal amount of amniotic fluid (oligo- or polyhydramnion) or a shortening of the cervical length. All these circumstances can greatly affect both maternal and fetal morbidity and mortality, especially in low-income settings where medical care is limited.

In gynecology, POCUS can assist to identify the reason for abdominal pain, bleeding or abdominal distension or in defining a pelvic mass. It is possible to record uterine shape and position (anteverted vs retroverted) (Fig. 5), presence of fibroids, confirm the location of intrauterine contraceptive

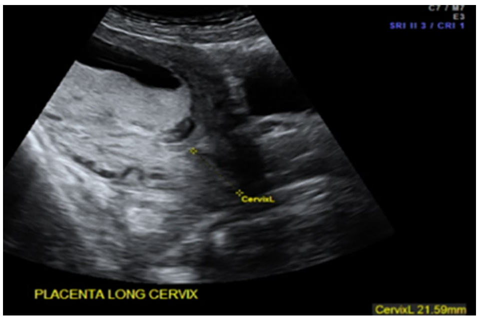

Fig. 1 Determination of the cervical length in the second trimester (TA view)

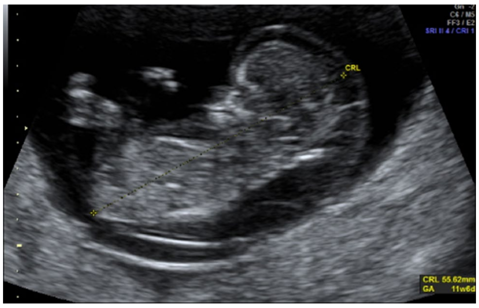

Fig. 2 Fetus with cystic hygroma and measurement of the crown–rump length in the first trimester (TA view)

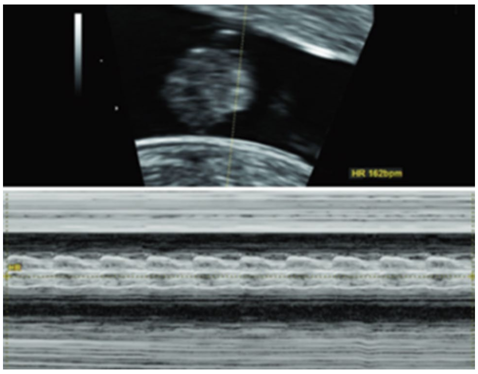

Fig. 3 Presentation of the fetal viability in the first trimester

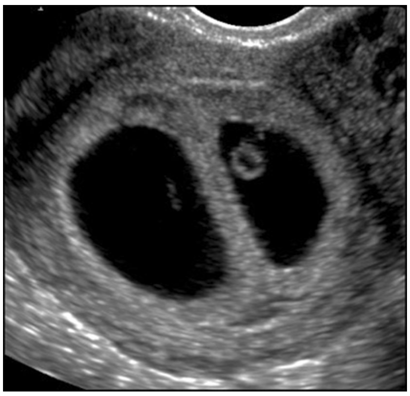

Fig. 4 Dichorionic–diamniotic twins showing a lambda sign in the first trimester

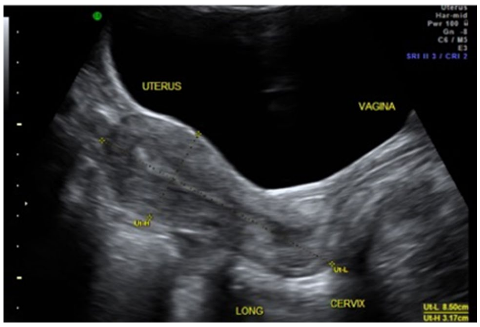

Fig. 5 Identification of the uterine position (sagittal view from TA)

Fig. 6 Confirmation the location of intrauterine contraceptive devices in situ (TA)

devices (Fig. 6), measure endometrial thickness, detect polyps or blood/fluid in the cavity. It is also useful to visualize ovarian cysts, which may be actively bleeding, torted [21] or hemorrhagic, tubal pathology such as a hydrosalpinx (Fig. 6) and other forms of pelvic inflammatory disease [22, 23]. Even the therapeutic management of various symptoms can depend on ultrasound findings such as size and location of tubo-ovarian abscesses, where treatment can be adapted depending on the findings. There have been cases in the literature where ultrasound-guided drainage of gynecological abscesses has shown a low complication rate [24] and where the use of POCUS has shown an immense reduction of clinical complications [25]. However, it should be kept in mind that a negative finding on POCUS is not proof of the absence of a possible severe diagnosis [29] (Fig. 7).

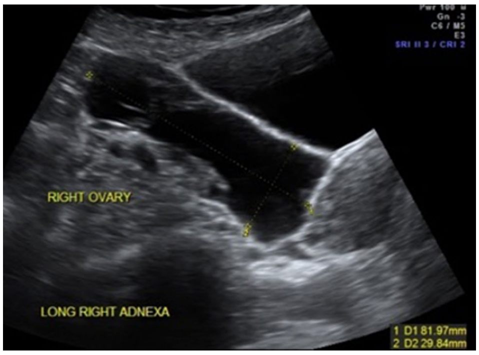

Fig. 7 Right hydrosalpinx in a patient suffering from pain

Limitations of POCUS in OBGYN

One of the limitations of POCUS in OBGYN is the limited availability of transvaginal ultrasound probes. Although the transabdominal approach of scanning the pelvic region is used in the majority of POCUS examinations, the transvaginal (TV) approach is the preferred method of assessment in gynecology as well as in early pregnancy due to its superior results [26]. This is due to the use of a higher-frequency (7.5–12 MHz) transducer as well as the anatomical approach, which allows for closer contact with the organs of interest.

The current literature reveals a lack of knowledge regarding the application and methods of POCUS in OBGYN, although ultrasound is already widely used in the management of obstetric and gynecological emergencies. In countries where ultrasound is performed by radiologists or emergency physicians there is also a perceived lack of confidence by obstetric specialists in POCUS studies performed by emergency clinicians [33]. A survey investigated the confidence in scans done by internal medicine specialists and concludes that there is a paucity of highly qualified POCUS training in the field of emergency medicine [27].

Limited research has been performed in the field of POCUS among OBGYN specialists, particularly the level of proficiency and confidence in this modality and the efficiency of training sessions [28].

New residents in particular lack the theoretical and practical knowledge, which is required in daily clinical routine, even though there are the ones performing most of the initial physical and ultrasound examinations. The literature concludes that much practical training and a high frequency of supervision is necessary to master clinical skills [29]. The authors of these studies suggested that a better understanding of the training that is undergone by emergency physicians may inspire more trust and confidence in the results leading to a better credibility of the images and improve clinical decision-making processes [27].

Need for POCUS programs in OBGYN?

The major issue concerning the practice for POCUS is its training within a clinical facility with trained personnel and equipment. It is acknowledged that guidelines are needed to establish the use of POCUS in a safe and effective way [30].

For the implementation of ultrasound training for OBGYN residents, a core curriculum is needed. This must contain clear learning objectives and well-defined outcome measures [31]. Such a curriculum was introduced by the European Board and College of Obstetrics and Gynaecology (EBCOG) within the last years [31]. Nevertheless, appropriate ultrasound and interpretation skills are needed by the examiner and, thus, carefully selected evaluation and teaching tools have to be assessed for these trainings [32]. A curriculum also has to be developed with local needs in mind, e.g., there are data suggesting that only one fifth of OBGYN residents are actually planning to perform or interpret obstetric ultrasound studies in their postgraduate training in the USA [29].

At the moment, there are no POCUS programs concerning OBGYN offered in Europe. The International Society for Ultrasound in Obstetrics and Gynecology (ISUOG) offers courses for healthcare practitioners and has a web-based learning platform (https://www.isuog.org/education.html), but this is not focused on point-of-care applications.

In Germany, training mainly consists of various DEGUM-approved courses especially teaching fetal duplex sonography and fetal echocardiography or IOTA-certification courses.

Current recommendations for the DEGUM Level I (for fetal ultrasound) study go beyond the minimum requirements of current maternity guidelines; they are much better suited to the current requirements of a second-trimester ultrasound. It enables qualified DEGUM Level I investigators to perform a ultrasound screening exam. These recommendations also define the requirements for advising pregnant women in the scope of ultrasound examinations, as well as the prerequisites for obtaining the DEGUM Level I qualification [32].

Besides the high-qualified educational programs an OBGYN POCUS program should focus on specific clinical indications such as the identification of intrauterine pregnancy, the diagnosis of acute pelvic pain as a common presenting complaint, ruptured ectopic pregnancy or pelvic inflammatory disease and tubo-ovarian abscess. Thus, the benefit of establishing a POCUS program lies in its interdisciplinary expandability. In addition to the training of applications in the field of OBGYN, a POCUS course would also include the rapid sonographic diagnosis of pneumothorax, free fluid or the differential diagnosis of flank pain which is not taught in the current OBGYN programs in Germany [9].

In the field of emergency medicine, certain OBGYN applications are essential. In emergency clinical care, the determination of intrauterine pregnancy in the first trimester and the detection of fetal heartbeats are crucial and of great clinical importance. The diagnosis of an ovarian cyst or tubo-ovarian abscess is not essential as national and international needs assessments have shown [33].

In a third world setting, POCUS takes on a different perspective. Patients may have to travel long distances to access medical care. Many cannot afford the cost of transportation to a medical facility. There, POCUS could be used to identify high-risk patients who can be referred to regional hospitals for further management. Thus, a key feature of POCUS is that it is not a replacement for comprehensive ultrasound practice, but a focused ultrasound examination often performed under suboptimal conditions and with time limitations [28].

Conclusion

POCUS is a clinical examination performed by the attending physician and is seen as an extension of the physical exam to gain information that influences the patient's management and diagnosis. It is not a detailed ultrasound examination, and may provide only limited information, but can be used for the investigation of various, potentially severe gynecological and obstetrical symptoms.

The continuing development of portable ultrasound devices that are considerably cheaper than conventional ultrasound machines might facilitate access of more patients to ultrasound in the future. Standardization of training, ongoing education and assessment of practitioners performing POCUS is needed to establish its widespread uptake successfully. The main limitations for any implementation of POCUS trainings include access to tutors, time restriction and a lack of access to suitable and standardized POCUS equipment.

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Die Gesundheitsversorgung aus der Ferne, auch bekannt als Telemedizin, hat sich in den letzten 50 Jahren entwickelt und die Art und Weise, wie die Gesundheitsversorgung weltweit erbracht wird, verändert. Ihre Integration in zahlreichen Bereichen ermöglicht eine hochwertige Versorgung, die die Hindernisse der geografischen Entfernung, des fehlenden Zugang zu Gesundheitsdienstleistern und Kosten überwindet. Als sehr wirksames Diagnoseinstrument hat die Anwendung des Ultraschalls in der Telemedizin in den letzten Jahren erhebliche Fortschritte gemacht, insbesondere in einkommens- und ressourcenarmen Gebieten. Die Literatur in Pubmed aus den Jahren 1960-2020 wurde mit den den Stichworten "ultrasound", "telemedicine", "ultrasound remote" und "tele-ultrasound" ausgewertet, um eine eine SWOT-Analyse (Stärken, Schwächen, Chancen und Risiken) durchzuführen. Bei der Betrachtung der Stärken und Chancen betonten wir praktische Aspekte, wie die Nützlichkeit und die Kosteneffizienz von Tele-Ultraschall, außerdem die Aspekte der medizinischen Ausbildung im Bereich Tele-Ultraschall. Bei den Schwächen und Bedrohungen konzentrierten wir uns auf Probleme, die nicht sofort gelöst werden können, die einer sorgfältigen Prüfung oder Weiterentwicklung bedürfen, wie z. B. eine neue Software, die noch nicht kommerziell verfügbar ist.

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Review

Ultrasound in Telemedicine: A Brief Overview

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Abstract: The delivery of healthcare from a distance, also known as telemedicine, has evolved over the past 50 years, changing the way healthcare is delivered globally. Its integration into numerous domains has permitted high-quality care that transcends the obstacles of geographic distance, lack of access to health care providers, and cost. Ultrasound is an effective diagnostic tool and its application within telemedicine has advanced substantially in recent years, particularly in high-income settings and low-resource areas. The literature in Pubmed from 1960–2020 was assessed with the keywords "ultrasound", "telemedicine", "ultrasound remote", and "tele-ultrasound" to conduct a SWOT analysis (strengths, weaknesses, opportunities, and threats). In addressing strengths and opportunities, we emphasized practical aspects, such as the usefulness of tele-ultrasound and the cost efficiency of it. Furthermore, aspects of medical education in tele-ultrasound were considered. When it came to weaknesses and threats, we focused on issues that may not be solved immediately, and that require careful consideration or further development, such as new software that is not yet available commercially.

Keywords: ultrasound; telemedicine; eHealth; tele-ultrasound

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1. Introduction

The term telemedicine was coined in the 1970s to describe the practice of delivering health care services through the use of information and communications technology, whereby geographic distance is not as constraining, as in the case of traditional medical practice. Telemedicine is not only used to exchange valid information for the diagnosis, treatment, and prevention of disease and injuries and research and evaluation, but also for the continuing the education of healthcare providers to advance individual and community health [1,2].

Telemedicine has been shown to improve access to healthcare and reduce costs, especially in areas with a limited healthcare infrastructure due to geographical barriers [3]. Recently, increased digitalization and the development of telehealth applications have finally reached the field of medical imaging. As telemedicine has evolved over the last few decades, ultrasound technology matured in parallel [4]. Ultrasound became a bedside tool in the 1990s that physicians, such as those who work in the emergency department, could use regularly because it is a fast, robust, and reliable way of determining a patient's status at the outset of treatment. Tele-ultrasound is defined as the use of ultrasound with telecommunications and/or an additional instructor who is telemedically connected to the process. The utilization of tele-ultrasound has been rapidly increasing worldwide since the 1990s and is commonly used for emergency, abdominal, and obstetrical ultrasound by general practitioners in remote areas worldwide. One of the beneficiaries of this is other doctors, but in a broader sense, it benefits patients as well. Moreover, it can be a cost-saving measure as it eliminates both long transportation times and extra doctor visits. A lack of access to ultrasound doctors, despite technological advancements and mobile devices with high bandwidth that allow for seamless live-image transmission, is a concern in both low-income and high-income countries. Moreover, the main challenge in telemedicine remains an organizational one, knowing how and when to take advantage of the technology.

Tele-Ultrasound in a Historical Context

According to the World Health Organization (WHO), in clinical situations, medical imaging is needed to make a diagnosis in 20–30% of cases, and ultrasound and/or conventional radiography are sufficient for 80–90% of those cases. However, two thirds of the world population does not have any access to medical imaging [5].

The beginnings of tele-ultrasound date back to the era of space exploration in the 1960s, when the first remote ultrasound scans were carried out on astronauts with remote guidance from experts in the Mission Control Center [6] (Figure 1). Those ultrasound systems were capable of high-definition sonographic imaging for the cardiac, vascular, general, abdominal, thoracic, and musculoskeletal systems, among others (Ashot 2006).

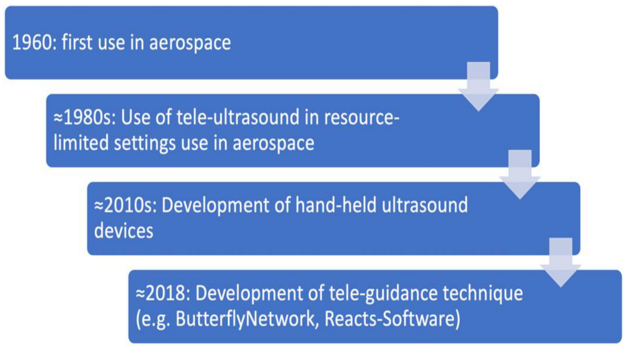

Figure 1. Timeline of use of tele-ultrasound.

The technology remains relevant in aeronautics and recently several studies have assessed the use of ultrasound by non-physician crew members at the International Space Station, which entailed prior training in ultrasound [6–10].

From space, the focus has shifted to earth. Here, especially in remote areas in New Zealand and Sub-Saharan Africa, tele-ultrasound has proven successful. Focusing mainly on emergency ultrasound [11] and Point-Of-Care Ultrasound (POCUS), it has been shown that remotely-guided Focused Assessment with Sonography for Trauma (FAST) ultrasound examinations with minimally trained health care workers are possible and effective [12,13]. In obstetrics and gynecology, several successful prenatal tele-ultrasound projects have been described in literature [14,15]. Many countries harbor only a small number of qualified fetal-medicine specialists who are capable of pre-natal ultrasound imaging, which does not adequately cover demand, but which is highly significant in diagnosing and preventing potential birth defects. Studies, mainly from remote areas such as rural Australia, have tried to identify the need for fetal therapy [16].

Tele-ultrasound performed in resource-limited settings can produce satisfactory images of diagnostic relevance which have an impact on medical treatment and outcomes [17].

2. Materials and Methods

A systematic review of the literature was conducted. The databases searched were Medline (1950 to October 2020) and Embase (1980 to October 2020), the Cochrane Library, all sections, and the Web of Science with Conference Proceedings (1970 to 2020). The searches were not limited by language. Auto-alerts in Medline were also run during the course of the review. Reference lists of relevant articles were also checked.

All relevant randomized controlled trials (RCTs) or quasi-RCTs were included. Due to the small number of RCTs, we also included nonrandomized studies (NRSs). Prospective observational studies with controls, retrospective matched-pair studies, and comparative studies from well-defined registries/databases were also included.

The terms to be examined were "ultrasound", "telemedicine", "ultrasound remote", and "tele-ultrasound", which helped to complete a SWOT (strengths, weaknesses, opportunities, threats) analysis (Figure 2).

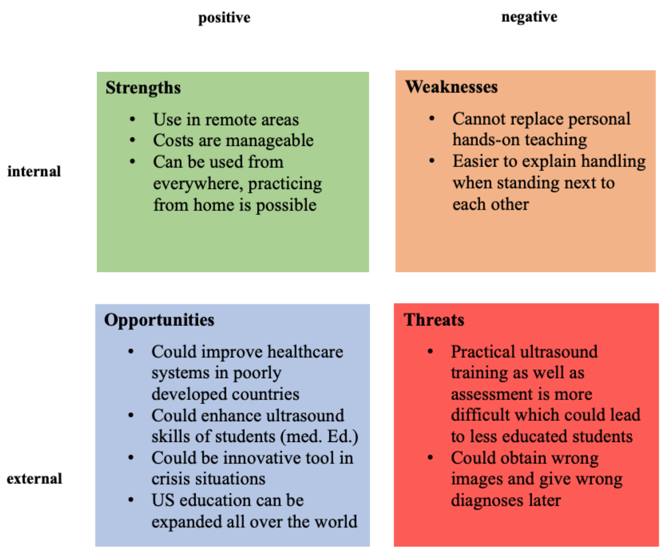

Figure 2. SWOT analysis of the use of tele-ultrasound.

Strengths and opportunities were considered based on practical aspects such as the practicality of using tele-ultrasound and cost efficiency. Additionally, aspects of medical education related to tele-ultrasounds were discussed.

When we analyzed weaknesses and threats, we focused on issues that are unlikely to be resolved immediately and which may require thorough consideration or further development, such as new software that has not yet been commercially released. All articles were screened for positive statements on approval by a local ethics committee, adherence to guidelines for animal care, and/or obtaining informed consent.

The present study is a review of previously published studies, and institutional review board approval and patient consent were not necessary. Only human studies with a full text in English were assessed for inclusion. Studies without detailed methods and results sections were excluded.

3. Results

3.1. Practicality of Use

Tele-ultrasound can be used in urban as well as in rural areas. It can improve the healthcare system and patient outcomes, especially in under-resourced areas [17]. From the point of view of medical education, it can enhance ultrasound skills and establish a basic knowledge of ultrasound. By expanding this method with tele-applications, practical ultrasound could be taught anywhere in the world.

In times of pandemics, such as COVID-19, with social distancing regulations and isolation measures, it can help to ease the pressure on healthcare systems by providing diagnostic alternatives. Rapid technical development and competition in the field of medical software engineering have made the cost of tele-ultrasound manageable. Even low-cost, readily available tools such as web interfaces or commercial messenger tools can be used for tele-supported ultrasound, with the advantage of being independent of any special setting and providing the flexibility to perform ultrasound when and wherever it may be necessary [18]. Recently, new software applications have been introduced that support the teaching of knobology and handling of the probe. Thus, one can even practice at home, independently of any course sessions (Figure 3).

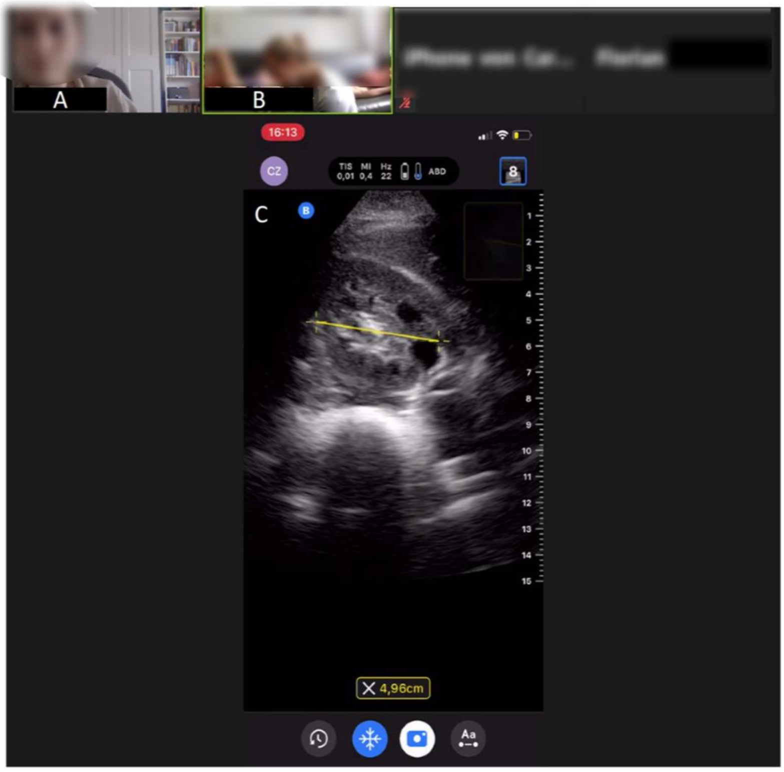

Figure 3. Ultrasound image from a tele-didactic ultrasound teaching study on abdominal ultrasound from the medical faculty of the University of Bonn, Germany. (**A**) Peer tutor, (**B**) student exercising ultrasound on another student, (**C**) ultrasound image of the right kidney, which will be improved via tele-guidance by the peer tutor. An experienced ultrasonographer is also online in order to assist if any questions arise.

3.2. Cost Efficiency

In the scenario of real-time tele-ultrasound consultations and tele-education, savings in the conventional costs of patient transfer (e.g., transfer from GP to clinic) and human resources (e.g., clinical specialist in remote areas) need to be balanced against accruing telecommunication costs. An Australian study demonstrated that tele-ultrasound can result in a net saving of AUD 6340 and, at the same time, enabled almost four times the number of consultations than if the service had not been available [19]. In this study, a real-time fetal tele-ultrasound consultation service had been implemented and integrated into the daily clinical practice. Patients in Townsville could be assessed by subspecialists in Brisbane, 1500 km away, using the service. Ninety percent of the babies born during the 90 tele-ultrasound consultations for the first 71 patients showed good outcome data. The existence of all key anomalies and diagnoses was established in this study. Without telemedicine, 24 of the 71 patients would have been physically referred to Brisbane. Thus, this study underlined the cost effectiveness of the practice in a rural region.

As technology improves, wireless networks and cell phone access become more reliable, and companies such as Apple, Skype and many start-ups provide commercially available real-time audiovisual software in compliance with patient protection laws such as the American HIPAA ("Health Insurance Portability and Accountability Act"), making tele-ultrasound a feasible proposition.

Cost is a commonly expressed concern regarding tele-ultrasound with a special emphasis on the need for affordable tele-ultrasound platforms to make its use feasible. In the literature, numerous studies have used telemedicine platforms with open-source, low-cost, commercially available software such as over-the-counter hardware and low-cost portable ultrasound machines to minimize costs. Two studies explored the issue from the patients' perspective and found that the introduction of tele-ultrasound was associated with lower out-of-pocket costs for the patient due to a reduced need for travel to larger medical centers with formal imaging capacity [15,20]. In another study, e-learning was found to be more effective than conventional education and superior to self-learning for enhancing novice learners' ultrasound technical skills without increasing their workload [21].

3.3. Medical Education

In terms of medical education, e-learning can serve as both a self-study tool, as well as a teaching device, when used in conjunction with colleagues or supervisors. With the emergence of faster network technology (5G/6G) and mobile app platforms for live interaction and handheld ultrasound devices, tele-ultrasound and new fields of applications in pre-clinical settings and outpatient areas such as midwifery, geriatric facilities, and therapeutic use will be enabled with these developments [22].

The existing literature indicates that e-learning can provide an effective way of improving educational outcomes for healthcare professionals. Several studies have shown that tele-learning methods lead to similar results to traditional, face-to-face, teacher-centered instruction [23]. Especially when it comes to the field of tele-ultrasound, didactic concepts are particularly important. Theoretical ultrasound knowledge can be learned using a "flipped classroom", a didactic format of blended learning, whereby students acquire knowledge at home and put it into practice during classes. In the past, attempts to offer targeted, individualized learning environments were abandoned due to the excessive expenditure of money. Nowadays, software-based, highly individualized learning is the norm rather than the exception and has shifted the paradigm. In this ongoing educational evolution, tele-ultrasound devices have several crucial advantages over traditional stationary ultrasound systems. Tele-ultrasound devices are connected to the internet, and interaction between every active participant is made easier, which simplifies communication and ideally speeds up the learning process. The internet, of course, provides access to a plethora of teaching and learning software. The combination of being continuously interconnected, elaborate software, and sufficient computing power has paved the way towards a personalized learning experience. The latest applications and web-based learning platforms can observe and track user profiles. In this way, individual learning behavior can be analyzed and optimized. Especially, theoretical ultrasound knowledge and knobology can be taught in this manner.

However, practical tele-guided ultrasound teaching and assessment comes with costs and challenges. In addition to purchasing the ultrasound equipment, the teacher and student need a video-based platform to show and see the student's performance and the position of the transducer. Furthermore, the real-time sonogram must be streamed in order to give the student instructions during the training. However, the limited evidence base of this relatively new field of medical education demands further research to corroborate its efficacy in comparison with conventional teaching methods (Table 1).

Table 1. Virtual ultrasound education requirements.

Dimension	Requirement	Remarks
	Theoretical teaching	
Propaedeutics, sonoanatomy, knobology, image optimization	Teaching material available and accessible -live -on demand Theoretical lectures, how-to videos, annotated image material with physiological variants and pathological findings Interactive elements, questionnaires, quizzes In live (real-time) formats, sufficient internet bandwidth required	Availability via videoconferencing platforms, video repositories, or learning management systems (LMS) preferred Especially in videoclips (cine-loops), smooth display during online lectures often limited by internet connectivity and bandwidth issues
	Practical teaching	
Image acquisition	Storage capability for still images, clips for asynchronous review Annotations possible Two-way communication between learner and educator Video-based real time instructions Artificial intelligence elements (optional) Augmented reality elements (optional)	Multiple communication pathways for two or more learners, collaborative learning optional (videoconference) Availability of probands limited, self-scanning possible in some pocus modalities
Image interpretation	Annotated image material with physiological variants and pathological findings for pattern recognition Active expert review of images Structured feedback In patient cases, corresponding other imaging/diagnostic modalities for confirmation and cross-reference of ultrasound findings	
Tracking and assessment of learning pathway	Ongoing quality assurance Structured assessment of learning progress Tracking capabilities in learning system	
Miscellaneous	Data protection regulations followed	

The most common components such as the handling and orientation of the probe, as well as image adjustments, may be evaluated with video footage that is recorded and reviewed afterwards or via a live stream.

These applications can be upgraded by augmented reality devices and experimental visual guidance tools that enhance the tele-guided experience and enable a more realistic method of learning [24]. Visual guidance is a computer-assisted method of demonstrating to an examiner the movement of the ultrasound probe as it is manipulated over a patient's body toward a desired anatomical location.

The latest technical advancement in the field of tele-ultrasound is tele-guided ultrasound, which enhances and enables tele-educational tools in a more precise way. Tele-guided ultrasound means that someone is controlling the ultrasound probe and has access to all device settings remotely. For assessing not only image quality, but also the proficiency of the tele-mentored ultrasound image acquisition some studies have combined different tools.

Furthermore, progress is being made in educational tele-guidance tools. These serve as image quality indicators that provide real-time feedback from the physician on the healthcare worker's scan technique. These tools aim to improve the quality and speed of the captured images. Thus, education in medical ultrasound can be expanded in remote areas if basic equipment (US machine, Internet, and telemedicine software) is available.

As an example of the use of tele-ultrasound in medical teaching, a tele-didactic ultrasound course was designed by Höhne et al. [25] in light of the current COVID-19 pandemic and the end of classical classroom teaching, which was previously considered vital in ultrasound training. The purpose of the study was to determine if online ultrasound teaching was effective. It also aimed to identify a suitable evaluation approach for evaluating US skills from afar. This pilot study demonstrated the effectiveness of online lectures in the context of ultrasound medical education. Furthermore, it illustrates that teleguided ultrasound training is feasible and should be addressed in medical schools, as well as the learning possibilities of tele-digital ultrasound.

3.4. Weaknesses and Threats

As far as weaknesses and threats are concerned, we analyzed issues that might need further development or deep consideration, such as new software that is not yet commercially available in comparison to traditional ultrasound (Table 2). Generally, in a tele-scenario with a remote expert, securing the multidimensional problem of "transducer angles", "transducer position", "patient body posture", and "patient breathing state" may be difficult. Furthermore, the device settings, device type, and transducer type all have an impact on whether or not a representation is useful. As a result, the use of tele-ultrasound may be contingent not only on the technological infrastructure and individual abilities of the two linked examiners, but also on the capacity of the two remote persons to interact successfully as a team.

Table 2. Advantages and disadvantages of conventional ultrasound versus tele-ultrasound.

-	Traditional Ultrasound Teaching	Tele-Ultrasound Teaching
Image acquisition	Trained provider	Untrained provider with real-time remote expert supervision
Image optimization	Directly possible by expert provider/educator, including manual intervention and correction of probe movements	Indirectly possible via verbal commands by expert provider/educator
Operation of complex ultrasound applications/functions/measurements	Direct	Not possible or indirect
Image interpretation	Clinical context known by local provider, supported by personal impression, direct correlation possible	Clinical context must be communicated, personal impression limited, correlation limited
Situational perception	Physical presence of supervisor	Tele-presence, perception reduced to 2D visual and audio
Integration into patient management	Direct interaction of provider with team (e.g., when pausing chest compressions during CPR)	Indirect interaction
Availability in austere settings	Reduced in terms of equipment, providers, experts and educators. Sometimes unavailable.	Enhanced by technology
Availability of experts	Lower Limiting factor in education. Need travel, accommodation, time.	Higher Low threshold, no travel time.
Equipment requirement	Ultrasound device	Ultrasound device and transmission technology Network capability
Additional expenses	Expert funding, travel, accommodation	No travel and accommodation costs
Geographical distance	Device with patient and diagnostician confined in very local space	Distance between tele-medicine sites only limited by data transfer range
Time lag	None	Ranges between none and significant
Data transfer	Normally wired and a data transfer rate in the gigabit range	Wireless or wired, with mega or gigabit per second speeds.
Data security	Local storage, general data protection considerations	Special considerations required, especially in case of transmission and processing of health-related personal data across different legislative spaces and IT-solutions
Legal framework, liability	Local framework applies	Special considerations required, as provider and supervisor may operate under different legislations

3.5. Image Quality

A quality assessment tool was developed a few years ago to standardize sonographic B-images [26]. As an important feature, it attempts to quantify the sonographer's influence with regard to the final image quality. This method can also be adopted for tele-ultrasound. Furthermore, the examiner's skill, as well as the patient's current state and cooperation, are all known to influence ultrasound imaging. Gallstones, for example, may only be scanned when the patient is in a precise inspiratory position and with extremely specific transducer angles and placements. As a result, even in the absence of tele-transmission, the imaging result is not always consistent. When two examiners look at the same patient, they will almost always produce different visuals and, in some situations, diagnoses. This general weakness naturally also has an influence on the use of ultrasound in telemedicine and must always be taken into account in all applications.

The latest developments in the field of telecommunication have paved the way for several attempts to test tele-ultrasound with mobile device application [22] or via web-based applications [27]. These studies have shown that commercially available video chat software can transmit high-quality and clinically useful ultrasound images. For nearly every anatomic location assessed in these studies, images obtained by means of this method were non-inferior to images obtained directly from a stationary ultrasound machine. There were also mobile ultrasound apps that went beyond simply projecting live images, with built-in tools to grade the images that study participants took and determined whether they passed or failed.

Data transfer rates have come a long way since the early stages of telemedicine two decades ago, when devices with a bandwidth of 2 Mbit/s were used successfully for obstetric tele-ultrasound [15]. Nowadays, the transmission of real-time ultrasound video footage to a remote iPhone using inexpensive technology is feasible, as shown in the literature. It can be accomplished without the loss of image quality and a minimal delay and works even with 3G mobile connection [28].

3.6. Safety of Data

As the value of personalized data increases and cheap data storage is abundantly available, telemedicine companies can record and analyze a complete set of parameters longitudinally in real-time, which is an unprecedented feat in the history of medicine. However, patients' access to and control over these stored data are not always guaranteed. In Western societies, where people are wary of privacy violations, these developments should spark an intense public discourse, which seems to lag behind the staggering pace of the technological advancement.

In a tele-guided setting, there are several ways to document the obtained images and results. There are various ultrasound documentation programs on portable devices and guidelines on how to appropriately document an ultrasound examination [29]. Moreover, there are cloud-based monitoring systems that do not require bedside supervision and documentation, which may enhance the ability of physicians to study and document ultrasound images [30]. Data protection is an important issue related to these cloud-based documentation applications. Although recent cloud-based products comply with EU regulations regarding data privacy and protection, this remains a hot topic.

4. Artificial Intelligence and Tele-Ultrasound

Excellent-quality ultrasound images serve as the foundation for expert interpretation. Artificial intelligence (AI) is emerging to provide a means for autonomously gathering images, even for the uninitiated. Obstetricians have perfected the art of capturing and evaluating fetal images for pregnancy monitoring. Startup enterprises in the United States and Europe have acquired regulatory approval to advise inexperienced clinicians to take images for clinical purposes using AI guidance. The ultrasound probe is put on the patient after entering information such as the patient's height, weight, and gender. The clinician is then instructed on how to move the probe (clockwise, counterclockwise, up, or down), and the picture is autocaptured as soon as the best image is detected.

There is still a scarcity of validation data for high-quality images acquired using this method. According to trials conducted by nurses with no previous echocardiography experience who used this equipment on hundreds of patients, high-quality video photographs may be obtained well over 90% of the time. That result holds true for images of organs that are not constantly moving, such as the heart, and should be more suited for AI algorithmic direction. Researchers are collecting massive amounts of ultrasound images from a range of patients to assist and drive algorithm development even further. These images will be linked to ground-truth diagnoses and verified clinical results. The implications of AI-assisted ultrasound guiding may be crucial for all practitioners in the future. For example, an emergency room doctor may snap a photograph of any region of a patient's body and then send the video loop to a radiologist for interpretation. Deep learning algorithms for exact ultrasound interpretations are being investigated in the meantime; however, they are still in the early phases of development [31]. The advantages might be extended to rural regions, as well as middle- and low-income nations, where worker capacity or skill in image capture may be limited or non-existent, democratizing imaging technology. More widespread clinical use of smartphone ultrasonography has begun in rural Africa and India, and AI guidance for image capture may be adopted soon. In the COVID-19 outbreak, new uses of AI guidance have lately been seen [32]. Researchers are using deep learning approaches to develop algorithms for automating acquisition and severity evaluations to help in real-time clinical decision-making. If fully confirmed, the easily available objective image data might assist in the diagnosis, triage, and surveillance of seriously sick patients. In the future, a patient with heart failure may transmit to their doctor a clinical grade echo of their heart, whereas a person with acute stomach discomfort might obtain targeted photographs that indicated a kidney stone.

5. Discussion

The rapidly evolving technology will likely promote the widespread implementation of tele-ultrasound procedures, especially in remote areas and in the first-responder setting. Further investigation of real-time image transfer and communication paradigms in prehospital scenarios and practical applications is warranted. Pocket and other portable ultrasound machines are the most commonly used ultrasound devices for tele-ultrasound. The potential impact of tele-ultrasound is substantial when considering both the scope of clinical fields of application (e.g., respiratory failure, hemodynamic compromise, procedural guidance) and the number of stakeholders (e.g., patients, providers, health systems). Technologically speaking, ultrasound machines have become smaller, more portable, and durable, and the relative cost has decreased dramatically. Smartphones are ubiquitous, and dozens of software applications run seamlessly on them simultaneously. Therefore, smartphones are capable of functioning as affordable handheld telemedicine platforms. Finally, global connectivity is steadily increasing, particularly wireless cellular and internet access. These advances have made tele-ultrasound feasible and have given it a durable competitive advantage compared to conventional ultrasound, which will boost its application in the near future.

Nevertheless, tele-guided ultrasound education also carries some weaknesses and risks. No tele-ultrasound module can fully replace real hands-on learning experiences. Although one can try to teach the handling of the probe via tele-guidance, it is easier to do this physically next to a student. The digital distance, which provides some benefits, appears as a barrier that cannot be eradicated when using tele-ultrasound. Therefore, tele-ultrasound is an option for remote or poorly developed areas, as well as an innovative tool in crisis situations.

The practical usefulness of tele-ultrasound has become more entrenched and advanced in the medical setting in recent years. A distinction must be made between tele-ultrasound and the pure transmission of ultrasound images, which does not have the aspects of real-time data transmission with a corresponding second examiner. Particularly in the field of medical teaching, there is a specific difference between these two modalities.

Tele-ultrasound is on the advance, especially in the next few years, due to further progress in digitalization and technical miniaturization. Global pandemics, such as the current COVID-19 pandemic, have particularly marked and shaped this use of technology.

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Hintergrund:
Bei der Früherkennung von Arthritis, wie z. B. der Psoriasis-Arthritis, spielt die muskuloskelettale Ultraschalluntersuchung (MSUS) schmerzhafter Gelenke eine wichtige Rolle bei der Diagnose. Pathologische Befunde können bei der klinischen Untersuchung übersehen werden, vor allem wenn sie von nicht geschulten Ärzten durchgeführt werden.

Methoden: Um den Grad der MSUS-Expertise der Teilnehmer zu beurteilen, wurde ein Fragebogen SurveyMonkey® vor dem Kurs ausgefüllt. Das Kurskonzept (MUDE-Protokoll) umfasste nur die wichtigsten Ultraschallabschnitte aller Gelenke und konzentrierte sich auf den Nachweis von Gelenkergüssen und Hyperperfusion. Der Kurs bestand aus drei Modulen und wurde über sechs Monate durchgeführt. Das tragbare Butterfly IQ®-System in Kombination mit einem Apple iPad wurde den Teilnehmern zur Verfügung gestellt, um zwischen den Kursen üben zu können. Die abschließende Lehrevaluation wurde in Form einer objektiv strukturierten klinischen Prüfung (OSCE) durchgeführt.

Ergebnisse:
Zwölf Dermatologen nahmen teil. Die Umfrage ergab keine Vorkenntnisse über MSUS. Die mittlere Gesamtpunktzahl aller Teilnehmer an der OSCE betrug 21,86 (87,44 %) von insgesamt 25 Punkten, was der Schulnote gut entsprach.

Schlussfolgerung:
Das innovative MUDE-Protokoll eignet sich somit gut für die Ausbildung für die Ausbildung von Dermatologen in MSUS, unabhängig von den Vorkenntnissen.

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Establishment and validation of a didactic musculoskeletal ultrasound course for dermatologists using an innovative handheld ultrasound system – the MUDE study (Musculoskeletal Ultrasound in Dermatology)

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Summary

Background: In the early detection of arthritis, such as psoriatic arthritis, musculoskeletal ultrasound (MSUS) of painful joints plays an important role in diagnosis. Pathological findings can be missed during clinical examination, especially if conducted by physicians who are not trained. The objective of this study was to examine a pilot MSUS course designed specifically for dermatologists, the MUDE protocol.

Methods: To assess the degree of MSUS expertise of the participants, a questionnaire using SurveyMonkey® was completed before the course. The course concept covered only the most important ultrasound sections of all joints and focused on the detection of joint effusion and hyperperfusion. The course consisted of three modules and was carried out over six months. The portable Butterfly IQ® system in combination with an Apple iPad was provided to enable practice between the courses. The final teaching evaluation was carried out as an objective structured clinical examination (OSCE).

Results: Twelve dermatologists participated. The survey revealed no prior knowledge of MSUS. The overall score of all participants in the OSCE was 21.86 (87.44 %) out of a total of 25 points, which corresponded to the school grade good.

Conclusion: The innovative MUDE protocol is thus particularly suitable for the training of dermatologists in MSUS, irrespective of prior knowledge.

Introduction

Point of care ultrasound in the diagnosis of many diseases has been proven and established in numerous fields of medicine [1]. Its excellency and wide-spread use are attributed to the absence of radiation, portability, dynamic examination, and low cost [2]. Numerous diseases overlap both dermatology and rheumatology and many can lead to arthritis of one or more joints [3–5]. One of the most frequent is psoriatic arthritis (PsA), occurring in about 30 % of psoriasis patients [6] with prevalence rates of 1.8–2.1 and 2.1–2.5 per 100,000 individuals, respectively [7]. Non-specific musculoskeletal complaints even occur in about 50 % of psoriasis patients [8]. Several publications have emphasized the importance of early arthritis detection and diagnosis of PsA and other arthritis diseases in order to decrease joint disability and reduce referral rates to rheumatologists [9–12]. This process can take months or even years, exposing patients to the risk of developing irreversible joint damage [13].

Musculoskeletal ultrasound (MSUS) can rapidly and accurately detect the typical hallmarks of PsA and other arthritic diseases [14]. It is a common adjunct of an advanced rheumatological examination and a keystone in the diagnosis of PsA and other arthritis diseases. Using MSUS, the physician can often differentiate instantly between inflammatory and degenerative pathologies, which are much more common. Major advances in imaging resolution, capabilities, and cost of MSUS systems now allow physicians access to equipment that provides high-resolution images [15]. Portable ultrasound machines (PUM) such as the Butterfly IQ system® equipped with an iPad or iPhone as a

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monitor facilitate the spread of ultrasound (US) throughout all medical fields and enable diagnosis at the bedside.

This proof-of-concept study aimed to establish and evaluate a modular MSUS course specifically designed for dermatologists (the musculoskeletal ultrasound for dermatologists – MUDE protocol), using a modern high-resolution PUM, in order to facilitate the diagnosis of PsA and other arthritis disorders. It is the first worldwide attempt to conduct an MSUS course specifically adapted for dermatologists, designed according to the widely accepted DEGUM (Deutsche Gesellschaft für Ultraschall in der Medizin - German Society for Ultrasound in Medicine) guidelines for ultrasound teaching [16].

Materials and Methods

Participants and devices

The study was conducted from March 31, 2020 to September 30, 2020. Twelve dermatologists took part in the study. Six were working in the Clinic for Dermatology at the University Hospital Bonn. Of these six, one was a specialist in dermatology and five were assistant physicians. The other six participants were specialists in dermatology, working in private practices in and around Bonn and were members of the PsoNet Bonn/Rhein-Sieg, a network of dermatologists specialized in the treatment of psoriasis. The recruitment was carried out by the department of rheumatology and clinical immunology at the University Hospital Bonn, Germany.

Each study participant was equipped with a Butterfly IQ ultrasound device with an iPad (version 9, display size 10.2" Retina from 2020, Apple, San Cupertino, USA). The ultrasound frequencies range between 1 and 10 MHz in general and 6 to 10 MHz in the musculoskeletal preset. The probe automatically adjusts frequencies according to image depth. This PUM was used in every training session. In addition, to consolidate the newly learned ultrasound skills, participants were also provided with the ultrasound machine during the six months of training to allow further practice between the ultrasound courses (Figure 1a).

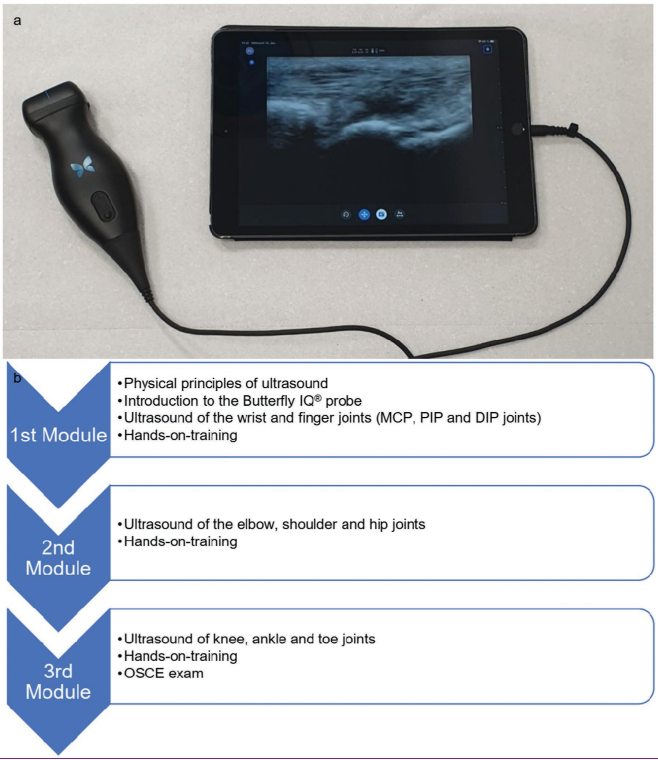

Figure 1 The portable ultrasound machine used in the study and the MUDE ultrasound course module structure. Butterfly IQ ultrasound device with an iPad, display size 10.2", 2020, Apple, San Cupertino, USA (a, b).
Abbr.: MCP, metacarpophalangeal joint; PIP, proximal interphalangeal joint; DIP, distal interphalangeal joint; OSCE, objective structured clinical examination.

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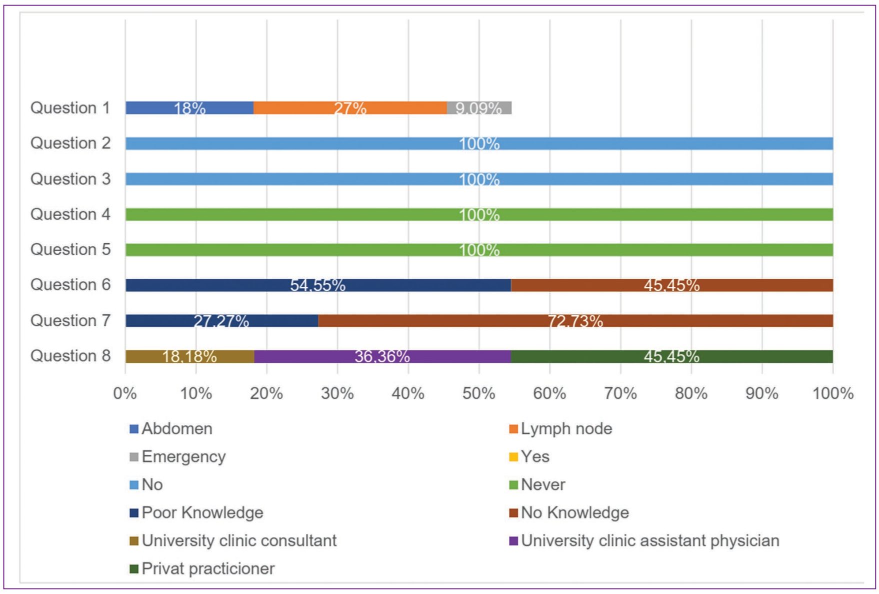

Figure 2 Pre-course survey results. Question 1: Have you ever taken part in a DEGUM-certified ultrasound course? Question 2: Have you been certified by the German Society for Ultrasound in Medicine (DEGUM)? Question 3: Do you have experience in musculoskeletal ultrasound? Question 4: How often have you performed musculoskeletal ultrasound? Question 5: How often have you evaluated ultrasound images of joints? Question 6: How would you rate your own theoretical knowledge of musculoskeletal ultrasound? Question 7: How would you rate your own practical skills in musculoskeletal ultrasound? Question 8: Do you work at the University Hospital Bonn or in a private practice?

Pre-course survey on ultrasound knowledge

We prepared a survey utilizing the SurveyMonkey® platform to assess the participants‘ prior knowledge about ultrasonography in general and MSUS in particular. Figure 2 shows the questions and results of the survey.

Medical education tools

We used Kern's six step approach in the development of the MSUS course curriculum [17]. To determine which topics to include in the MSUS curriculum we relied on the following resources:

- The German Society for Ultrasound in Medicine (Deutsche Gesellschaft für Ultraschall in der Medizin, DEGUM) which has an MSUS section. The section defines standard ultrasound planes for each joint.
- The published literature on MSUS skills or algorithms that are crucial for the detection of PsA and other arthritic diseases [18–22].

The MSUS planes identified by the above listed sources were then discussed extensively with board-certified MSUS physicians of the Department of Rheumatology. Clinical members from DEGUM/EFSUMB (European Federation of Societies for Ultrasound in Medicine and Biology) level I–III were heavily involved in the process. Since the learning goals comprised theoretical knowledge as well as practical skills, different educational strategies were blended to cover all areas and aspects. We employed the techniques developed, used, and evaluated by the DEGUM for ultrasound instruction: lectures for the theoretical knowledge and supervised hands-on training for the practical sessions. The units focused on a three-level training curriculum based on the Association for Medical Education in Europe (AMEE) levels: well-founded theoretical knowledge, basic practical skills under guidance, and independent learning of practical skills [23].

Course development

Based on the DEGUM ultrasound course structure, a three-module training concept was developed (Figure 1b).

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The interval between each course was chosen to be two months, resulting in a six-month total duration of this pilot study. To ensure simplicity, we concentrated on the most sensitive ultrasound planes for all joints (Online Supplement 1a–c) regarding the two most important signs of arthritis: joint effusion and synovial hyperperfusion [24, 25] (Table 1).

Each module began with a 60-minute oral presentation of the above-mentioned topics and was prepared and presented by a DEGUM/EFSUMB level III MSUS instructor. Anatomy and landmarks, as well as images of the ultrasound planes, were shown and explained, including possible pathologies in rheumatic and degenerative diseases. Followed by a short 30 min-break, the attendees were given the opportunity to have three hours of hands-on training with an experienced DEGUM/EFSUM level I–III tutor. For this purpose, the twelve participants were assigned to four groups, each consisting of three dermatologists. For training purposes, we arranged the presence of adult, healthy volunteers for each group.

Course Assessment

The efficacy of the MSUS course was measured with various tools. At the end of the course, each participant completed an objective structured clinical examination (OSCE) [26, 27]. The participants were tested by independent raters (two EFSUMB/DEGUM level II and one EFSUMB/DEGUM level III). A practical case study combined with a patient case study was used to guide participants through the exam. This OSCE parcour (Online Supplement 2a–4b) assessed basic skills and pattern recognition in MSUS in a broad range of single tasks. Based on these objectives, task sheets for hands-on procedures, checklists, and scoring instructions were designed. Ten minutes were assigned for each OSCE station, including eight minutes of exam and immediate feedback, and approximately two minutes to walk to the next station.

In each OSCE station, 25 achievable points in the following tasks could be obtained: device handling, knobology, anatomical landmarks, and use of the power-Doppler [28]. This was consistently applied to each OSCE module station. All participants rotated through three OSCE stations, each displaying the content of the three ultrasound course modules. Performance scores were reviewed using the following five-point scoring system: < 60 % (Failed): 5, ≥ 60 – < 70 % (Sufficient): 4, ≥ 70 % – < 80 % (Satisfactory): 3, ≥ 80 % – < 90 % (Good): 2, ≥ 90 % (Very good): 1.

Statistical analysis

Statistical analysis was performed using Microsoft Excel software, version 2009 and with R statistical software (version i386 4.0.2). For quantitative parameters (for example, age of the participants), the mean standard deviation (SD) and range were determined for each. Significant changes were calculated by using t-test, x^2-test, and ANOVA calculation. *P* values less than 0.05 were considered statistically significant. Furthermore, for each OSCE station, mean values with mean SD and specific confidence interval were calculated.

The study was approved by the Ethics Committee of the University Hospital Bonn, Germany. All participants gave written informed consent before participation in the study.

Table 1 Overview of the joints included in the MUDE protocol and the corresponding ultrasound planes.

Joint	Ultrasound plane
MCP, PIP, DIP hand	Dorsal and palmar longitudinal
Wrist	Dorsal longitudinal and palmar transversal
Elbow	Ventral longitudinal humeroradial and dorsal longitudinal
Shoulder	Ventral and dorsal transversal
Hip	Ventral longitudinal
Knee	Suprapatellar longitudinal and medial/lateral longitudinal
Ankle	Ventral longitudinal
MTP, PIP, DIP feet	Dorsal longitudinal

Abbr.: MCP, metacarpophalangeal joint; PIP, proximal interphalangeal joint; DIP, distal interphalangeal joint; MTP, metatarsophalangeal joint.

Results

The mean age of our cohort, which included nine females (75 %), was 39 years (SD ±10 years). The mean time from attaining medical licensure from the German board of physicians (Ärztekammer) was 10.7 years (SD 10.4 years). Eight participants had been specialists in dermatology since a mean duration of 11.4 years (SD 11 years). Four were assistant physicians practicing dermatology for a mean of 3.1 years (SD 1.0 years).

The pre-course survey was answered by eleven of the twelve attendees (92 %). All of the respondents stated to have never performed an MSUS examination or even viewed MSUS images. Poor theoretical and practical knowledge has been outlined in the following queries. Six dermatologists reported having taken part in DEGUM ultrasound courses other than MSUS courses in the past. Three participated in courses for high frequency ultrasound such as lymph node ultrasound, two in courses for abdominal ultrasound, and one in a course for emergency ultrasound. None of the participants possessed a DEGUM/EFSUMB certification

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Table 2 Objective structured clinical examination (OSCE) results for all three stations.

OSCE stations	Mean absolute	Standard deviation	Confidence interval	Mean percentage	Standard deviation	Confidence interval	Grade
1	18.92	± 3.07	16.97–20.87	75.67 %	± 12.27 %	67.87–83.46 %	Satisfactory
2	23.83	± 0.99	23.21–24.46	95.33 %	± 3.94 %	92.83–97.84 %	Very good
3	22.83	± 0.37	22.60–23.07	91.33 %	± 1.49 %	90.39–92.28 %	Very good
Stations 1–3	21.86	± 2.12	16.59–27.13	87.44 %	± 8.49 %	66.36–108.53 %	Good

grade. Detailed graphic presentation of the data can be found below (Figure 2).

Didactic medical findings that define Kern's six-step approach

In the literature, there is extensive support for the requirements that a musculoskeletal sonographer should meet during ultrasound training [29]. This implies that all trainees should undergo at least a basic level of theoretical and skill-based training in MSUS. This is particularly relevant as ultrasound technology becomes more accessible and integral to the diagnosis of PsA [18]. The required assessments consisted of a three-step approach for the participants. This approach is founded upon the incorporated theoretical teaching. Within it, hands-on-training to identify PsA was the major component.

OSCE results

All participants were assessed at three different OSCE stations. A total of 25 points could be scored at each OSCE station. The first station focused on finger, hand, and wrist joints (Online Supplement 2a, b). The points achieved at the first station ranged from twelve to 25 points. This station consisted of four major tasks: handling of the probe, knobology, (precise) visualization of the anatomical target region, and application of power Doppler. The mean total score achieved at the first station was 18.92 (75,7 %) points, yielding the grade 3.

At the second OSCE station, which focused on elbow, shoulder, and hip joints (Online Supplement 3a, 3b. 1, 3b. 2), results ranged from 22 to 25 points, yielding a mean of 23.83 points (95.3 %) and a grade of 1. This station included six different major tasks (handling of the probe, knobology, anatomical target regions shoulder, elbow, and hip, and use of power Doppler).

The third OSCE station consisted of four major tasks (Online Supplement 4a, b) (handling of the probe, knobology, anatomical target regions knee joints, ankle joints, and toe joints, and use of power Doppler). The results from this OSCE station ranged from 22 to 23 points, with a mean of 22.83 points (91.3 %) and the grade 1.

The overall mean score was 21.86 out of 25 (87.4 %), resulting in the grade 2. There was no statistically significant difference between the assistant physicians and the dermatology specialists regarding the OSCE results (Table 2).

Discussion

This is the first study to investigate the individual and practical learning outcomes of physicians in dermatology in a newly developed MSUS course, the MUDE protocol, using a modern PUM following a course concept designed according to the widely accepted DEGUM guidelines for ultrasound teaching [16].

Musculoskeletal ultrasound has been shown to be more sensitive than physical examination for detection of arthritis [30], though it is less sensitive than fluorescence optical imaging (FOI) [31]. Fluorescence optical imaging is an invasive method that is not widely available, whereas MSUS has no such limitations. Several publications emphasize the importance of early arthritis detection and diagnosis in PsA in order to decrease joint disability and minimize the delay in referral to a rheumatologist [32]. Solmaz et al. [33] showed in a pilot study on 51 patients with psoriasis, of whom 20 were diagnosed with PsA, that MSUS, performed by the rheumatologist, is useful in early detection. However, due to the high frequency of nonspecific pain in psoriasis, it is not possible for every patient with psoriasis and joint complaints to be assessed by a rheumatologist. Different screening tools have been developed for dermatologists to identify patients with a higher risk of PsA. However, the limited specificity of these tools restricts their use in clinical practice [34–36]. To date, there have been no attempts to introduce an MSUS course specifically designed for dermatologists in order to enable screening of patients with musculoskeletal complaints.

The present study focused on the training of dermatologists in the most important MSUS standard sections for every joint, following the MUDE protocol, in order to detect joint

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effusion and hyperperfusion of the synovia using a PUM, which, due to its compact design, can easily be transported to the bedside or used in outpatient clinics. The MSUS competency exam contained two components: ultrasound image acquisition and interpretation. Although knowledge of anatomy and pathology as well as the ability to interpret ultrasound images can be tested by a multiple-choice question audit, practical tests of ultrasound examination abilities is the most important method. We therefore used an OSCE format, which has previously been shown, using a comprehensive and reliable OSCE parcour, to be suitable for a broader assessment of the sonographer's competencies [24]. Furthermore, comprehensive checklists have been developed for our MSUS course in order to minimize examiner-dependent deviations [37].

Several studies have shown that a valid MSUS OSCE can be performed using normal anatomy even with blinded experts [38, 39]. These studies have mainly focused on postgraduate training in internal medicine residency programs. To date, no study has examined postgraduate MSUS training for dermatologists. Participants reached an overall grade of 2 (Good), with an overall mean OSCE score of 87.4 %. Our study showed that the MSUS training implemented using the MUDE protocol is suitable for dermatological training. Furthermore, we were able to demonstrate that learning success is independent of the dermatological experience and age of the participant, and requires no prior MSUS knowledge, as revealed by our pre-course survey.

Nevertheless, our study contains several limitations, including the relatively small sample size of twelve dermatologists. This limitation is due to the limited number of PUM devices and the intensive small group lessons during the MSUS course. Additionally, ultrasound examination of the joints was performed under ideal controlled conditions. Furthermore, long-term retention of both functional and theoretical knowledge was not evaluated in the course design [40]. It has previously been shown that longitudinal training of mandatory MSUS knowledge and practice can lead to the acquisition and retention of MSUS skills. Therefore, the present study and training concept must be implemented early to provide residents with a foundation for MSUS skills. These skills can then be developed further and refined in a clinical setting, allowing trainees to build up experience for future practice [41]. We could not assess individual examinees by multiple blinded examiners in order to test for inter-observer reliability in the real course setting. Otherwise, the time required for the OSCEs would have doubled, leading to feasibility issues [42].

Conclusions

This is the first study to demonstrate the efficacy of an MSUS course developed for dermatologists using a modern PUM. Our pilot study revealed that MSUS training in dermatological postgraduate programs is feasible and should be considered for inclusion in postgraduate dermatological education.

A clear improvement in both the dermatologists' knowledge and their practical skills in MSUS was observed during the course. Therefore, our MSUS course concept will enhance the interdisciplinary approach to musculoskeletal pain between dermatology and rheumatology, possibly accelerating its diagnosis. Due to the flexibility of application, PUM devices are optimal for ultrasound education programs. Turning the smartphone or tablet into an ultrasound machine is less time consuming and improves patient care for many rheumatological diseases. Further prospective studies will be necessary to investigate the clinical benefit and the detection rate of arthritis diseases here specifically PsA, by dermatologists using MSUS. Our group is in the process of conducting such a prospective study (the PsoSone study), which is currently being evaluated.

Conflict of interest
Financial support was received from Novartis Pharma.

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Höhne E*, Recker F*, Schmok E, Brossart P, Raupach T, Schäfer VS (2021). Conception and feasibility of a digital tele-guided abdomen, thorax, and thyroid gland ultrasound course for medical students (TELUS study). Ultraschall Med. doi: 10.1055/a-1528-1418.

Einleitung:

Aufgrund der aktuellen COVID-19-Pandemie hat sich ein Großteil der medizinischen Ausbildung auf Onlineunterricht verlagert, was zu Herausforderungen bei der adäquaten Ultraschall (US) Ausbildung führt. Das Ziel dieser Studie war die Konzeption eines telemedizinischen US-Kurses für Medizinstudierende mit der anschließenden Evaluation praktischer Untersuchungskompetenzen.

Methoden:

Zwischen dem 1. April und dem 20. Juni 2020 wurde am Universitätsklinikum Bonn ein tele-medizinischer US-Kurs mit Medizinstudenten durchgeführt. Die Studierenden absolvierten insgesamt sieben Ultraschallmodule, bei denen sie mobile Ultraschallgeräte anwandten. Jedes Modul wurde in einem Flipped-Classroom-Konzept mit der Amboss®-Plattform konzipiert, um den Studierenden die Möglichkeit zu geben, optional zusätzliches E-Learning Material zu nutzen. Als Abschlussprüfung wurde eine objektive Bewertung der US-Kompetenzen (OSAUS) durchgeführt. Zusätzlich wurden die US-Bilder aus Kursstunden und Prüfung mit der B-QUIET Rating Methode bewertet und die dort erreichten Punkte mit den Ergebnissen der OSAUS Prüfung verglichen.

Resultate:

Insgesamt nahmen 15 Medizinstudierende teil. In OSAUS wurden durchschnittlich 154.5 (SD ± 11.72) von insgesamt 175 Punkten erreicht (88.29%). Die OSAUS-Ergebnisse stimmen mit der Punktzahl aus der Bildbewertung mit B-QUIET überein. Die Interrater-Analyse der bewerteten US-Bilder zeigte eine gute Übereinstimmung mit einem ICC (2,1) von 0.895 (95% -Konfidenzintervall 0.858 <ICC <0.924).

Schlussfolgerung:

Die US-Lehre mittels Teleguidance hat sich in dieser Pilotstudie als erfolgreiches Lehrkonzept erwiesen. Dieses zukunftsweisende Lehrkonzept ermöglicht die US-Ausbildung von Medizinstudierenden auch in Zeiten, in denen Präsenzlehre nicht möglich ist. Die digitale Umsetzung mit einem erschwinglichen, tragbaren Point-of-Care-US-Gerät bietet eine unglaubliche Chance, die US-Ausbildung weltweit zu beschleunigen.

Conception and Feasibility of a Digital Tele-Guided Abdomen, Thorax, and Thyroid Gland Ultrasound Course for Medical Students (TELUS study)

Entwicklung und Durchführung eines digitalen telemedizinischen Abdomen-, Thorax- und Schilddrüsen- Ultraschallkurses für Medizinstudierende

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Key words

ultrasound education, tele-medicine, tele-ultrasound, course concept, medical students

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ABSTRACT

Purpose Medical education has been transformed during the COVID-19 pandemic, creating challenges regarding adequate training in ultrasound (US). Due to the discontinuation of traditional classroom teaching, the need to expand digital learning opportunities is undeniable. The aim of our study is to develop a tele-guided US course for undergraduate medical students and test the feasibility and efficacy of this digital US teaching method.

Materials and Methods A tele-guided US course was established for medical students. Students underwent seven US organ modules. Each module took place in a flipped classroom concept via the Amboss platform, providing supplementary e-learning material that was optional and included information on each of the US modules. An objective structured assessment of US skills (OSAUS) was implemented as the final exam. US images of the course and exam were rated by the Brightness Mode Quality Ultrasound Imaging Examination Technique (B-QUIET). Achieved points in image rating were compared to the OSAUS exam.

Results A total of 15 medical students were enrolled. Students achieved an average score of 154.5 (SD ± 11.72) out of 175 points (88.29 %) in OSAUS, which corresponded to the image rating using B-QUIET. Interrater analysis of US images showed a favorable agreement with an ICC (2.1) of 0.895 (95 % confidence interval 0.858 < ICC < 0.924).

Conclusion US training via teleguidance should be considered in medical education. Our pilot study demonstrates the feasibility of a concept that can be used in the future to improve US training of medical students even during a pandemic.

ZUSAMMENFASSUNG

Ziel Das Ziel dieser Studie war die Konzeption eines telemedizinischen Ultraschall (US)-Kurses für Medizinstudierende zu Zeiten der COVID-19-Pandemie mit anschließender Evaluation praktischer Untersuchungskompetenzen.

Material und Methode Es wurde ein telemedizinischer Ultraschallkurs mit Medizinstudierenden durchgeführt. Die Studierenden absolvierten insgesamt 7 US-Module. Jedes Modul wurde in einem Flipped-Classroom-Konzept mit der Amboss-Plattform konzipiert, um den Studierenden die Möglichkeit zu geben, zusätzliches E-Learning-Material zu nutzen, das optional war und Informationen zu jedem der US-Module lieferte. Als Abschlussprüfung wurde eine objektive Bewertung der US-Kompetenzen (OSAUS) durchgeführt. Zusätzlich wurden die US-Bilder aus Kursstunden und Prüfung mit der B-QUIET-Rating-Methode bewertet und die dort

* Elena Höhne and Florian Recker contributed equally (first-shared authors).

erreichten Punkte mit den Ergebnissen der OSAUS-Prüfung verglichen.
Ergebnisse Insgesamt nahmen 15 Medizinstudierende teil. In OSAUS wurden durchschnittlich 154,5 (SD ± 11,72) von insgesamt 175 Punkten erreicht (88,29 %). Die OSAUS-Ergebnisse stimmen mit der Punktzahl aus der Bildbewertung mit B-QUIET überein. Die Interrater-Analyse der bewerteten US-Bilder zeigte eine gute Übereinstimmung mit einem ICC (2,1) von 0,895 (95 %-Konfidenzintervall 0,858–0,924).
Schlussfolgerungen Die US-Lehre mittels Teleguidance hat sich in dieser Pilotstudie als erfolgreiches Lehrkonzept erwiesen. Dieses zukunftsweisende Lehrkonzept ermöglicht zudem die US-Ausbildung von Medizinstudierenden in Zeiten der COVID-19-Pandemie, in denen Präsenzlehre nicht möglich ist.

Introduction

Traditionally, physicians have acquired ultrasound (US) skills during residency training. However, in recent decades, US has been introduced in undergraduate medical education [1]. Many authors [2–5] have described that US is not just limited to diagnostic imaging but can be used in teaching to support the understanding of complex anatomical structures. As a result, innovative training methods have been designed and implemented for medical students. Over the past few decades, technological advances in both US and the application of telemedicine have been made [6].

There have been attempts to implement distance learning of US skills with mobile devices [7] or web-based applications [8], including physicians and non-physician medical providers, which have been found to be effective. Tele-guided US is the latest technological innovation in the tele-ultrasound sector and hand-held US devices, such as the Butterfly IQ system [9], facilitate live teleguidance and enable the exchange of expertise at the bedside [10] by using the respective application software. The current COVID-19 pandemic resulted in the discontinuation of traditional classroom/presence teaching that is considered crucial in US education. Alternative teaching approaches as well as the expansion of digital learning opportunities became necessary to ensure adequate training of medical students.

The aim of our study is to examine the educational outcome of a newly designed digital tele-guided US course of the abdomen, thorax, and the thyroid gland with the implementation of a modern hand-held US device (the TELUS study), enabling a flipped classroom setting.

Materials and Methods

This study was conducted by two board-certified US specialists (one certified EFSUMB/DEGUM level I, the other level III) with longstanding experience in US. The participating students were enrolled in the fourth and fifth year of undergraduate medical education and they were given the opportunity to choose the US course as an elective subject. Each student had to provide an additional volunteer during the course and the exam acting as a US model for training at home. The participants received a mobile ButterflyIQ US device [9] for the course period with the necessary equipment and used exclusively an iPhone, version 7 or newer. The corresponding software ButterflyIQ version 1.25 facilitates the recording of live videos with simultaneous US and camera images as needed for tele-guidance transmission. In addition, the app allows saved images to be added to worksheets that are built by the tutors and can consist of various query types (e. g., multiple choice questions, free text answers) addressing the different organ modules.

Tele-ultrasound course structure

The course was composed of seven modules taking place weekly focusing on organs and structures of the abdomen, the thorax, and the thyroid gland. The organ modules were chosen based on the structure of the DEGUM basic US course of the abdomen. Since point-of-care US (POCUS) is of high importance in medicine, the different modules should provide the students with a general understanding of its applicability. Due to the technical equipment and resolution of the hand-held device, small vessels and bile ducts were not integrated into the course format.

Each module was designed using a flipped classroom concept [11] in cooperation with the Amboss platform [12], which is a German commercial learning platform developed for medical students. Flipped classroom approaches deviate from traditional classroom teaching and exchange transmissive lectures with active in-class tasks and pre-/post-class work at home [13]. Consequently, the participating students received a supplementary e-learning offer available at Amboss that was optional and provided chapters to each of the US organ modules. The information about organ anatomy, examination indication and procedure in the e-learning chapters included normal findings and images of typical pathologies. A chapter with videos demonstrating the correct US technique for each organ structure was also provided [14]. In addition, medical students were asked to answer multiple choice questions after reading the articles to enable self-testing. Students acquired theoretical and practical basics of a new module topic at their own pace by working on the chapters and questions. Thus, participants had more time to study independently during the course and the chance to receive individualized feedback from the tutors. Each course module started with a short lecture outlining the specific topics of the corresponding US module. All tutors gave basic information about the organs including anatomy and possible pathologies as well as instructions to simplify the probe handling needed to obtain the required US images. Typical pathologies were included in each lecture to facilitate student preparation for their first contact with difficult or emergent clinical situations, and to underline the diagnostic and therapeutic utility of each US module.

After the lecture was given, the required US examination was demonstrated by one of the tutors. The tutor's mobile phone screen as well as their camera image was shared with the students during the demonstration to visualize the best image acquisition

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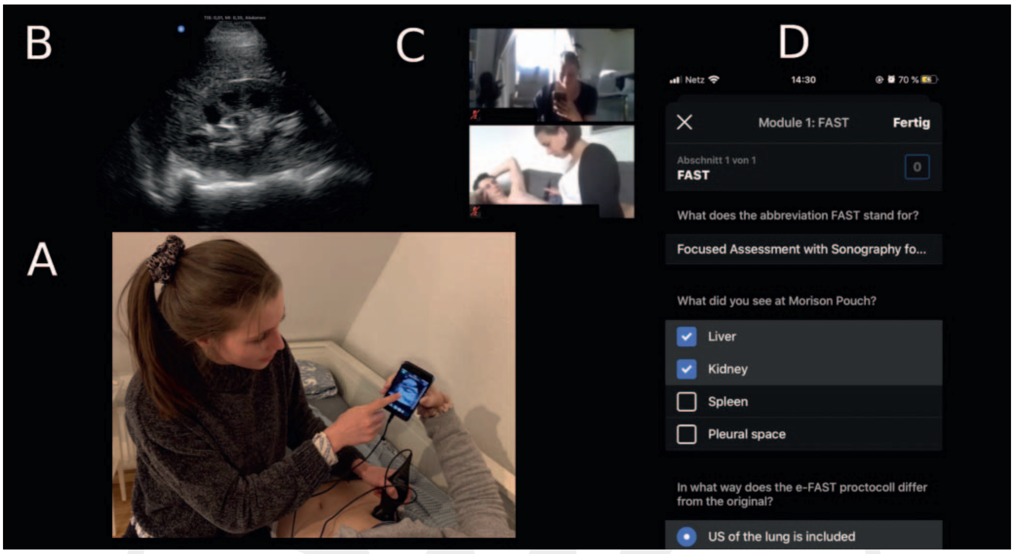

▶ **Fig. 1** Implementation of the digital ultrasound course concept. Classroom setting is displayed, demonstrating simultaneous screen transmission of ultrasound (US) and camera images. **A** The peer tutor's camera image is shared with the students while demonstrating the US examination, **B** At the same time the tutor's mobile phone screen is shared with the students in order to visualize the US image acquisition, **C** Students performing the US examination on their own, **D** Example of a worksheet, which had to be completed within the app and was stored along with the US images in the cloud.

technique. Accordingly, students were trained to obtain the predefined US images via simultaneous screen transmission of US and camera images showing probe position (▶ **Fig. 1**). Subsequently, the participants received time to perform the examination on their own and were advised to save images of each US section that was predetermined. In some cases, further modifications of the images were required (e. g., measuring of the organ size). During the active tasks, the tutors observed the students' cameras and the US images in order to assist in the handling of the probe, in case of difficulties, and to provide live guidance. At the end of each module, US images were uploaded to a cloud-based system and a worksheet containing specific questions for each module (identification of anatomical structures, multiple choice questions, or short written questions that aimed to test for obtained knowledge) had to be completed.

Assessment tools

The didactic efficacy of the US course was measured with different tools (▶ **Fig. 2**).

A digital Objective Structured Assessment of Ultrasound Skills (OSAUS) [15] was completed as the final exam by each participant after attending all US course modules at eight weeks. The OSAUS scale contained seven key elements (▶ **Table 1**) and made it possible to evaluate student performance regarding different organs.

Independent raters assessed medical students (EFSUMB/DEGUM Level I and III and a peer tutor) via a practical case study that led the students through the examination. The peer tutor was a student at the same age and level as the participating students who was trained prior to the study to assist in lectures and US demonstrations during the course lessons as well as the student assessment. Each student had 30 minutes to complete the final exam, with approximately five minutes assigned to each task. The exam took place in the same setting as the course lessons and the students scanned a person of their choice at home while sharing their camera and mobile display with the raters. Students had to complete five tasks in the OSAUS, which corresponded to the course modules and included the following:

a) Focused Assessment with Sonography for Trauma (FAST) examination (demonstration of the spleen (F) was incorporated into this module)
b) US of the lungs (B- and M-mode)
c) US of the kidneys (including determination of size) and the bladder (including measurement of residual volume)
d) US of the aorta and vena cava (including measurement of diameter)
e) US of the thyroid gland (including determination of gland volume)

All images taken during the course and exam were rated using the Brightness Mode Quality Ultrasound Imaging Examination Technique (B-QUIET) [16]. B-QUIET has been developed as an approach to standardize US image interpretation (▶ **Table 1**). Images of the course were compared to images of the final OSAUS

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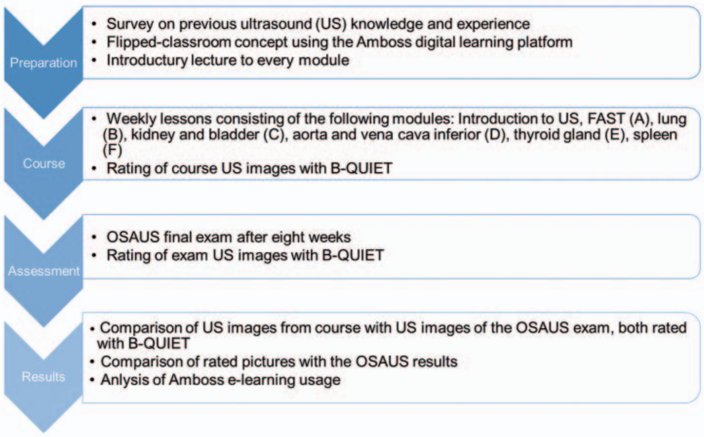

▶ **Fig. 2** Structure of the tele-guided ultrasound course. The course concept is displayed along with the different instruments to measure efficacy. OSAUS: Objective Structured Assessment of Ultrasound Skills, FAST: Focused Assessment with Sonography for Trauma, B-QUIET: Brightness Mode Quality Ultrasound Imaging Examination Technique, US: ultrasound.

▶ **Table 1** Evaluation criteria of Objective Structured Assessment of Ultrasound Skills (OSAUS) and Brightness Mode Quality Ultrasound Imaging Examination Technique (B-QUIET) score.

Objective Structured Assessment of Ultrasound Skills (OSAUS)	Brightness Mode Quality Ultrasound Imaging Examination Technique (B-QUIET)
1. indication for the examination	**identification/orientation**
reviewing patient history, indication	1.0 date/time
2. applied knowledge of ultrasound (US) equipment	1.1 patient name/MRN/sonographer
familiarity with equipment and functions	1.2 body marker
3. image optimization	1.3 comments (image title, labeled structures)
optimal image quality	**technical**
4. systematic examination	2.1 resolution – application/focal zone
systematic approach, presentation of relevant structures	2.2 depth – field of view
5. interpretation of images	2.3 gain (segmental, overall)
recognition of image pattern and interpretation	**image anatomy**
6. documentation of examination	3.1 near field (top of screen)
image recording and documentation	3.2 receding edge (right side)
7. medical decision making	3.3 far field (bottom of screen)
ability to integrate scan results into patient care	3.4 leading edge (left side)
5 points could be obtained within each category with a total of 35 points	within each category 4 points could be obtained and a total of 44 points

A digital Objective Structured Assessment of Ultrasound Skills (OSAUS) was completed as the final exam by each participant after attending all US course modules. Furthermore, US images of the course and exam were rated by the Brightness Mode Quality Ultrasound Imaging Examination Technique (B-QUIET). The different criteria for assessment are displayed.

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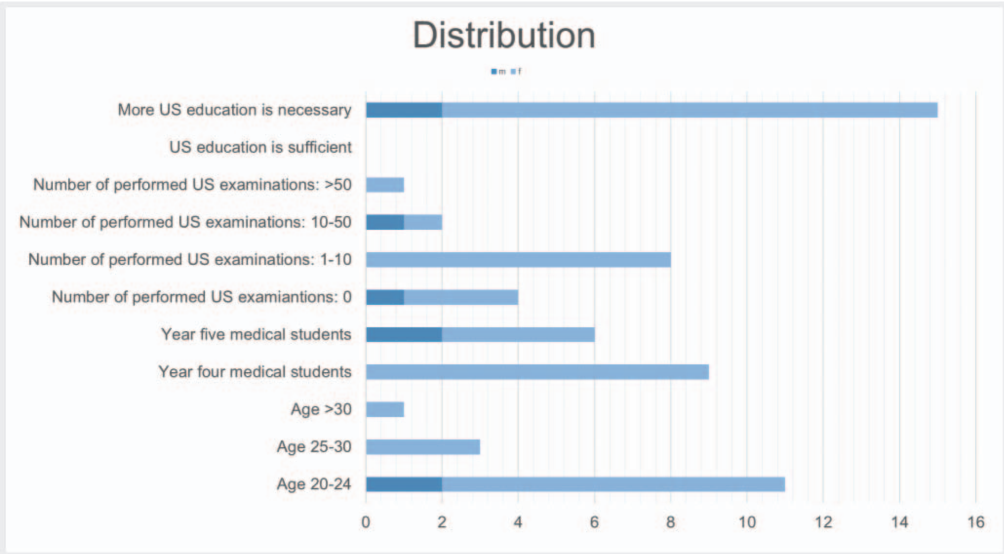


▶ **Fig. 3** Student characteristics. Pre-course survey on ultrasound education and experience as well as year of study. US: ultrasound, m: male, f: female.

exam to determine whether the students' image quality improved, decreased, or remained constant. Students had approximately one hour to take images in each course module compared to the five minutes per task during the exam.

All images (n = 497) were evaluated by two raters (EFSUMB/DEGUM Level I and III), who likewise assessed student performance in the OSAUS exam. A total of 104 of these images were randomly chosen and rated by the peer tutor and an intraclass correlation coefficient was determined afterwards for the three independent raters. Raters were blinded to the images originating from the course and final exam. Within the OSAUS exam, theoretical knowledge and performance of physical examination were assessed. Thus, more than practical ability was evaluated, whereas the B-QUIET image rating considered image quality and therefore the direct outcome.

Statistical analysis

Statistical analysis was performed with R statistical software (version i386 4.0.2). Means and standard deviations were calculated as descriptive parameters. In case of correlations between OSAUS and image rating results, Spearman's rank-order correlations [17] were determined since no normal distribution could be assumed. Differences were considered statistically significant if p was < 0.05. Using the scientific B-QUIET score [16] for standardized US image interpretation, a total of 497 images were rated and inter-rater reliability was assessed. Inter-rater reliability of image ratings with B-QUIET and the OSAUS protocol was assessed separately according to the intraclass correlation coefficient (ICC) (2.1) [18]. The ICC can be interpreted according to Rosner [19]: ICC < 0.4 indicated poor reliability, 0.4 ≤ ICC < 0.75 fair to good reliability, and ICC ≥ 0.75 excellent reliability.

The study was approved by the local ethics committee (no. 129/29) and all participants gave written informed consent to participate in the study.

Results

Participants characteristics

A total of 15 medical students (13 females (87 %), two males (13 %)) with a mean age of 24.7 years (SD± 3.6 years) were enrolled in the study. The number of study participants was based on the number of US probes available. Half of the students (53 %) had performed US on a patient on their own less than ten times and four students (27 %) had never performed US independently before (▶ **Fig. 3**). All students wished for more US education, as they felt that the amount offered by medical faculty was inadequate [20].

Objective Structured Assessment of Ultrasound Skills (OSAUS) results

Participants had to complete five different tasks in the OSAUS [15] exam. For each task, 35 points could be obtained for a total of 175 points. The average number of points achieved was 154.5 (SD ± 11.7) out of 175 points (88.29 %). The highest median number of points was scored in the thyroid gland module (E) with an average result of 31.8 points (SD± 2.6), while the lowest average score was obtained in the aorta and vena cava module (D) with 30.1 points (SD± 3.2). The three OSAUS raters showed an inter-rater reliability of 0.874 (95 % confidence interval 0.65 < ICC < 0.956).

Image analysis results using B-QUIET

The students' images were rated with the B-QUIET [16] method, where a maximum of 44 points could be obtained per image. Images from the course and the exam were evaluated for each module (▶ **Table 2**). The ICC (2.1) was determined for the three independent raters and the detected ICC (2.1) was 0.895 (95 % confidence interval 0.858 < ICC < 0.924).

The best rated US course images were observed in the lung (B) module with a mean score of 34.4 (SD± 3.2) points, whereas in the final exam, the highest mean score was achieved in the thyroid gland (E) module with a total of 35.0 (SD± 4.4) points. The images of the aorta and vena cava (D) achieved the lowest mean score in both the course and final exam. The mean score of the US course images was 31.2 (SD± 3.8) points, while the highest score reached was 39 points. The mean exam score of the US images was 32.3 (SD± 4.0). Therefore, students obtained one point more per image in the exam compared to the course modules before.

There was no substantial correlation between the total points in OSAUS and the total or average points per image rating in B-QUIET. However, the students reached the highest mean score in OSAUS in module E (thyroid) with 31.8 (SD± 2.6) points, which is also the module with the highest average points in the B-QUIET rating of images (35.0 SD± 4.4).

Similarly, in module D (aorta and cava), students received the lowest score in OSAUS with 30.1 (SD± 3.2) points, and the images were rated with a mean score of 30.6 (SD± 3.5), which is the lowest observed in the final exam (▶ **Fig. 4**).

Furthermore, there was no significant correlation between the number of performed US examinations before the course and the points achieved in OSAUS.

Tracked data e-learning results

The tracked data of the flipped classroom format offered by Amboss displays favorable use of the optional e-learning material, which consisted of chapters dealing with the corresponding module and a multiple choice question tool. The number of times students accessed the chapters and multiple-choice questions was analyzed and each time the material was accessed was registered corresponding to the weekly module sessions. All students accessed at least one chapter and four students (27 %) worked on all chapters. Twelve students (80 %) took part by answering the MCQ questions and answered more than 90 % correctly. The majority of online access to chapters and questions was documented shortly before the final OSAUS test. (▶ **Fig. 5**).

Discussion

This is the first pilot study to investigate the learning outcome of German medical students in a newly developed, automated, tele-guided US course of the abdomen, the thyroid gland, and the thorax. In addition, it is the first study to test the use of the B-QUIET [16] image analysis method as well as the OSAUS [15] protocol in a digital tele-guided US course together.

▶ **Table 2** Mean results of the OSAUS exam as well as the the course and exam B-QUIET image rating.

module	rating of US course images using B-QUIET	rating of final exam images using B-QUIET	OSAUS results
A (FAST)	30.2 ± 3.9 (68.6 %)	31.1 ± 4.0 (70.7 %)	31.0 ± 4.0 (88.6 %)
B (lung)	34.4 ± 3.3 (78.2 %)	34.5 ± 3.8 (78.4 %)	30.9 ± 2.4 (88.3 %)
C (kidney, bladder)	31.8 ± 3.6 (72.7 %)	33.1 ± 3.6 (75.2 %)	30.7 ± 3.1 (87.7 %)
D (aorta, vena cava)	30.1 ± 3.3 (68.4 %)	30.6 ± 3.5 (69.6 %)	30.1 ± 3.2 (86 %)
E (thyroid gland)	32.4 ± 3.2 (73.6 %)	35.0 ± 4.4 (79.6 %)	31.8 ± 2.6 (90.9 %)

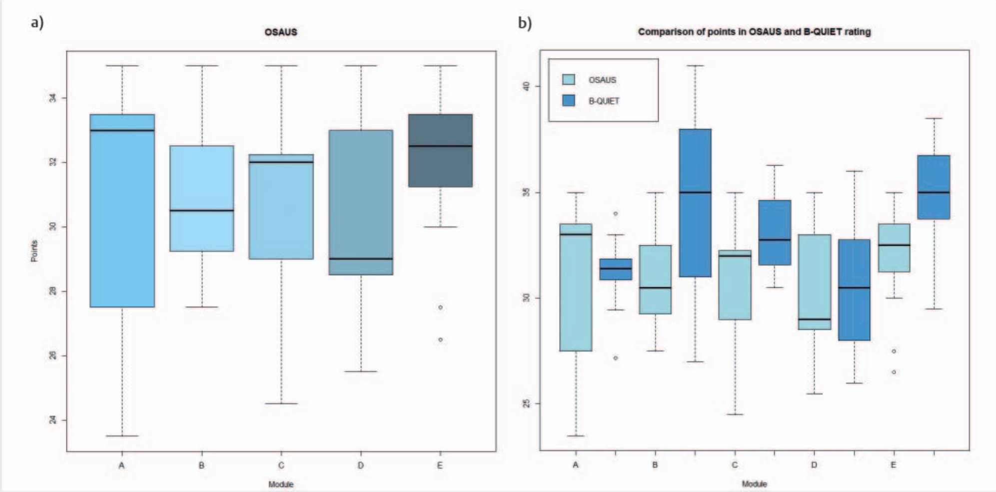
The US images saved by students during the course and the exam were rated using B-QUIET and can be compared to the OSAUS final exam results. The mean score and standard deviation are displayed as well as the percentage of highest achievable score. OSAUS: Objective Structured Assessment of Ultrasound Skills, FAST: Focused Assessment with Sonography for Trauma, B-QUIET: Brightness Mode Quality Ultrasound Imaging Examination Technique.

US in medical education has been shown to be an achievable objective that is well-accepted by medical students. It has the potential to help medical students achieve basic competency in FAST US examination after only five hours of training. In addition, student assessment of their own performance shows high proficiency of the program [21]. The use of the Objective Structured Clinical Examination (OSCE) [22] has been investigated in many studies [23, 24], and Todsen et al. [25] demonstrated high reliability as well as evidence of construct validity of the OSAUS scale in an educational setting.

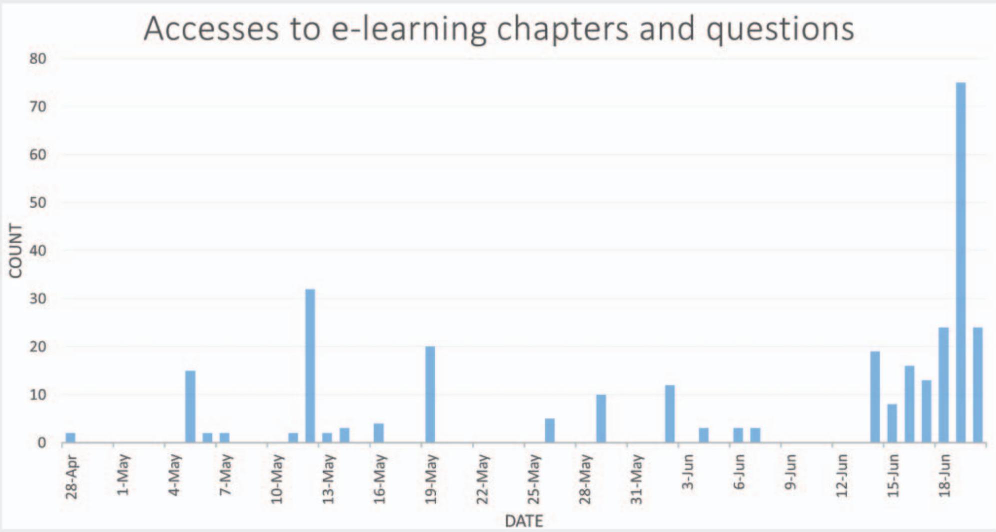
The existing literature indicates that e-learning can provide an effective method for improving educational outcomes [26] and manages to lead to similar results as traditional, face-to-face, teacher-centered courses [27]. To date, there has been no distance learning concept that has been tested for US in medical education.

Approximately one point more per image was achieved in the final exam compared to course images, which is remarkable since students had one hour to take images during each course module, while they only had roughly five minutes per task during the exam.

There was no substantial correlation between the total points in OSAUS and the total or average points per image rating in B-QUIET, indicating that the student with the highest number of points in OSAUS does not necessarily also have the best rated images. The missing correlation can be explained by the different sections that were tested with OSAUS. More than the practical



▸ **Fig. 4** Comparison of assessment methods. **a** Objective Structured Assessment of Ultrasound Skills (OSAUS) results of the final exam, **b** Comparison of achieved points in the OSAUS exam and image rating, using the B- QUIET method. A maximum of 35 points could be reached within each module in the OSAUS exam and 44 points could be achieved in image rating. A (Focused Assessment with Sonography for Trauma), B (lung), C (kidney, bladder), D (aorta and vena cava), E (thyroid gland) OSAUS: Objective Structured Assessment of Ultrasound Skills, B-QUIET: Brightness Mode Quality Ultrasound Imaging Examination Technique.



▸ **Fig. 5** Time course of the tracked flipped classroom concept using the Amboss platform. Tracked data regarding Students' use of the e-learning concept of the Amboss platform. The e-learning offer was used weekly before the course. The number of times students accessed the platform was highest prior to the final exam which was scheduled for the 20th of June.

ability was evaluated in the exam (indication and systematic examination, for example), whereas the B-QUIET image rating considered image quality and the direct outcome. Therefore, the two different assessment forms have different advantages. B-QUIET might be more objective, whereas OSAUS aims to measure not only image optimization but the ability to perform and explain the US examination.

Our study has several limitations, including the relatively small sample size which resulted from the limited number of hand-held US devices. However, the feasibility of the course would be difficult with a larger number of participants since the tutor must be accessible for the students at all times [28]. Therefore, conducting a power analysis would be essential for future studies. Due to the prevailing contact restrictions, it was not possible to compare the results to a group that underwent direct hands-on teaching on a live patient. Thus, the lack of a control group is a major limitation of our study. Additionally, US scanning was performed on young and healthy volunteers and none of the models had abnormal findings or were obese. As the students could not witness unusual findings, images and videos of typical pathologies were incorporated in the lectures and e-learning chapters. In the future, US pathologies could be taught using low-cost models (e. g., 3D printing), depending on the application area. Long-term retention of both functional and theoretical information was not evaluated in the course. Selection bias cannot be excluded, as more motivated students may have participated. Since students had their equipment at home during the whole course time, it is not clear whether the examination outcome results only from the course or is affected by self-practice. Our study should be seen as a proof-of-concept study, demonstrating the feasibility of tele-US teaching. A power analysis as well as additional studies including control groups should be performed in the future to allow a comparison to hands-on teaching. In the future, these concepts could be used not only to organize digital teaching but also to strengthen health services research and US training in remote areas. Turning a smartphone into a US machine with a hand-held US device like the ButterflyIQ system is more affordable for medical education and could be an incredible opportunity to expedite US training worldwide. Especially in times of a nationwide medical crisis such as COVID-19, it is essential that medical faculties draw the right conclusions from their experience and focus on an advanced approach to expand practical teaching strategies.

Conclusion

The TELUS study demonstrates the feasibility of a tele-guided US course concept using a hand-held US device that can be easily transported anywhere for practice. Consequently teleguided US training should be considered in future medical education. As can be seen in the current pandemic situation, the expansion of digital learning opportunities is not only necessary, but unavoidable.

Conflict of interest

Erik Schmok is an employee of Amboss.

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Zielsetzungen:

Derzeit wird Ultraschall (US) in großem Umfang für die Diagnose der Riesenzellarteriitis (GCA) eingesetzt. Unser Ziel war die Entwicklung eines kostengünstigen US-Trainingsmodells für die Diagnose der GCA der Arteria temporalis und der Arteria axillaris mit Hilfe eines modernen 3D-Drucksystems zu entwickeln

Methoden:

Wir entwarfen ein US-Trainingsmodell, das die Messung der Intima-Media-Dicke (IMT) der Arteria temporalis und der Arteria axillaris unter Verwendung von Autodesk Fusion360. Dieses Modell wurde mit einem modernen 3D-Drucker (Formlabs Form3) gedruckt und in ballistische Gelatine eingebettet. Die Ultraschallbilder einschließlich der Messung der IMT durch Ultraschallspezialisten bei GCA wurden mit Ultraschallbildern bei akuter GCA und gesunden Probanden verglichen.

Ergebnisse:

Unser Ultraschall-Trainingsmodell der Axillar- und Temporalarterie zeigte eine sehr ähnliche Ultraschallmorphologie im Vergleich zu realen US-Bildern und erfüllte die OMERACT Ultraschalldefinitionen normaler und pathologischer Temporal- und Axillararterien bei GCA. Die IMT Messungen entsprachen den veröffentlichten Cut-off-Werten für normale und pathologische IMT-Werte bei GCA und gesunden Personen. Beim Testen der Modelle unter verblindeten US-Spezialisten für GCA wurden die IMT-Werte in allen Testrunden mit einem Intraklassenkoeffizienten von 0,99 korrekt identifiziert.

Schlussfolgerung:

Die Herstellung von kostengünstigen Ultraschall-Trainingsmodellen normaler und pathologischer temporaler und axillärer Arterien für GCA, die die OMERACT-Ultraschalldefinitionen erfüllen und den veröffentlichten IMT Cut-off-Werten bei GCA entsprechen, sind machbar. Ultraschallspezialisten identifizierten das jeweilige Modell in jedem Fall korrekt.

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Development and Proof of Concept of a Low-Cost Ultrasound Training Model for Diagnosis of Giant Cell Arteritis Using 3D Printing

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Abstract: Objectives: Currently, ultrasound (US) is widely used for the diagnosis of giant cell arteritis (GCA). Our aim was to develop a low-cost US training model for diagnosis of GCA of the temporal and axillary artery using a modern 3D printing system. Methods: We designed an US training model, which enables measurement of the intima-media thickness (IMT) of temporal and axillary arteries using Autodesk Fusion360. This model was printed using a modern 3D printer (Formlabs Form3) and embedded in ballistic gelatine. The ultrasound images including measurement of the IMT by ultrasound specialists in GCA were compared to ultrasound images in acute GCA and healthy subjects. Results: Our ultrasound training model of the axillary and temporal artery displayed a very similar ultrasound morphology compared to real US images and fulfilled the OMERACT ultrasound definitions of normal and pathological temporal and axillary arteries in GCA. The IMT measurements were in line with published cut-off values for normal and pathological IMT values in GCA and healthy individuals. When testing the models on blinded US specialists in GCA, they were identified correctly in all test rounds with an intra-class coefficient of 0.99. Conclusion: The production of low-cost ultrasound training models of normal and pathological temporal and axillary arteries in GCA, which fulfil the OMERACT ultrasound definitions and adhere to the published IMT cut-off values in GCA, is feasible. Ultrasound specialists identified each respective model correctly in every case.

Keywords: giant cell arteritis; model development; diagnosis; ultrasound; 3D printing

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1. Introduction

Giant cell arteritis (GCA) is a systemic autoimmune disease and the most common form of vasculitis in adults over 50 years of age, characterized by the inflammation of medium- and large-sized arteries. The temporal and axillary arteries are commonly involved. Early changes consist of transmural inflammation of the arterial wall, while later complications include lumen changes, such as stenosis or aneurysms [1]. A rapid diagnosis and treatment are important in order to prevent serious vascular complications such as blindness and other vascular events [2]. The current recommendations by European League Against Rheumatism (EULAR) highlighted the diagnostic value of ultrasound of the temporal and axillary arteries in GCA [3]. Ultrasound is commonly available in rheumatology practice and is patient-friendly, reproducible, and repeatable [4]. For diagnosis of GCA, the OMERACT ultrasound definitions and the respective cut-off values for normal and pathological temporal and axillary arteries are used [5]. Several studies showed that ultrasound training with novice sonographers resulted in excellent ultrasound reliability in patients suspected of GCA [6,7]. Thus, the role of ultrasound in training and education in GCA is crucial. Since every single GCA case is unique and without appropriate training models that are realistic and long lasting, practicing these skills can prove to be difficult, which poses a huge challenge for rheumatologists worldwide.

Three-dimensional (3D) printing is an emerging technology that builds up a physical model commonly in a layer-by-layer manner using a 3D computerized model reconstructed from a series of images such as computed tomography (CT) or magnetic resonance imaging (MRI) datasets [8–10]. In clinical practice, 3D printing is reported to have been used in a variety of subjects. The most striking usage is to study complex cases and practice procedures in medical education [11–13]. Fused deposition modelling (FDM) and stereo-lithography (SLA) 3D printing technique is a promising method for making vessel-mimicking phantoms (VMPs) with a complex vessel lumen [14,15]. Theoretically, 3D printed models have better spatial and structural visualization and can be used as didactic tools for better understanding of vessel wall pathologies in GCA, including increased intima-media thickness (IMT), aneurysms and vascular stenosis [11,16]. However, there is no rheumatology ultrasound vasculitis model for GCA available to date, which could be used for teaching purposes.

In this study, we aimed to establish a low-cost 3D-printed ultrasound training model of a normal and pathological temporal and axillary artery in GCA, fulfilling the OMERACT ultrasound definitions for GCA and the published cut-off values of the IMT.

2. Materials and Methods

The process of producing the final model is described in the following next three steps.

2.1. Step 1—Creating Three-Dimensional Models of the Temporal and Axillary Artery

Based on ultrasound images of patients, the published OMERACT ultrasound definitions of normal and pathological axillary and temporal arteries in GCA and the published cut-off values [5], artery models were designed and converted using Fusion360TM (Autodesk Inc., San Rafael, CA, USA) into a stereo-lithography (.stl) file (Figure 1).

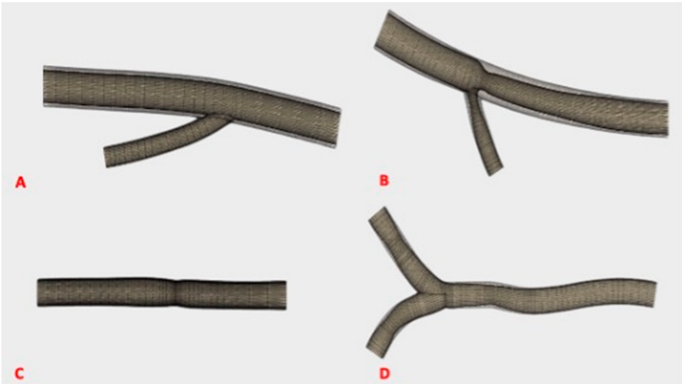

Figure 1. Digital model of a normal and pathological axillary artery. (**A**) Model of a normal axillary artery. (**B**) Model of a pathological axillary artery in giant cell arteritis with an increased intima-media complex. (**C**) Model of a normal temporal artery. (**D**) Model of a pathological temporal artery in giant cell arteritis with increased intima-media complex.

2.2. Step 2—Printing Process

We used the Formlabs Form3®, a low-force Stereo-lithography^{tm} based 3D printer (Formlabs Inc., Somerville, MA, USA), which uses liquid flexible resin incorporated as print material. In this way, the print resolution increased to 50 µM per line. However, the program was more complex than FDM and included a chemical reaction of the resin under laser light instead of merely melding the PLA. It also comprised of a step to wash the prints in isopropanol alcohol in a form wash station and a step to harden the material in a form cure station with 405 nm Light-emitting diode (LED) light. We used black resin from Formlabs® Inc. and this resulted in a possible resolution of 0.05 mm up to 0.025 mm, which produced less interpolation during the print process. The intended artery wall thickness did result in prints, but the weight of the resin of the model in large prints started to deform itself as each layer is pulled from the transparent surface at the bottom of the resin tank during the printing process. The differences between the various resins lie on the one hand in their heat stability and on the other hand in the overall stability of the printing material used. In addition, each resin displayed a different echogenicity.

Thus, we had to use support structures to reduce these deformations. Furthermore, the chemical printing process, the isopropanol bath, the LED-light, and the 60 °C heat hardening process put additional stress on the prints. In addition to the software settings for the print, the low-force Stereo-lithography[tm] printing process introduced new influencing factors for the prints, which had to be considered.

In contrast to the FDM printer, where we could not easily influence the way each layer was printed, we were forced to design model specific support structures, which did not interfere with the ultrasound purpose of the prints in this new printing process (Figure 2).

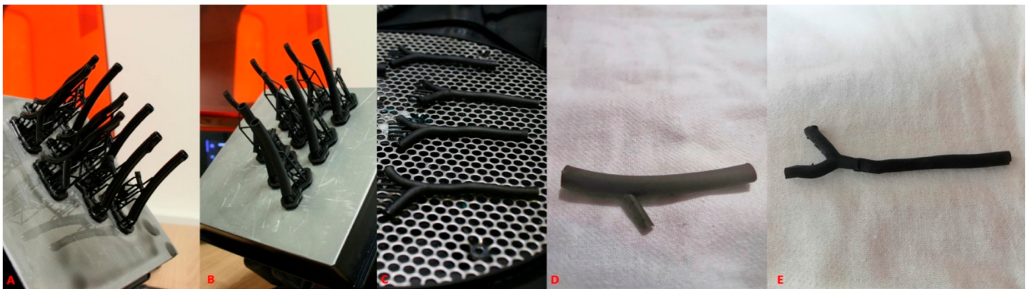

Figure 2. Demonstration of the printed models of the temporal artery with the low-force Stereo-lithography[tm] technique and supporting structures. Manufacturing process of the temporal artery models at various stages. (**A**) Picture taken just after the printing process finished of an axillary artery model. (**B**) Image after washing of the axillary artery models in isopropanol alcohol. The black resin is much less brittle after the hardening process, so the supports were cut away after the washing process. (**C**) Picture after hardening of temporal artery models with 405 nm LED light. (**D**,**E**) high resolution images of a temporal and axillary model respectively.

2.3. Step 3—Embedding of the Model in Gelatine

In order to allow a realistic ultrasound experience and correlate with real ultrasound images, we embedded our 3D models into a specific clear ballistic gelatine. Ballistic gelatine is a testing medium scientifically correlated to swine muscle tissue (comparable to human muscle tissue), with similar ultrasound propagation velocity as that of human connective tissue.

Embedding the models into the gelatine was performed as follows. First, the oven-safe glassware, an oven and one pound of gelatine were prepared (Figure 3A). Next, the gelatine was obtained from the manufacturer in square blocks of 41 cm × 15 cm × 15 cm for EUR 204.50. The blocks of ballistic gelatine were cut into 1 cm × 1 cm cubes to decrease melting time (Figure 3B). Thereafter, the oven was set to 130 °C, and the oven-safe glassware containing cubed pieces was placed into it. The material was checked regularly until it has melted completely, approximately requiring one hour (Figure 3C). Finally, the melted gelatine was poured into the container, and the vessel models with different wall thickness were placed around 1 cm underneath the gel surface (Figure 3D). The gelatine was then cooled. Once the material hardened, the gelatine model was removed from the glassware (Figure 3E). Reusing the gelatine is relatively easy. The embedded model is broken out of the gelatine. Then the remaining gelatine residue can simply be reheated in a pot and is reboiled into a liquid mass. After that, it can be reused to embed structures. Even after multiple boiling and embedding processes (>20 times), the gelatine did not change its properties.

Figure 3. Embedding procedure of the printed model into ballistic gelatine. (**A**) Materials needed (oven-safe glassware, melting pot, one pound of gelatine. and injection syringe for filling of vessel lumen), (**B**) gelatine melting process, (**C**) melted gelatine, (**D**) embedding of the printed models into the gelatine, (**E**) hardening process of the gelatine, (**F**) final artery model.

2.4. Ultrasound Examination of the 3D-Printed Models

All ultrasound examinations were performed with an Esaote MyLab Twice eHD ultrasound machine built in 2014. We used the same ultrasound technique as described by the OMERACT ultrasound group on large vessel vasculitis [4]. The following settings were applied for the examination of the temporal arteries (axillary arteries): B-mode frequency 18 MHz (14 MHz), image depth 1.5 cm (3 cm), and 1 focus point at 0.5 cm (1.5 cm) below skin surface. For the common superficial temporal artery parallel to the surface, IMT measurements were performed. In the transversal and longitudinal sections, measurements were carried out in mm on the vessel wall distal to the probe. We used the OMERACT ultrasound definitions as described before [5]. Two ultrasound specialists (PK and VSS) in diagnosis of GCA examined each model of a normal and pathological temporal and axillary artery including measurement of the IMT. The sonographers were blinded to inspect whether the model of the respective artery was pathological or not. We tested four models five times. Examination was repeated after 48 h for determination of intra-rater reliability. Examiners had to choose if the respective model displayed a normal or pathological temporal or axillary artery and perform an IMT measurement at the most prominent site. The vessel wall pathology of the axillary and temporal artery could not be identified from the outside of the model, as the changes were restricted to the intima of the vessel, nor were the models somehow distinguishable.

2.5. Statistical Analysis

Statistical analysis was performed with R statistical software (v.i386 4.0.2). Means and standard deviations were calculated as descriptive parameters. Inter-rater agreement was calculated using intra class coefficient (ICC) (2.1) between the readers. The ICC were interpreted according to Rosner [17]: ICC < 0.4 indicated poor reliability, 0.4 ≤ ICC < 0.75 fair to good reliability, and ICC ≥ 0.75 excellent reliability. Bland–Altman plots were designed with StataIC v.16.1 software (StataCorp, Lakeway, TX, USA) [18]. For quantitative parameters, the mean SD and range were determined. Significant changes were calculated by using *t*-test and Spearman correlation [19].

3. Results

Our 3D printed artery models fulfilled the OMERACT definitions of normal and pathological temporal and axillary arteries in GCA [5] (Figures 4 and 5). In addition, we were able to replicate the IMT of the corresponding arteries, allowing the measurement of the IMT values of the normal and pathological arteries. These values corresponded to the published cut-off values [20–22] for ultrasound diagnosis in GCA of the temporal or axillary arteries.

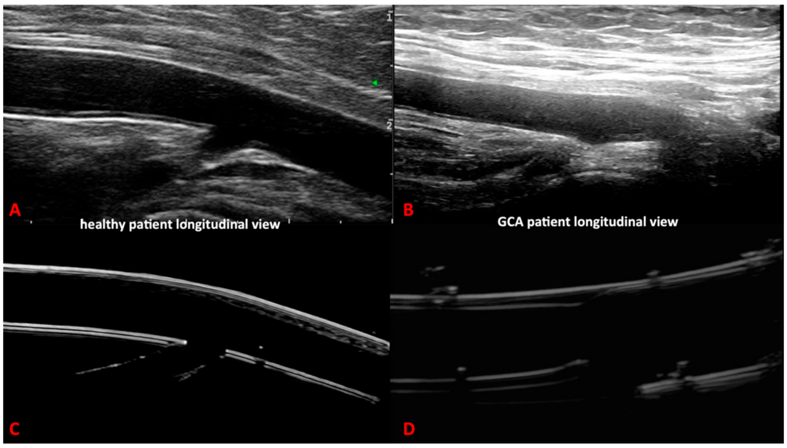

Figure 4. Comparison between ultrasound images of the axillary artery of the 3D printed models (**C**,**D**) and real ultrasound images in healthy and giant cell arteritis patients (**A**,**B**).

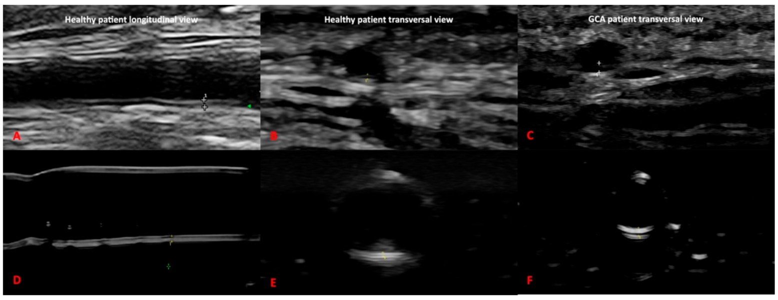

Figure 5. Comparison between ultrasound images of the temporal artery of the 3D printed models of healthy (**D**,**E**) and pathological setting (**F**) and real ultrasound images in healthy (**A**,**B**) and giant cell arteritis patients (**C**).

3.1. Identification of Each 3D-Printed Artery Model

The two ultrasound specialists examined the four different models five times each on two different days. Correct identification of the pathological and physiological temporal and axillary arteries was achieved by both examiners in all examination rounds. Consequently, the detection based on the vessel models was 100% correct. The total averaged measured values of the four different models were as follows: for the normal axillary model, 0.44 mm (SD ± 0.30), and for the pathological axillary model, 1.11 mm (SD ± 0.34). Further, the data were, for the model of the normal temporal artery, 0.27 mm (SD ± 0.31), and for the pathological, v.0.48 mm (SD ± 0.30). When testing the reliability of the four different models, the two independent raters (PK and VSS) showed an inter-rater reliability (ICC 2.1) of 0.99 (95% interval 0.98 < ICC < 0.995) in detecting pathological vs. normal temporal and axillary artery models. Comparing the IMT measurements, the two raters displayed a strong degree of agreement between the different measurements. There were no cases in all four models where the two raters made measurements outside the standard deviation (Figure 6) [18].

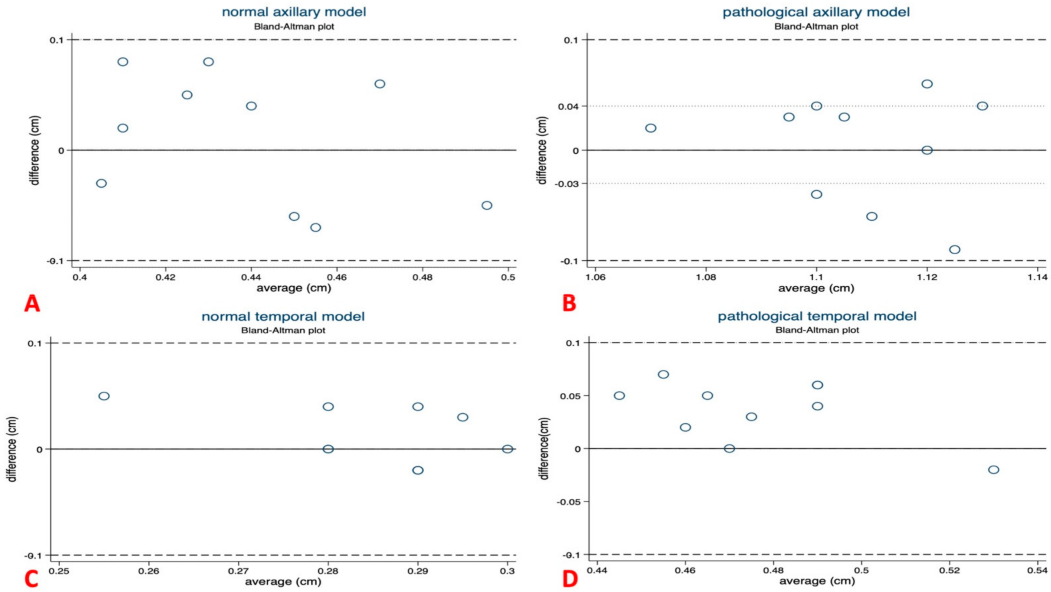

Figure 6. Bland–Altman plots on reliability of the four different US models. (**A**) Bland–Altman-plot of the normal axillary model (p = 0.536); (**B**) Bland–Altman-plot of the pathological axillary model (p = 0.853); (**C**) Bland–Altman-plot of the normal temporal model (p = 0.280); (**D**) Bland–Altman-plot of the pathological temporal model (p = 0.003). Overall range of intima-media thickness measurements was good to excellent in all four models.

Applying the OMERACT definitions for normal and pathological temporal and axillary arteries, the sonographers made the correct diagnosis in every round and every model. Furthermore, all four models were shown to be suitable for the simulation and training of sonographic detection of GCA.

3.2. Cost Effectiveness

A single model print took approximately nine hours and used 2.8 mL of resin, costing approximately EUR 0.45 and approximately EUR 1.20 for electricity used during printing, yielding a total of EUR 1.65 per model. The printer took about 19 h to complete 12 prints in total. Additionally, we used some isopropanol, which can be reused many times, and extra electricity for washing and hardening. The cost of the gelatine was EUR 4.08 per model, resulting in a total price of EUR 5.28 per model.

Of course, additional costs such as depreciation of the 3D printer and personnel costs have to be considered as well; these are dependent on the 3D printer as well as country-specific wages.

4. Discussion

Ultrasound can be performed simultaneously with recording history of the patient and clinical examination by the clinician and is widely used in European countries by now. It is patient-friendly, reproducible, and repeatable. It can be used in fast-track clinics offering appointments for patients within 24 h, to rapidly confirm or exclude the diagnosis of suspected GCA [23].

When training a physician in ultrasound in suspected GCA, the most common problem is the number of patients the physician has to examine before he is experienced in ultrasound diagnosis of GCA. Failure to accurately diagnose and expeditiously treat GCA may lead to vision loss and other severe ischemic complications, whereas misdiagnosis of non-GCA pathology as GCA leads to inappropriate glucocorticoid use and toxicity.

Thus far, there is no ultrasound model in the literature available for training and teaching purposes regarding the ultrasound diagnosis of GCA. In this first probability study, we were able to demonstrate the feasibility and reliability of a low-cost 3D printed vessel model of a normal and pathological temporal and axillary artery in GCA.

Designing a suitable vessel model and finding the perfect gelatine did take us a total of 12 months, as we struggled with different materials and 3D printers. However, we were finally able to 3D print a standardized artery model of the axillary and temporal artery, with either normal or pathological IMT changes fulfilling the OMERACT definitions [5] and displaying typical IMT changes [23]. When we tested the four models on two experienced sonographers in vascular ultrasound in GCA, the intra-class coefficient of normal and pathological temporal and axillary arteries in GCA were excellent for the diagnosis of GCA.

Compared to conventional ultrasonic coupling agents, this study had the following innovations. The components of the model described in this paper are unique when compared with other materials used to create models. It is unlike agar models, which need to be refrigerated, and it does not tear easily. Furthermore, our material does not require mixing with other agents such as fibre, gauze, and sawdust to create tissue like densities. Our gelatine does not dry out or decay, and it is reusable. The material is clear which allows trainees to have direct visual access to the vessel. The ultrasound training models displayed a very similar ultrasound morphology compared to real ultrasound images and fulfilled the OMERACT ultrasound definitions of normal and vasculitis of temporal and axillary arteries during the two exercises.

Of course, every single GCA case is unique, and in the present study, we only designed one model version for each, normal and pathological, of the temporal and axillary artery each. First, this is a pilot study to verify its feasibility in design and production of a training model for vascular ultrasound in GCA. Second, we thought it was enough to use only temporal and axillary artery models for medical education purposes, as these are the most frequently examined arteries in suspected GCA [3]. We received exceptional results after testing our model with two highly skilled sonographers. Every model version of the axillary and temporal artery was identified correctly as normal or pathological. Further, the IMT measurements were reproducible and reliable, helping in diagnosis. We propose to study this model in a larger cohort of ultrasound specialists in GCA, which is planned for 2021 within the OMERACT ultrasound large vessel vasculitis group.

However, there were some limitations. Firstly, although the printing materials of the vasculitis model were cheap, with about EUR 5.28 per model, the cost of 3D-printed parts depended heavily on the manufacturing facility and the resin used. Therefore, it could be cost effective to print more models in the long run. Cheap desktop 3D-printers allow cheaper 3D models but have fewer quality approvals and controls than commercial manufacturers, who are required to meet high quality standards, like the printer we used [11]. We used Formlabs Form3®, an excellent material for 3D printing of medical materials that is supplied with the form cure and wash station and manufactured resin without ever being touched. Secondly, the models were fragile after the hardening process and easy to break by compression as the training of "compression" signs cannot be carried out. Thirdly, these 3D prints are not without drawbacks. Several factors such as the path for the laser and the chemical process of hardening resin with the laser impacted the precision of the print. It remains a challenge to accurately print out vascular structures; however, we were able to reproduce many models with very similar IMT measurements. This may however differ when other printers are used.

5. Conclusions

We were able to produce a low-cost 3D model of normal and pathological temporal and axillary arteries in GCA with a price of EUR 5.28. In the near future, we plan to test our models in a greater cohort of ultrasound specialists and further work on the resolution of the vessel model as well as produce different versions in order to offer a wider range of pathologies.

Author Contributions: Conceptualization F.R. and V.S.S.; methodology F.R. and V.S.S.; software L.J., M.L. and P.V.; validation P.K., V.S.S., and F.R.; formal analysis F.R. and V.S.S.; investigation F.R. and V.S.S.; data curation L.J. and F.R.; writing—original draft preparation F.R., L.J., and V.S.S.; writing—review and editing F.R. and V.S.S.; visualization F.R. and V.S.S.; supervision V.S.S.; project administration F.R. and V.S.S. All authors have read and agreed to the published version of the manuscript.

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Hintergrund

In der geburtshilflichen und gynäkologischen Praxis ist der Ultraschall das wichtigste diagnostische Instrument. Dennoch verfügen nur wenige Kliniken über standardisierte und strukturierte Ausbildungspläne für junge Geburtshelfer im Bereich des geburtshilflichen und gynäkologischen Ultraschalls. Da Ultraschalldiagnostik am besten in kleinen, betreuten Gruppen erlernt werden kann, haben wir ein umfassendes Ultraschall-Curriculum für alle postgraduierten Assistenzärzte unserer Abteilung entwickelt und implementiert, das auf einem Peer-Teaching-Konzept basiert.

Methoden

Wir wendeten das sechsstufige Modell von Kern für die Entwicklung von Lehrplänen an, das Folgendes umfasst: (1) Problemerkennung und allgemeine Bedarfsermittlung, (2) Bedarfsermittlung für die anvisierten Lernenden, (3) Ziele und Zielsetzungen, (4) Ausbildungsstrategien, (5) Umsetzung und (6) Bewertung und Feedback.

Ergebnisse

Assistenzärzte im 1. und 2. Ausbildungsjahr erhielten zusätzlich zu ihren obligatorischen Klinik-Rotationen einen theoretischen und praktischen Ultraschall-Grundkurs (sechs Module). Die sechs Hauptthemen wurden nach der Relevanz für den Dienst priorisiert und umfassten die Hauptmerkmale gemäß DEGUM, EBCOG und ISUOG. Die Einheiten konzentrierten sich auf eine dreistufige Ausbildung in Anlehnung an die AMEE-Stufen: theoretisches Wissen, fundiertes theoretisches Wissen und grundlegende praktische Fertigkeiten unter Anleitung und selbständiges Erlernen der praktischen Fertigkeiten.

Eine strukturierte und standardisierte sonographische Ausbildung ermöglicht es jungen Assistenzärzten für Gynäkologie und Geburtshilfe, die Themen konzeptionell zu erfassen und praktisch umzusetzen. Darüber hinaus zeigt das Kurskonzept eine hohe Interrater-Übereinstimmung unter DEGUM-zertifizierten Prüfern. Weitere Forschung ist erforderlich, um die Lernergebnisse für Assistenzärzte und die Verbesserung des Patientenergebnisses durch die Einführung eines solchen Ultraschall-Curriculums zu analysieren.

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GENERAL GYNECOLOGY

Development and implementation of a comprehensive postgraduate ultrasound curriculum for residents in obstetrics and gynecology: a feasibility study

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Abstract

Background In obstetric and gynecological practice, ultrasound is the essential diagnostic tool. Nevertheless, few clinics have standardized and structured training curricula for young obstetricians in the field of obstetric and gynecological ultrasound. Since ultrasound is best learned hands-on in small supervised groups, we developed and implemented a comprehensive ultrasound curriculum for all postgraduate residents of our department using a peer-teaching concept.

Methods We used Kern's six-step model of curricular development comprising (1) problem identification and general needs assessment, (2) needs assessment of the targeted learners, (3) goals and objectives, (4) educational strategies, (5) implementation, and (6) evaluation and feedback.

Results Assistant physicians in the 1st and 2nd year of training received a theoretical and practical ultrasound basic course (six modules) in addition to their obligatory clinic rotations. The six main topics were prioritized according to service relevance and included the main features according to DEGUM, EBCOG and ISUOG. The units focused on a three-level training based on the AMEE levels: theoretical knowledge, well-founded theoretical knowledge and basic practical skills under guidance and self-employment of practical skills.

Conclusion Structured and standardized sonographic training allows young gynecology and obstetrics residents to conceptually grasp and practically implement topic-related themes. Furthermore, the course concept demonstrates the high inter-rater agreement among DEGUM-certified examiners. More research is needed to analyze the learning outcomes for residents and the improvement of the patient's outcome by establishing such an ultrasound curriculum.

Keywords Ultrasound education · Obstetrics · Gynecology · Curriculum development

Background

The advantages of ultrasound as an imaging modality are several and include: image resolution and definition of anatomy, real-time imaging that allows immediate diagnosis and that can be precisely controlled by the operator, wide availability of ultrasound equipment and the existence of multiple simple and straightforward practical techniques covering a broad range of applications [1].

Especially in obstetrics and gynecology (OBGYN) ultrasound has a long history and is the major diagnostic tool which is used in daily practice [2]. While many obstetricians and gynecologists in training attend courses addressing the finer points, relatively few are willing to attend courses on basic theoretical and practical ultrasound techniques. The failure of basic training to keep up with diagnostic and technical developments opens the door to misinterpretation, mistakes and poor reproducibility in using the equipment. At the same time, throughout the specialty ever greater reliance is placed on ultrasound diagnoses in management for both obstetrics and gynecology [3]. Thus, the key areas for improvement are lack of sufficient training, inability to request assistance from senior colleagues when needed and human error.

Especially new residents have a lack of theoretical and practical ultrasound knowledge which are highly required in their daily clinical routine in a department for obstetrics and gynecology. There are several studies which show that a

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lot of practical training and a high frequency of supervision is necessary to master this clinical skill [4, 5]. We therefore aimed to develop a comprehensive postgraduate curriculum for a limited number of essential skills and practical knowledge that satisfy the demands of daily routine including night shift. Thus, at the OBGYN department of the university hospital Bonn a new training curriculum was set up.

By doing so, several aspects have to be considered in the development of an ultrasound curriculum. Given the ever increasing amount of knowledge and number of skills medical one has to tackle during the selection of learning goals is warranted [6, 7]. A successful ultrasound course should not only sample a wide range of ultrasound techniques, but also teach under which circumstances ultrasound might be the appropriate imaging technique. Performing an ultrasound examination involves theoretical knowledge about the physics of ultrasound and anatomy, pattern recognition for pathologies, as well as the ability to use the device correctly to obtain meaningful images. Thus, the range of skills that can be taught and the numbers of students is limited by the number of available instructors [8–10].

Methods

We used Kern's six-step approach in our development for a postgraduate ultrasound curriculum in our OBGYN department [11].

Problem identification

To determine what best to include into an ultrasound curriculum for postgraduate gynecological and obstetrical residents, we consulted several main resources:

- The German ultrasound society (Deutsche Gesellschaft für Ultraschall in der Medizin, DEGUM) which has an own ultrasound section for Gynecology and Obstetrics. In this several quality levels are described (level I-III) with the required standard sections and fetal measurements [12–14].
- The European Board and College of Obstetrics Gynecology (EBCOG) which sets the European standard for every resident [15].
- The International Society for Ultrasound in Obstetrics and Gynecology (ISUOG) which has published international recommendations for basic training in obstetric and gynecological ultrasound [16].
- The published literature to research ultrasound skills or algorithms that are crucial for every postgraduate resident in this field and which are proposed [17].

Needs assessment of the targeted learners

The ultrasound examination techniques identified by the above described needs assessment were discussed extensively with members of the department for gynecology and obstetrics at our hospital.

Goals and objectives

For each identified ultrasound technique, technical, physiological and pathological properties were operationalized in January 2019. Again, clinical members with DEGUM qualification level I–III of the providing specialty were heavily involved in the process.

Educational strategies

Since the learning goals comprised theoretical knowledge as well as practical skills, different educational strategies were blended to cover all areas and aspects. We employed the techniques developed, used and evaluated by the DEGUM for ultrasound training: scripts and lectures for the theoretical knowledge and supervised hands-on training for the practical scanning. The units focused on a three-level training based on the Association for Medical Education in Europe (AMEE) levels: theoretical knowledge, basic practical skills under guidance and self-employment of practical skills [18].

Implementation

For the implementation, a suitable slot in the daily clinical routine was chosen and all participants of the curriculum were involved. Subsequently the infrastructure necessary to sustain the organization of the ultrasound curriculum was established.

Evaluation and feedback

The evaluation of the comprehensive curriculum and the learning curve is made up by logbook that every resident has to fulfill. The most important standard sections have to be presented there. This includes 10 cases of fetal biometry consisting of the biparietal diameter (BPD), the fronto-occipital diameter (FOD), the abdominal transversal diameter (ATD) and abdominal sagittal diameter (ASD) and the femur length (FL). Further, five cases with the measurement of the crown-rump length (CRL) and five cases with the cervical length should be submitted. In addition, five cases each with the presentation and measurement of uterus and ovaries had to be submitted.

This documentation logbook had to be submitted within 8 weeks after the ultrasound course.

Results

Problem identification

In the literature, there is extensive support for minimum requirements which all OBGYN residents should obtain during their training [16, 17]. It follows that all OBGYN trainees should receive, at minimum, a basic level of theoretical and skill-based education in both obstetric and gynecological ultrasound [3]. This is particularly relevant as ultrasound technology becomes more accessible and integral to the management of women's health [19]. The real-time, dynamic nature of ultrasound lends itself well to being performed and interpreted by obstetricians/gynecologists to facilitate timely and appropriate treatment decisions. Central to the utility of ultrasound in OBGYN is education [20].

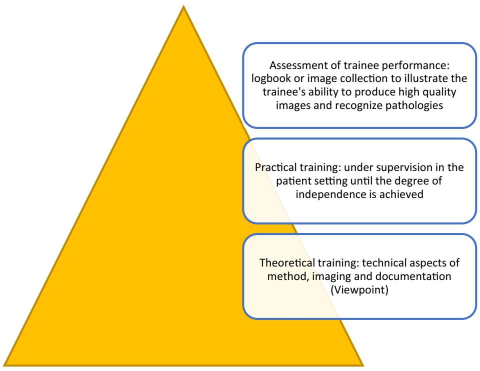


Fig. 1 The three-step approach by establishing the comprehensive curriculum

Needs assessment and targeted learners

The needed assessments were made up of a three-step approach for the residents. This approach incorporated the theoretical teaching as the fundamental basis. Further, the hands-on training was seen as the major part when focusing on night shift crucial topics. The last step was the self-made documentation (Fig. 1).

Goals and objectives

The needs assessment process resulted in identifying the following goals and objectives: the successful resident will be able to (Fig. 2):

First module

- Describe the physical basics of ultrasound, different ultrasound probes, internal documentation software (Viewpoint GE®) and basics of German maternity policies.

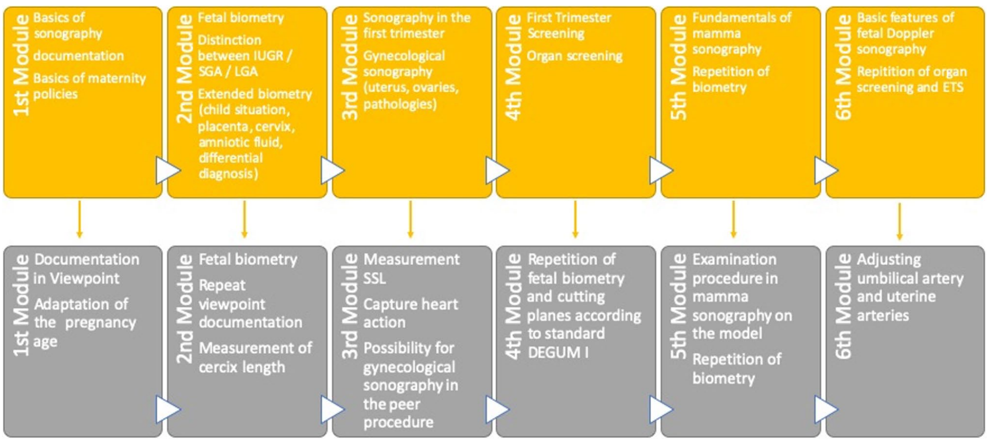


Fig. 2 The different learning goals of the comprehensive ultrasound curriculum

Second module

- Demonstration of the major features of the fetal biometry (BPD/FOD, ASD/ATD, FL) and ultrasound presentation of these essentials.
- Use of growth charts, the distinction between intrauterine growth restricted (IUGR), small for gestational age (SGA) and large for gestational age (LGA) fetuses and to depiction of extended features, such as child presentation, normal and abnormal placentation, measurement of cervical length, assessment of amniotic fluid.

Third module

- Denominates the fundamental basics of the first trimester screening (measurement the crown-rump length, capturing heart beat action, non-invasive prenatal testing) and the organ screening with standard sections.
- Describes the ultrasound features of the gynecological physiology, such as standard sections and measurement of the uterus (sagittal/transversal), measurement of the endometrial thickness, presentation of the ovaries and the main pathological findings such as myomas.

Fourth module

- Repetition of the essential basics of the sonography in the first trimester (measurement of CRL, assessment of gestational age) and focusing on basis pathologies, such as megacystis, anencephaly, omphalocele and gastroschisis.
- Is able to perform the documentation in Viewpoint® and adapts the gestational age by ultrasound.

Fifth module

- Depicts special applications for breast ultrasound (examination procedure) and describes fundamental sonographic features.
- Repetition of the fetal biometry and the sonographic measurement of the cervical length.

Sixth module

- Can adjust the umbilical artery and uterine arteries using duplex ultrasound.
- Repetition of the fetal biometry and the sonographic measurement of the cervical length.

Educational strategies

The theoretical knowledge is conveyed in a 30–45 min lecture for all new residents performed by a senior resident or consultant at the beginning of each module. In addition, all learning goals are covered in a script that is handed to the residents. All pathologies are represented with image examples. The practical hands-on part is afterward delivered to the residents by means of a 1–2 h tutorial divided into different sessions with a ratio of one senior physician for every four to five new residents.

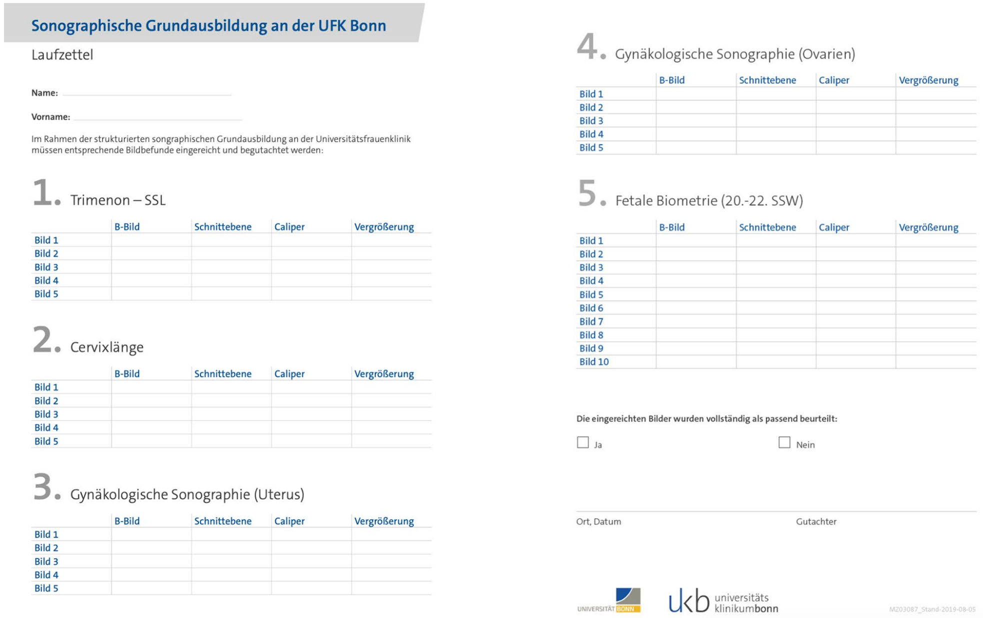
Implementation

The first module was implemented in February 2019 at the OBGYN department. Involving the respective members that participated in the curriculum and in the training of the residents, a suitable slot for the implementation of the project in the curriculum was identified which was stated to be best after the normal clinical routine. Then the infrastructure to sustain the organization of the ultrasound curriculum was created. Moreover, a specific working group has been established as a long-term support for this tutor-based project. The practical share of the course formats presented was over 70 percent of the total course. The corresponding tutors were all DEGUM-certified. The tutors were present for the entire duration of the course and supported the practical training in small groups of 3–4 trainees each. The images and sectional planes created during the course were discussed directly with each participant during practice and, if necessary, the transducer guidance was also corrected individually during training. The participants practiced the sectional planes according to the DEGUM and ISOUG guidelines, which are shown in Fig. 2. The practical parts lasted approximately one-and-a-half hour per module, so that each participant had sufficient time to improve their practical ultrasound skills. The participants were all young residents who had started their careers in the past 3–6 months and who did not have basic ultrasound skills in gynecology or obstetrics.

Feedback

A standardized logbook for the documentation of the most important standard sections and OBGYN ultrasound applications for the night shift was set up (Fig. 3).

14 residents took part in the training program. A completion rate with submitted pictures of 92% (13/14 participants) was achieved. The corresponding images were viewed and evaluated by DEGUM-certified examiners. Thus, a total of 390 images were rated by the examiners. Inter-reader agreement was calculated using kappa coefficients between the readers. The kappa coefficients were divided as follows: <0.0 = poor, 0–0.20 0 slight, 0.21–0.40 = fair, 0.41–0.60 = moderate, 0.61–0.80 = substantial, and 0.81–1.0 = almost perfect agreement according to Landis and Koch [21]. The inter-reader agreement showed to be 0,8348 (95% confidence interval 0.8007–0.8688) overall. The results show that the investigators had a very



Sonographische Grundausbildung an der UFK Bonn

Laufzettel

Name:

Vorname:

Im Rahmen der strukturierten songraphischen Grundausbildung an der Universitätsfrauenklinik müssen entsprechende Bildbefunde eingereicht und begutachtet werden:

1. Trimenon – SSL

	B-Bild	Schnittebene	Caliper	Vergrößerung
Bild 1				
Bild 2				
Bild 3				
Bild 4				
Bild 5				

2. Cervixlänge

	B-Bild	Schnittebene	Caliper	Vergrößerung
Bild 1				
Bild 2				
Bild 3				
Bild 4				
Bild 5				

3. Gynäkologische Sonographie (Uterus)

	B-Bild	Schnittebene	Caliper	Vergrößerung
Bild 1				
Bild 2				
Bild 3				
Bild 4				
Bild 5				

4. Gynäkologische Sonographie (Ovarien)

	B-Bild	Schnittebene	Caliper	Vergrößerung
Bild 1				
Bild 2				
Bild 3				
Bild 4				
Bild 5				

5. Fetale Biometrie (20.-22. SSW)

	B-Bild	Schnittebene	Caliper	Vergrößerung
Bild 1				
Bild 2				
Bild 3				
Bild 4				
Bild 5				
Bild 6				
Bild 7				
Bild 8				
Bild 9				
Bild 10				

Die eingereichten Bilder wurden vollständig als passend beurteilt:

☐ Ja ☐ Nein

Ort, Datum Gutachter

ukb universitäts klinikumbonn

Fig. 3 The standardized logbook for the documentation for the residents

good agreement when rating the images. In total, of the 390 images submitted in the course concept, the raters found 364 images to be suitable according to DEGUM standards (93.3%). This shows that the learning curve of young residents in OBGYN can be rapidly improved with the course concept shown. In addition, it demonstrates the rapid acquisition of standardized ultrasound image documentation in the field of obstetric sonography for young residents. Furthermore, the data also show that DEGUM-certified raters have a very high rate of image rating agreement, thus setting the same quality standards.

Discussion

We used Kern's six-step approach [11] to develop a comprehensive postgraduate ultrasound curriculum for OBGYN residents that fulfills the requirements of the DEGUM and ISUOG [16] recommendations and can be implemented and sustained for all residents.

There are several factors to be considered when implementing an ultrasound curriculum. First and foremost, knowledge about ultrasound physics, anatomy and pathologies is necessary. The scanning skills including the ability to generate an adequate image are the most crucial parts in ultrasound and are best learned by hands-on practice in very small supervised groups [8, 22].

The first task thus was to identify the most relevant skills to include in the curriculum. The skills proposed by the DEGUM and ISUOG [16] were a good starting point since they sample a large variety of techniques, for example fetal biometry, measurement of the cervical length, the use of duplex ultrasound focusing on the umbilical artery and the uterine arteries and the basic knowledge of these techniques.

A second vital consideration related to the recruitment of instructors. We decided to involve tutors from all three DEGUM qualification levels to minimize group sizes and thus maximize the hands-on time for the individual resident.

By implementing this course, we set a required standard for every new resident in our department for gynecology and obstetrics. Furthermore, we could get a harmonization of the common, in-clinic work processes by establishing this comprehensive ultrasound curriculum.

By this, we could establish a fast increasing of practical skills in the field of fetal biometry and gynecological sonography. Nevertheless, there are studies that propose between 200 and 300 supervised scans to gain a real improvement in the practical skills [23, 24]. Further, there are large differences in the learning curves for different types of examinations as some may be learned quickly whereas others require repeated practice over longer periods of time [25, 26]. These large variations underline the need for competency based education rather than ´one size fits all´ approach to ultrasound training [27]. A central concept of competency based education is to determine when trainees are sufficiently qualified for independent practice [28] which is a limitation of this comprehensive curriculum development. A weakness and limitation of the presented study is the presentation of the pure outcome of the described training format. Further studies must be conducted here to discuss the growth curve of the learning behavior with the respective pre- and post-testing. This could be done using practical ultrasound examination formats such as objective structured clinical examinations (OSCE). As a further step one could combine this developed curriculum with a published scale for assessment of ultrasound competence, the Objective Structured Assessment of Ultrasound Skills (OSAUS) [20]. This scale has shown evidence of validity and high reliability by judging the ultrasound skills competence for users.

Using a course-based training enables full control over the contents and splitting it up in a six-module-system made it adjustable to the busy timetable every new resident has at the beginning of his residency. Moreover, it makes it more adaptable to different clinical settings and is generalizable to OBGYN departments.

As described we developed a comprehensive ultrasound curriculum that at first fulfills the requirements of the DEGUM and the ISUOG, second, samples important pathologies novice physicians may encounter, and third can be implemented and sustained for all residents. Future studies now should investigate the potential impact of the curriculum on patient care especially in the night shifts.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by FR and AG. Implementation of the study and data collection were performed by FR, MD and PB. The first draft of the manuscript was written by FR and all authors commented on previous versions of the manuscript. UG and AG edited the manuscript. All authors read and approved the final manuscript.

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Availability of data and material Not applicable.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare no conflicts of interest.

Ethics approval Due to an educational quality assurance, no ethics vote of the ethics committee of the University of Bonn was required.

Consent to participate Informed consent was obtained from every participant in this study.

Consent for publication All authors gave consent for publication.

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Diskussion

Die aufgeführten Arbeiten beschäftigen sich inhaltlich mit der Frage, wie sich der aktuelle Stand in der Aus- und Weiterbildung in der Sonographie im Fachgebiet der Geburtshilfe und Frauenheilkunde darstellt. Ebenfalls werden die Anwendungen und Einsatzmöglichkeiten von Point-of-Care-Sonographie im Fachgebiet der Geburtshilfe und Frauenheilkunde untersucht sowie der Einfluss neuer Technologien in der Aus- und Weiterbildung der Point-of-Care-Sonographie beleuchtet.

Weltweit wird Ultraschall von einer Vielzahl von Gesundheitsdienstleistern in der Geburtshilfe und der Gynäkologie durchgeführt und eingesetzt, z. B. von Geburtshelfern/Gynäkologen, Radiologen, Sonographeuren, Hebammen und Krankenschwestern. Die Praxis unterscheidet sich je nach Ausbildung und Tradition nicht nur zwischen den Ländern sondern sogar innerhalb der Länder.

Wenn aber eine qualitativ hochwertige Versorgung national und international angeboten werden soll, ist es unerlässlich, dass diejenigen, die Ultraschalluntersuchungen in der Gynäkologie und Geburtshilfe durchführen und interpretieren, eine entsprechende Ausbildung absolviert haben und qualifiziert sind, sicher und kompetent zu arbeiten. Nationale und internationale Gesellschaften versuchen daher schon länger Standardisierungen im Bereich der Ultraschalldiagnostik in Geburtshilfe und Gynäkologie und Geburtshilfe zu etablieren. Hier sind insbesondere die Deutsche Gesellschaft für Ultraschall in der Medizin (DEGUM) und die International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) zu nennen.

Im heutigen Bereich der Gynäkologie und Geburtshilfe, in dem die Point-of-Care-Ultraschalluntersuchung (Moore and Copel 2011) immer mehr zu einer Erwartung und zu einer Anforderung wird, wird die Auffassung vertreten, dass die Ausbildung von Gynäkologen und Geburtshelfern über die Kenntnis der Indikationen für die Ultraschalluntersuchung und den Umgang mit den nachfolgenden Befunden hinausgehen sollte (Salvesen et al. 2010). Daraus folgt, dass alle Auszubildenden in der Geburtshilfe und Gynäkologie zumindest eine grundlegende theoretische und praktische Ausbildung in der geburtshilflichen und gynäkologischen Sonographie erhalten sollten (Rao et al. 2008). Dies ist besonders wichtig, da konventionelle Ultraschalltechnologie und der Point-of-Care-Ultraschall immer leichter zugänglich werden, mittlerweile nicht nur in einer Spezialpraxis oder einer Ultraschallabteilung, sondern in jeder Frauenarztpraxis und auf fast allen geburtshilflichen und gynäkologischen Stationen sowie im Kreißsaal genutzt wird und somit schon jetzt einen festen Platz in der Behandlung der Frauengesundheit einnimmt. Dabei stellt die Untersuchung des fetalen Herzschlages, die Lage der Plazenta sowie Kindslage unter der Geburt oder auch die Detektion freier Flüssigkeit im Becken nur einige Anwendungen dar, wo POC-US breitflächig eingesetzt wird (Kodaira et al. 2021). Der dynamische Echtzeit-Charakter des Ultraschalls eignet sich gut für die Durchführung und Interpretation durch Geburtshelfer und Gynäkologen, um rechtzeitige und angemessene Behandlungsentscheidungen zu erleichtern (Collins et al. 2019). Mitentscheidend für den Nutzen des Ultraschalls in der Gynäkologie und Geburtshilfe ist eine gründliche, praxisorientierte und zielführende Ausbildung. Sowohl die grundlegenden Pflegestandards als auch die Forschung und Entwicklung auf dem Gebiet des Ultraschalls hängen in hohem Maße von einer angemessenen und gewissenhaften Fachausbildung ab. Dabei konnte die vorliegende Arbeit erstmalig grundlegend die Anwendungen der POC-US im Bereich der gynäkologischen und geburtshilflichen Ultraschalldiagnostik aufzeigen sowie den hohen Ausbildungsbedarf dieser Technik untermauern (Recker et al. 2021c). Ebenfalls konnten wir auch den Ansatz interdisziplinärer Point-of-Care-Ausbildungskonzepte und deren Umsetzung in klinische Lehrformate darstellen (Grobelski et al. 2021).

Dabei sollte die grundlegende Ultraschallausbildung bereits im studentischen Bereich beginnen (Lewiss et al. 2014). In den vergangenen Jahren hat sich die Sonographie, insbesondere durch die Miniaturisierung der Technologie einen höheren Stellenwert im Bereich der „undergraduate“ Ausbildung erarbeitet. Jedoch wurde der Ultraschall curriculär nur in begrenztem Umfang in die Lehrpläne für Medizinstudenten aufgenommen (Hofer et al. 2008) und nicht systematisch als Lehrveranstaltung implementiert, die von allen Studenten in der medizinischen Grundausbildung zu absolvieren ist (Hoppmann et al. 2011). In letzter Zeit wurde jedoch das Bewusstsein für die Relevanz in der medizinischen Grundausbildung gefördert, sodass hier nun internationale und nationale Interessensbekundungen von Seiten der Fachgesellschaften (Cantisani et al. 2016) und der Studierenden (Wolf et al. 2019) ausgehen.

Eine der hier vorgelegten Arbeiten (Recker et al. 2021a) hat sich dabei auch mit der Sichtweise von Medizinstudierenden auf die Sonographie in der medizinischen Ausbildung beschäftigt, die die Grundlage für die weitere Aus- und Weiterbildung im Bereich der gynäkologisch-geburtshilflichen Sonographie darstellt. Dabei zeigt sich auf nationaler Ebene eine hohe Übereinstimmung mit den internationalen Ansprüchen und Erwartungen (Prosch et al. 2020) sowie auch den von uns publizierten Empfehlungen der World Federation for Ultrasound in Medicine and Biology (WFUMB) im Bereich der Ultraschallausbildung von Medizinstudierenden (Dietrich et al. 2019) und der internationalen Fachgesellschaften im Bereich der Ultraschalllehre (Hoffmann et al. 2020).

Ein besonderer Fokus wird hierbei auf die Point-of-Care Sonographie gelegt, da diese sich auch als gute Einstiegsmodalität in die Sonographie erweist (El-Baba et al. 2021). Gegenwärtig ist die fokussierte Ultraschalldiagnostik ein obligatorischer Bestandteil der Ausbildungsprogramme für Notfallmedizin, Geburtshilfe und Gynäkologie, Innere Medizin und Radiologie und wird für Ausbildungsprogramme in der Allgemeinchirurgie und Anästhesiologie empfohlen (ACGME 2021). Die traditionelle Ausbildung von Assistenzärzten wurde zunächst in der Radiologie und der Geburtshilfe und Gynäkologie eingeführt, obwohl diese Programme so konzipiert waren, dass sie eine umfassende Ultraschalluntersuchung in dem jeweiligen Fachgebiet vermitteln [12]. Die vielleicht fortschrittlichsten Ausbildungsprogramme in der fokussierten Sonographie stammen aus der Notfallmedizin, wo den Assistenzärzten empfohlen wird, 11 verschiedene Ultraschallschwerpunkte zu beherrschen (Akhtar et al. 2009). Diese Empfehlungen wurden jedoch nicht von Lehrplänen, Kompetenzbewertungen oder einer Methode zur Standardisierung der Qualität und Quantität der fokussierten Ultraschallexposition in verschiedenen Programmen begleitet. Diese Variabilität zwischen den einzelnen Fachgebieten und sogar zwischen den einzelnen Facharztausbildungen zeigt, dass ein gemeinsamer grundlegender Lehrplan erforderlich ist.

Die nationalen Ausbildungsanforderungen und der Weg zur Befähigung im Ultraschall unterscheiden sich von Land zu Land. In den Ländern, in denen bekanntermaßen die meisten Ultraschalluntersuchungen von Geburtshelfern und Gynäkologen durchgeführt werden (Frankreich, Deutschland, Schweiz), ist der Abschluss eines regulierten Zusatzprogramms (außerhalb der regulären Ausbildung zum Facharzt für Geburtshilfe und Frauenheilkunde) erforderlich (Salvesen et al. 2010). Dies ist zwar beruhigend im Hinblick auf die Gewährleistung der Kompetenz der Absolventen dieser Zusatzprogramme, doch nicht alle Auszubildenden in der Gynäkologie und Geburtshilfe durchlaufen diese hochrangige Ausbildung. In einigen europäischen Ländern gibt es formale Lehrpläne für Ultraschalluntersuchungen und in einigen Fällen gibt es Richtlinien für die Mindestanzahl von Untersuchungen, die zum Erreichen der Kompetenz erforderlich sind. Auch wenn klare nationale Standards für die Auszubildenden wichtig sind, werfen die unterschiedlichen Anforderungen (z. B. 80 protokollierte geburtshilfliche Untersuchungen in Dänemark vs. 400 in der Schweiz) die Frage auf, wie die Kompetenz in den einzelnen Ländern definiert ist. Das European Board and College of Obstetrics and Gynecology (EBCOG) versucht, dieses Manko zu beheben, indem es eine Reihe von Standards für die Durchführung von Ultraschalluntersuchungen in der Gynäkologie anbietet, ohne jedoch detaillierte Anforderungen an die Fähigkeiten zu stellen. Dennoch wird empfohlen, dass Geburtshelfer und Gynäkologen die relevanten Ultraschallaspekte der geburtshilflichen und gynäkologischen Krankheitsprozesse verstehen und mindestens 200 geburtshilfliche und 100 gynäkologische Ultraschalluntersuchungen protokollieren sollten, bevor sie selbständig Ultraschalluntersuchungen durchführen (Tolsgaard et al. 2014a). Die Anzahl der von AIUM und ISUOG empfohlenen Ultraschalluntersuchungen ist unterschiedlich (300 bzw. 100 für die Geburtshilfe und die Gynäkologie). Letztendlich hängt die spezifische Anzahl von Scans, die zur Erlangung der Kompetenz erforderlich sind, vom Auszubildenden und der Komplexität der Fälle ab. In der Ära der kompetenzbasierten Ausbildungsprogramme stellt sich die Frage, ob es überhaupt eine Mindestanzahl von Scans geben sollte (Tolsgaard et al. 2014b).

Als führende Organisation für den Einsatz von Ultraschall in der Gynäkologie und Geburtshilfe dienen die von der ISUOG veröffentlichten Empfehlungen für die Ultraschallausbildung als Richtwert (ISUOG 2014). Diese Empfehlungen können mit den Ausbildungsempfehlungen verschiedener internationaler Regulierungsbehörden verglichen werden. So hat beispielsweise das American College of Obstetricians and Gynecologists (ACOG) sein umfassendes Paket an Ultraschall-Fachkompetenzen an diese Empfehlungen angepasst (Abuhamad et al. 2018).

Auch das EBCOG hat mit dem Projekt "EBCOG-PACT" die Verbesserung der europäischen Ausbildungsstandards in der Geburtshilfe und Gynäkologie eingeleitet (The European Board and College of Obstetrics and Gynaecology. 2014). Im Rahmen dieses Projekts wurde ein europaweites Curriculum für die postgraduale Ausbildung in Geburtshilfe und Gynäkologie entwickelt. Das Curriculum ist gesellschaftsbezogen und basiert auf der neuesten medizinischen Ausbildungsmethodik. Es umfasst die Beschreibung der Ausbildungsergebnisse für das gemeinsame Kerncurriculum und die Wahlfächer, die zu vermittelnden allgemeinen Kompetenzen und Soft Skills sowie Strategien für die Ausbildung von geburtshilflichen Fertigkeiten, gynäkologischen Fertigkeiten, Ultraschallfertigkeiten und bio-psycho-sozialen und kommunikativen Fähigkeiten. Die Umsetzung des europäischen Curriculums für Geburtshilfe und Gynäkologie bietet den nationalen wissenschaftlichen Gesellschaften und Berufsverbänden sowie den Gesundheits- und Bildungsministerien die Möglichkeit, die Modernisierung nationaler oder lokaler OBGYN-Ausbildungsprogramme durchzuführen (Van der Aa et al. 2018). Dabei legt das dargestellte Curriculum auch einen besonderen Fokus auf die Weiterbildung in der gynäkologisch-geburtshilflichen Sonographie.

In einer der vorgelegten Arbeiten (Recker et al. 2022a) konnten wir hier erstmals die Effektivität eines kompakten Ultraschallcurriculums für junge Assistenzärzte aufzeigen, welche den Leitempfehlungen der ISOUG und dem EBCOG-Ultraschallcurriculum entsprach. Dabei wurden auch die internationalen Empfehlungen zur Curriculumsentwicklung miteinbezogen. Die hier dargestellten Ergebnisse stehen dabei im Einklang mit weltweiten Erfahrungen, die im Bereich der frauenheilkundlichen Ultraschallausbildung in den letzten Jahren gemacht wurden (Leonardi et al. 2018).

Dabei müssen auch neue und innovative Lehrmethoden im Bereich der Point-of-Care-Sonographie erwogen werden, welche perspektivisch insbesondere einen hohen Stellenwert in Ausbildung und Versorgung der geburtshilflichen Sonographie in abgeschiedenen Regionen haben können. So zeigt eine der vorgelegten Arbeiten (Höhne et al. 2021) erstmalig die Möglichkeit und die Effektivität eines komplett tele-medizinischen durchgeführten Ultraschallkurses auf, der anhand moderner Ultraschalltechnologie ermöglicht wurde. Die bestehende Literatur weist darauf hin, dass Applikationen von e-Learning sehr effektiv sein und ähnliche Ergebnisse wie Präsenzformate aufzeigen können (Tomlinson et al. 2013). Diese neuen Möglichkeiten können dabei auch im Einsatz der Diagnostik fetaler Erkrankungsbilder (Ferlin et al. 2012) sowie der Stärkung eines geburtshilflichen Managements dienen (Douglas et al. 2019), wie eine der vorgelegten Arbeiten aufzeigt (Recker et al. 2022b).

Mit der zunehmenden Komplexität der modernen Ultraschalltechnologie und der Einführung von Dienstzeitbeschränkungen ist ein rein klinisches Ausbildungsmodell nicht mehr praktikabel. Mit dem Aufkommen von originalgetreuen geburtshilflichen Ultraschallsimulatoren kann ein erheblicher Teil der Ausbildung in einem nicht-klinischen Umfeld stattfinden, was es dem Lernenden ermöglicht, bereits vor seiner ersten Ultraschalluntersuchung an einer Patientin umfangreiche Fähigkeiten zu erwerben und diese in kürzerer Zeit zu erlernen (Nitsche and Brost 2013). Diese Fähigkeiten werden anhand moderner Simulatoren und Simulationstechnik unterstützt und können in praktischen Kursen ausgebaut werden. So existieren publizierte Kursprogramme, bei denen hochwertige und hochpreisige Simulatoren in der gynäkologischen und geburtshilflichen Ultraschallausbildung eingesetzt werden (Rosen et al. 2017). Dabei kann dieser Ausbildungsstandard, der die Anschaffung hochwertiger und teurer Simulatoren erforderlich macht, durch neue Technologien wie dem 3D-Druckverfahren unkompliziert und wesentlich preisgünstiger umgesetzt werden. Dabei zeigen erste publizierte Daten den Einsatz im Druck von Feten, um diese den Eltern als plastisches Modell näher zu bringen (Tutschek and Blaas 2017). Eine der vorliegenden Arbeiten zeigt darüber hinaus auch auf, dass anhand von 3D-Drucktechnologie auch die Erstellung von realitätsnahen und schallbaren Ultraschallsimulatoren möglich ist, die individuell und preisgünstig angefertigt werden können (Recker et al. 2021b).

Zusammenfassung

Die Point-of-Care Sonographie hat mit zunehmender Etablierung als diagnostisches Verfahren und dem technischen Fortschritt in der Miniaturisierung in den letzten Jahren große Entwicklungen durchlaufen. Dabei spielt die Methode auch im Einsatzgebiet der Geburtshilfe und Gynäkologie eine immer größer werdende Rolle im klinischen Einsatz. Allerdings bedarf es hier grundlegenden Schulungen und Ausbildungskonzepten in der Aus- und Weiterbildung dieser neuen Methode der Ultraschalldiagnostik. Trotz jahrelanger Erfahrung und Ausbildung im Bereich der Ultraschalllehre gibt es immer noch keine internationalen einheitlichen Curricula und eindeutig empfohlene Lehrmethoden, wie Studierende und Assistenzärzte der Gynäkologie und Geburtshilfe in der Point-of-Care-Sonographiediagnostik unterrichtet werden sollen.
Die vorliegende Arbeit fasst Ergebnisse einer grundlegenden Einstellung zur Ultraschallausbildung von Medizinstudierenden zusammen und beleuchtet die verschiedenen Aspekte der Point-of-Care-Sonographie in der Geburtshilfe und der Frauenheilkunde. Dabei zeigt die Arbeit elementare Applikationen dieser Ultraschalltechnik fachspezifisch auf und beleuchtet die Aspekte der Einbindung in curriculäre Lehrstrukturen und Kurskonzepte. Sowohl innovative Formate in Präsenzlehre als auch neuartige, technologie-unterstützte Lehrformate, wie die Telemedizin, werden beleuchtet und untersucht. Es zeigt sich, dass auch solche Formate einen Lehrerfolg bringen und perspektivisch mitgedacht werden müssen. Des Weiteren bietet die Arbeit einen Blick in den Einsatz von neuartiger 3D-Drucktechnologie in der Ultraschallausbildung, der die Applikation und Individualisierung moderner und preisgünstiger Simulatoren ermöglicht.
Durch die technologische Miniaturisierung und neue portable Ultraschallgeräte wird eine vollkommen neue Definition der körperlichen Untersuchung möglich. Die zunehmende Verbreitung und Einsatz der mobilen Ultraschallgerätetechnologie und die vielfältigen neuen Möglichkeiten dieser Methode zeigen auf, dass perspektivisch sehr viel mehr Ärzte Ultraschallkenntnisse haben sollten als bisher. Basiskenntnisse in POC-US stellen auch eine Art „Türöffner" zur weitergehenden (spezialisierten) Ultraschallausbildung dar. Es bedarf der Ausbildung einer neuen Generation von Ärzten, die POC-US als Erweiterung ihrer eigenen Fähigkeiten betrachten, eine körperliche Untersuchung durchzuführen. Sie werden hierfür einen neuen „technischen" Sinn entwickeln, der zu Anamnese, Inspektion, Palpation, Perkussion,

Auskultation, Geruch hinzukommt und situativ benutzt und dem Ausbildungsweg der Benutzung eines Stethoskops ähneln wird. Dies führt zu einem Wandel in der medizinischen Ausbildung und dem klinischen Gebrauch dieser Technologie im Bereich der Frauenheilkunde, der die klinische Versorgung im Kreißsaal, auf Station und in den Ambulanzen revolutionieren wird. Dabei erweisen sich erstmalig POC-US-Befunde bei der fetalen Biomtrie, die mit einem portablen Ultraschallgerät erhoben wurden, als ebenso zuverlässig wie diejenigen, die mit einem High-End-Ultraschallgerät erhoben wurden (Leggett et al. 2022). Hier bedarf es jedoch zukünftig noch weiterer Studien, um die Effektivität der Point-of-Care-Sonographie in der Frauenheilkunde in spezialisierten Fragestellungen zu untersuchen.

Überlappung durch geteilte Erstautorenschaften

Die vorliegende Habilitationsschrift hat fünf publizierte Originalarbeiten zur Grundlage. Zwei der Arbeiten habe ich als Erstautor (Recker et al. 2021b)(Recker et al. 2022a) publiziert. Eine Arbeit habe ich mit Frau Elena Höhne als geteilter Erstautor zusammen veröffentlicht. Frau Höhne war medizinischer Doktorandin in unserer Gruppe dessen überdurchschnittliches Engagement mit einer geteilten Erstautorenschaft gewürdigt wurde. Eine weitere Arbeit habe ich mit dem Doktoranden Herrn Jakub Grobelski geteilt, dessen überdurchschnittliches Engagement ebenfalls mit einer geteilten Erstautorenschaft gewürdigt wurde. Mit dem studentischen Vorstandsmitglied der Deutschen Gesellschaft für Ultraschall in der Medizin (DEGUM) habe ich die Orginalarbeit über die studentische Ultraschallperspektive gemeinsam erhoben.
Darüber hinaus liegen der Habilitationsschrift drei weitere publizierte Übersichtsartikel zur Grundlage, die in dem wissenschaftlichen Kontext meiner Arbeit entstanden sind und hier ebenfalls Grundlage der Arbeit darstellen.

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