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Education of radiological technologists in the workplace of sonographers in different countries

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Abstract

Ultrasound is one of the most commonly used imaging modalities and a vital non-invasive diagnostic tool in modern medicine. This paper provides an overview of the education of radiologic technologists who work as sonographers in different countries and analyzes key areas of their practice, including cardiac, obstetric, and abdominal ultrasound. The role of sonographers in everyday clinical practice is examined as well as the educational guidelines necessary to acquire the competencies needed for standardized, high-quality work. In many countries, radiologic technologists with additional training assume the role of sonographers, which helps to alleviate the burden on the already strained healthcare workforce. The application of artificial intelligence (AI) is also discussed, as its use raises new ethical questions and considerations regarding competency acquisition. Based on international examples, this paper highlights the need for a legally and formally recognized educational pathway for radiologic technologists who wish to work as sonographers.

Keywords: competencies; education; radiologic technologists; sonographers; ultrasound

Abbreviations and acronyms: US (Ultrasound), CT (Computed Tomography), MRI (Magnetic Resonance Imaging), HEE (Health Education England), SCoR (Society and College of Radiographers), BMUS (British Medical Ultrasound Society), CASE (Consortium for the Accreditation of Sonographic Education), RCR (Royal College of Radiologists), FAST (Focused Abdominal Sonography for Trauma), AI (Artificial Intelligence), WIL (Work-integrated Learning)

Introduction

Ultrasound

Ultrasound (US) is a sound with a frequency above the upper limit of human audibility, typically exceeding 20,000 Hz [1]. This imaging modality is used to visualize internal organs and tissues, facilitating and accelerating diagnosis and detecting a wide range of health conditions [2]. While frequencies of 1–15 MHz are most common, higher frequencies of 20–40 MHz are also being applied in recent times [1]. The key components of an ultrasound examination are shown in Figure 1 [3].

The basis of US diagnostics is conventional B-scanning, also known as “brightness scan” [4]. Ultrasound devices consist of emitters and detectors that produce and receive longitudinal waves. These waves easily penetrate through tissue and are reflected from organs, bodily fluids, and bones, with the reflections then detected by a receiver [5]. Figure 2 shows a B-scan image on a US device [4].

The use of US began during World War II and quickly spread globally. The first scientific paper presenting medical US images was published by Dr. Karl Theodor Dussik in Austria [6]. Today, the demand for US examinations in hospitals continues to grow, making it a primary diagnostic method for numerous health conditions [7].

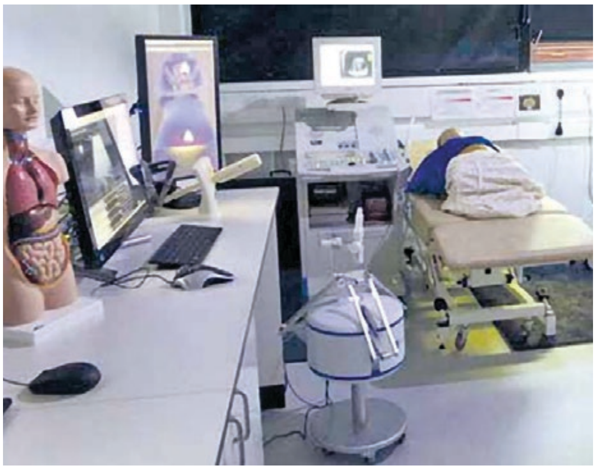

Figure 1. US equipment display
Source: https://openaccess.city.ac.uk/id/eprint/18310/1/Independent%20reporting%20sonographers-could%20other%20countries%20follow%20the%20UK%27s%20lead%202017.pdf

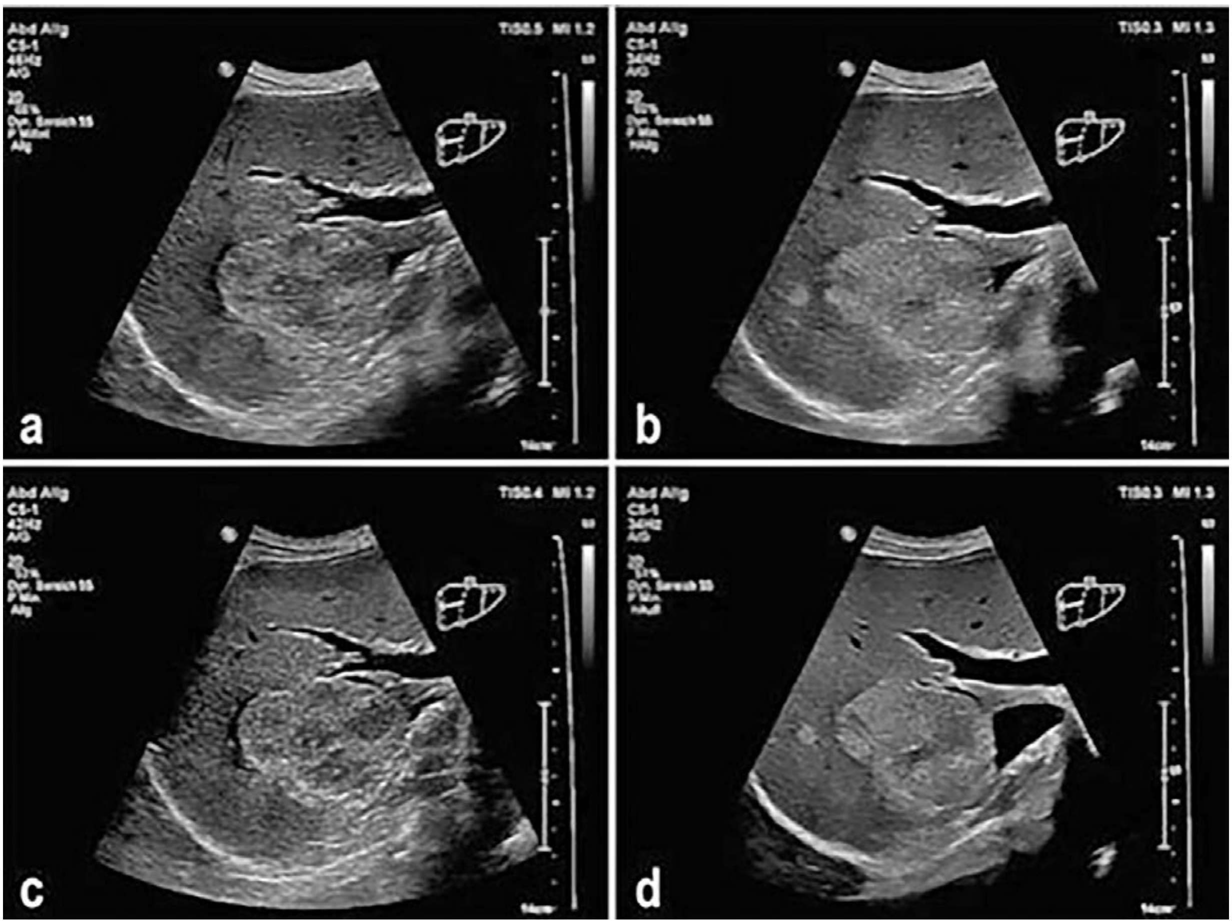

Figure 2. Conventional B-scan US of a solid echogenic lesion in the liver
Source: https://pmc.ncbi.nlm.nih.gov/articles/PMC10060993/

US offers several advantages as an imaging modality, including real-time imaging, wide availability, and applicability in a clinical context for monitoring, diagnosis, follow-up, and guiding interventional procedures. It provides excellent anatomical accuracy in depicting both superficial and much deeper structures and surpasses the spatial resolution of computed tomography (CT) and magnetic resonance imaging (MRI). Moreover, it does not use ionizing radiation and is significantly more affordable, with lower equipment and maintenance costs compared to the aforementioned CT and MRI [8]. The examination itself involves direct interaction between the sonographer and the patient, with medical history, observation, and palpation all contributing to an effective procedure [9]. During the examination, the patient lies or sits still while the probe, pre-coated with gel, is moved across the skin to acquire the images [5]. Even minor changes, such as the amount of pressure applied with the probe on the skin, the direction in which it is positioned, or changes in scale during interpretation, can significantly affect the outcomes [10]. Beyond medicine, US systems are used in a wide range of industries, including pharmaceutical, military, and general manufacturing [1].

Ultrasound and sonographers

Sonographers are medical professionals specialized in performing US examinations, while the interpretation of the results is usually carried out by a radiologist [1]. For over 40 years, US imaging has primarily been performed by sonographers and physicians specialized in radiology, cardiology, vascular surgery, and obstetrics and gynecology [11].

In the United Kingdom, the majority of obstetric and other US examinations are performed by radiographers with postgraduate education. These sonographers scan, interpret findings, and compile reports on the examinations conducted. The second-largest group performing US in the UK are radiology specialists. Given the growing demand for US services, teams from Australia and parts of continental Europe have begun to study the British model as a potential solution to meet demand in this field [12].

The development of new imaging modalities, changes in work practices, and interventional procedures in radiology have led to the growing use of combined skills across most US departments. Along with a shortage of radiologists, this has created a need for the sonographer's role to be expanded [13]. For a long time, sonographers were an unknown figure within the healthcare system [14]. In 2008, the College of Radiographers in the UK submitted a proposal to the then Health Professions Council to legally regulate the sonographer profession. In October 2009, a recommendation for legal regulation was presented to the Secretary of State for Health. However, the government clearly stated in an official document that it did not intend to introduce statutory regulation for sonographers. Regardless of the level of professional qualification attained, statutory registration is currently not available to everyone. Given these circumstances, many challenges and issues arise for sonographers when seeking employment or attempting to change their current workplace [15].

Aim of the paper

This paper aims to provide an overview of the concept of US and highlight the increasingly important role of radiologic technologists within US diagnostics. It explores how new technologies and the application of artificial intelligence can enhance competencies and guide future development. The paper also seeks to identify the challenges and opportunities that accompany the advancement of US and to encourage discussion on the expanded role of radiologic technologists, including their potential to independently perform US examinations.

Discussion

Sonographers' education

In most European countries, a shortage of radiologists has been recognized, while at the same time, the demand for US services continues to grow. In certain countries, radiographers are permitted to independently perform US examinations after completing the required education and clinical training [16]. Based on their training and acquired knowledge, they gradually develop skills through years of work experience, enabling them to perform US scans safely and reliably [17].

Health Education England (HEE) is collaborating with stakeholders to address workforce shortages and to increase clinical capacity for the timely education of sonographers [18]. The differences in practice between the UK and other European countries stem from factors such as training, duration of work experience, and the lack of adequate financial compensation for added responsibilities and advanced skills [16]. According to reports from respondents in nine countries (the United Kingdom, France, the Netherlands, Sweden, Denmark, Finland, Austria, Malta and Cyprus), radiographers in their countries actively perform US examinations. In contrast, four countries report no involvement of radiographers in US diagnostics: Croatia, Germany, Poland, and the Czech Republic [19].

Organizations such as the Society and College of Radiographers (SCoR), the British Medical Ultrasound Society (BMUS), the Consortium for the Accreditation of Sonographic Education (CASE), and the Royal College of Radiologists (RCR) continue to advocate for the legal regulation of the sonographer profession [20].

The most common educational pathway for future sonographers begins with an undergraduate degree in radiography, nursing or midwifery. Upon graduation, a period of acquiring adequate clinical qualifications follows before one can pursue postgraduate education [21]. Numerous discussions and proposals are ongoing regarding the optimal duration of the training period for newly qualified sonographers. According to recommendations from the SCoR and RCR, six months is suggested during which trainees focus on developing US scanning skills [13]. During this training phase, the trainees' abilities to conduct US examinations must be professionally assessed [22].

As an alternative to direct postgraduate enrollment, one higher education institution has developed a "3 + 1" program, which includes three years of undergraduate radiography education followed by one postgraduate year.. This approach effectively avoids interruptions in education and the need to find employment before entering postgraduate study. With each year, an increase in the number of qualified sonographers is expected, which should ultimately help alleviate the staffing shortage. However, the main concerns related to direct entry include: the limited

Table 1. Proposed Actions for Each Component of a Mentorship Program for Newly Qualified Sonographers [13]

Component	Proposed Actions
Transition	• Provide personal and professional support to reduce the effect of 'cultural shock' • Allow time and support for critical reflection • Support adaptation to the new role • Facilitate the development of professional and clinical competencies • Provide the mentor with a 'critical friend' for support
Role Development	• Clarify the professional expectations of the mentor • Ensure a clear understanding of the work role and identify areas where additional support is needed • Guide mentees toward opportunities for further professional and clinical development • Ensure access to a contact person during personal or professional difficulties • Ensure the mentor is aware of and committed to their scope of practice
Competence and Credibility	• Support clinical skills development by setting realistic goals • Promote the development of professional and communication skills with patients and colleagues • Facilitate integration and effective teamwork between the mentor and colleagues within the department and the wider multidisciplinary team
Embedding the Value of Lifelong Learning	• Ensure a clear understanding of professional responsibility and the code of conduct • Ensure that the mentor is aware of, and proactive in recognizing and utilizing, opportunities for continuing professional development

number of available places, short training time, lack of prior healthcare knowledge, underdeveloped communication and patient care skills and an excessive number of enrolled students relative to available resources [21]. Most students newly introduced to clinical training tend to prefer scanning after observing their mentors. Several reasons are cited for this, including easier anatomical recognition, mimicking techniques and simpler manipulation of the probe. In contrast, students nearing the end of their clinical training prefer to scan before their mentor intervenes [23].

Although the literature on mentorship program development is limited, there are indications that four key components should be included to ensure proper support for new professionals. This enables newly qualified sonographers to develop their own skills, which in turn leads to greater workplace confidence. Key recommendations for effective mentorship programs are presented in Table 1 [13].

Professional supervision is a mechanism that enables healthcare professionals to share their reflections on clinical situations and discuss emotional experiences within a safe and confidential environment. Due to increasing pressure and workload, there is growing physical exhaustion, stress and ultimately burnout among sonographers [24].

Consortium for the Accreditation of Sonographic Education (CASE) is a non-profit organization established in 1993. It is composed of six member organizations that accredit sonographic courses offered in the United Kingdom. CASE relies on volunteers united by a shared desire to ensure adequate levels of education and training for future sonographers [2]. These volunteers dedicate their time to preparing sonography students for future professional experiences [25]. In 2015, the Consortium adopted four core principles to be followed:

Reporting should not be separated from scanning.

Scanning is a *dynamic* process, and the assessment and interpretation of images depend entirely on the operator at the time of the scan.

The risk of patient harm and potential litigation resulting from inadequate service provision is high; therefore, competence in scanning is the most critical factor.

Developing innovative training pathways to meet the demand for US services should demonstrate increased efficiency in delivering diagnoses and treatment to patients [2].

Countries such as Australia and New Zealand have a long-standing and well-developed tradition in sonography, where sonographers independently perform complete US examinations. This means they provide formal reports, and as such, their examinations are considered fully comprehensive [9]. In contrast, Italy, France, and Spain have very few practicing sonographers, while in the Netherlands, Denmark, Sweden and Ireland, sonographers have well-established roles in clinical practice. The limited presence of sonographers in some countries likely stems from multiple factors, including the dominance of the medical profession, specific healthcare funding structures, deeply rooted professional mindsets, and, at times, a lack of willingness among sonographers to take on greater autonomy [26]. However, further research indicates that in France, Norway, Denmark, Sweden, Italy and Poland, radiographers are already performing US examinations [16]. This has prompted many questions and discussions regarding who should be responsible for writing the final US report [27]. Given the dynamic and transient nature of US, providing the final report at the time of the scan is considered the best and safest practice.. While some European countries have begun to adopt or define such practices, this approach remains more widely accepted in the United Kingdom, the United States, and Australia [28]. In the United Kingdom, there are currently eighteen higher education institutions and universities offering US courses accredited by CASE [29]. Unlike the situation in the UK, sonographers in some countries are still not widely accepted. For example, in Norway, the introduction of sonographer education has caused significant concern among Norwegian radiologists, and the Norwegian Society of Radiology issued a public statement recommending that professional positions not be allocated to sonographers [30]. Despite these negative views, five out of eight sonographers in Norway successfully found employment [31].

In June 2022, an online study was conducted in the Republic of Croatia titled "Organizational Aspects of Introducing Sonographers as an Additional Work Area for Radiologic Technologists" [32]. The study involved 69 participants. One group consisted of third-year graduate students of Radiologic Technology at the Faculty of Health Sciences in Split, while the other group included employed individuals who hold a master's degree in Radiologic Technology. The introductory part of the survey explained the term *sonographer*, defined as a radiologic technologist with a master's degree and additional professional training in US diagnostics. One of the initial questions assessed participants' knowledge of the term itself. The survey also examined the level of interest in further education if such a program were introduced at the Faculty of Health Sciences in Split. The results of the online survey confirmed a high level of interest in introducing this specific area of work for radiologic technologists. Such education could provide a crucial solution to the shortage of radiologists. However, for sonographers to successfully carry out their responsibilities, it is essential to ensure a high-quality educational program, comprehensive clinical training, and a clearly defined organizational structure [32].

Most common areas of sonographer practice

Echocardiography, also known as US imaging of the heart, is the most commonly used imaging method in modern clinical cardiology. In many countries, these examinations are performed by cardiac sonographers [33]. Although sonographers play an important role in adult cardiology services, significantly fewer healthcare institutions employ specialists in the field of pediatric cardiac US. Figure 3 illustrates the eleven areas in which pediatric echocardiograms are applied [34].

Examinations typically begin with basic assessments of cardiac function and may progress to more complex evaluations of cardiac structures or congenital heart diseases. The study of cardiac US encompasses both theoretical and practical knowledge of cardiac structure and function, anatomy, pathology, embryology, the physical basis and principles of US, as well as the operation of US devices [33]. The primary role of the cardiac sonographer is to generate high-quality US images of the heart and to collect Doppler data related to hemodynamics [14].

Since its first documented use in obstetrics in the United Kingdom, US has become a key method for monitoring pregnancy. It is used to diagnose and treat complications related to pregnancy [35]. Currently, there is no evidence

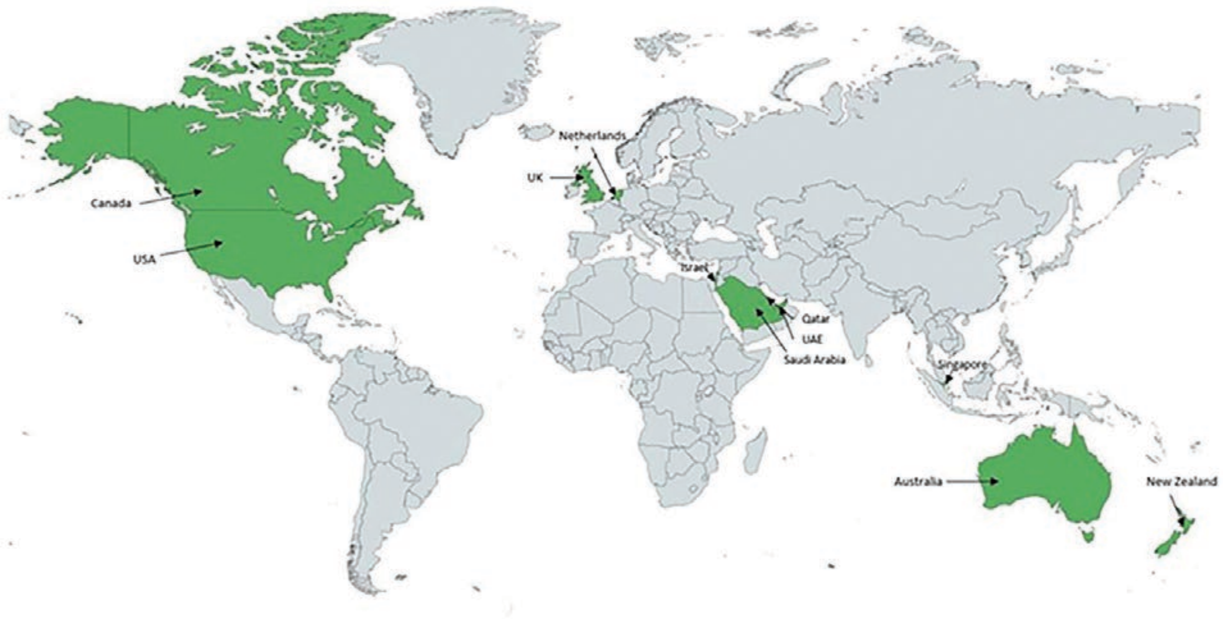

Figure 3. World map showing countries (in green) that use the dominant sonographer model for performing pediatric echocardiograms
Source: https://pmc.ncbi.nlm.nih.gov/articles/PMC9196029/

suggesting that the use of B-mode or M-mode US in the first trimester has negative outcomes. This conclusion is based on the fact that these modes operate at low acoustic intensity levels [36]. The introduction of 3D US has led to a revolutionary advancement in gynecology. Furthermore, with the use of 4D US, expectant parents are able to observe their baby sleeping, yawning or even smiling in real-time [37]. Figure 4 illustrates the three most commonly used US views of the fetus during obstetric examinations [37].

The role of sonographers in communication with patients remains a subject of ongoing uncertainty. Radiological associations state that decisions regarding patient communication fall exclusively under the authority of radiologists, who may choose whether such communication occurs during the examination or after its completion [38]. A sonographer performing an examination must remain neutral when communicating with pregnant women and is expected to support their decisions. Delivering results is a routine part of practice and often involves interpreting complex information. In 2020, a communication framework was developed for delivering unexpected pregnancy findings to expectant parents. This framework provides appropriate terminology designed to reduce the emotional burden placed on sonographers and to minimize their exposure to emotional stress [39].

The majority of sonographic workload involves abdominal and pelvic examinations, while breast, musculoskeletal, and vascular scans are less commonly performed [40]. Sonographers demonstrate excellent recognition of normal versus pathological abdominal ultrasound findings. The discrepancies between their reports and those of radiologists are minimal, negligible, and clinically insignificant [41].

For severely injured patients, a rapid and reliable assessment is crucial before initiating treatment. While CT is extremely precise in detecting internal injuries due to its detailed cross-sectional imaging capabilities, its high

Figure 4. Display of 2D, 3D, and 4D US images of the fetus
Source: https://ginekologija-boras.hr/2d-3d-4d-ultrazvuk-u-ginekologiji-i-trudnoci/

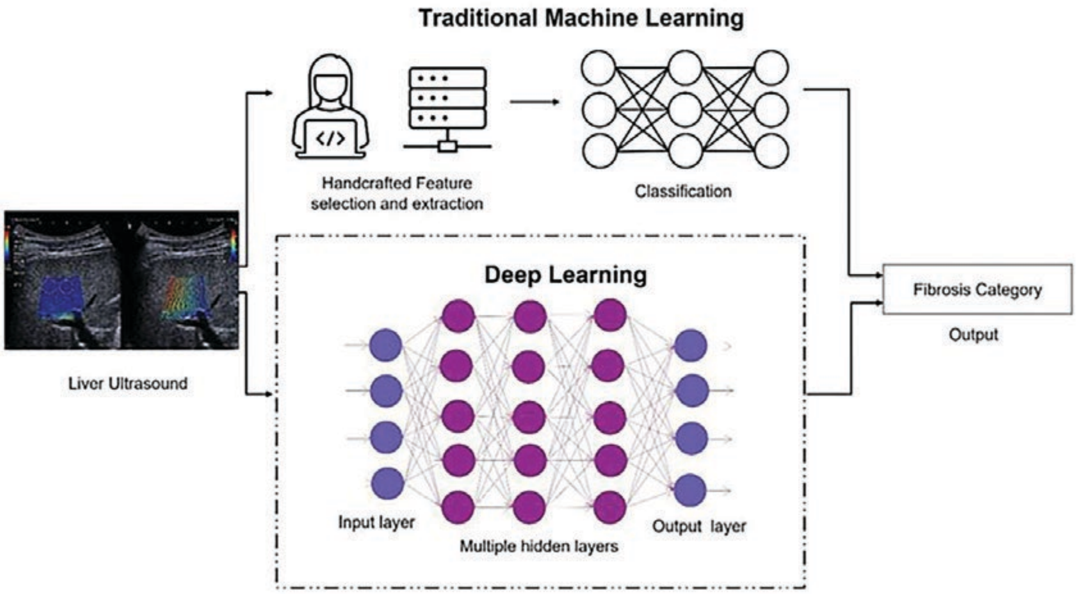

Figure 5. Schematic illustration of traditional machine learning versus deep learning
Source: https://pmc.ncbi.nlm.nih.gov/articles/PMC10034654/

cost and limited availability pose challenges, especially in remote rural areas. In contrast, Focused Abdominal Sonography for Trauma (FAST) is a cost-effective and non-invasive method that can be performed immediately in the resuscitation room. This approach eliminates the risks associated with transporting critically ill patients and is therefore often recommended as the first diagnostic step over CT [42]. The FAST scan is based on the detection or exclusion of free fluid, most commonly blood, resulting from internal organ damage. It is used to identify fluid in seven key areas of the abdomen: the right and left upper quadrants, the pelvic cavity, both paracolic gutters, and the renal fossae on both sides. In such emergency settings, ultrasound has proven to be highly effective, as it is fast, non-ionizing, and repeatable, which is critical if important findings are obscured during the initial scan [42].

In pediatric patients, the majority of injuries result from blunt trauma, and intra-abdominal injuries are detected in only 6% of cases. A positive FAST scan can help differentiate those who require urgent surgical intervention from those for whom a conservative treatment approach is appropriate. In addition, the FAST scan can provide insight into potential disease progression and evaluate conditions that may lead to serious complications [43].

Application of artificial intelligence in ultrasound

As artificial intelligence (AI) becomes increasingly present in everyday life, it is also gaining wider application across various branches of medicine. AI contributes to the development of numerous technologies in specialized clinical settings. Some of the most significant applications include enhanced boundary recognition during echocardiography and reduced variability in elastography [44]. However, the primary role of AI in medicine remains focused on detection and diagnosis. Such systems operate on two main principles: classification and segmentation. Classification systems assess the likelihood of malignant lesions, while segmentation systems offer precise delineation of lesion boundaries within the scanning planes [43]. Figure 5 illustrates the difference in functioning between machine learning and deep learning based on an US examination of the liver [44].

In modern US devices, the traditional method of beamforming is increasingly being replaced by software algorithms for virtual focusing. This shift enhances spatial resolution without causing significant loss of time or data, which was a common drawback of earlier methods [44].

Within the context of university-level education, it is necessary to assess the potential changes resulting from the introduction of various AI-based methods and to adapt the curriculum and teaching methods accordingly. Emphasis should be placed on the ethical and legal responsibilities associated with the use of AI in healthcare. Pesapane et al. argue that although AI can mimic the functioning of the human brain, its mode of "thinking" still differs from that of humans. Therefore, integrating AI concepts into existing educational programs is essential [44].

Artificial Intelligence and Echocardiography

There are already several ways in which AI is making cardiac imaging simpler, faster and more accurate. Once the software evaluates the images as diagnostically acceptable, they are automatically collected. In interpretation, AI can detect and extract information that may not be immediately noticeable to the observer, overcoming human limitations such as fatigue and subjectivity [45]. Current programs include the assessment of valve motion and segmentation, evaluation of chamber size and detection of pericardial effusion. By using automated algorithms designed to assist in interpretation, significant support is provided for the education of students and newly employed professionals, helping them to more easily master

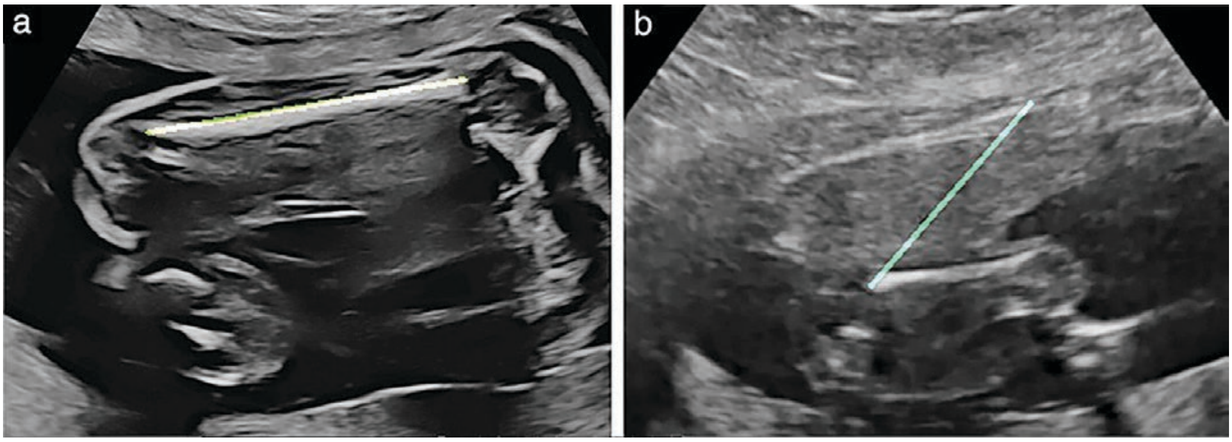

Figure 6. Grayscale ultrasound images labeled with real-time results from an AI model trained to detect and measure femur length
Source: https://obgyn.onlinelibrary.wiley.com/doi/10.1002/uog.26238

complex protocols. Although the future of AI in this field remains uncertain, it is believed that the key to success lies in the critical thinking skills of the sonographer and the careful development of AI algorithms [45].

Artificial Intelligence and Obstetrics

The use of AI in fetal US encompasses three main areas. At present, automated fetal biometry is the only function that has clinical application. Models have been developed that automatically measure parameters such as head circumference, biparietal diameter, femur length and crown-rump length [46]. To support these measurements, a display layer showing the automatically obtained biometric parameters may assist the sonographer in reviewing the estimated anatomical region and verifying the accuracy of the measurements. This method can be useful for measurements that are easily assessed visually but offers less benefit for more complex evaluations. Figure 6 shows one of the previously mentioned methods of automated measurement [46].

Another key area of application is the automatic detection and storage of standard imaging planes. This also contributes to significant time savings, as AI can automatically label each frame based on the displayed fetal anatomy. The final area of AI application represents the greatest challenge in fetal ultrasound: the automatic detection of fetal abnormalities [46].

During scanning, AI and the sonographer simultaneously analyze input data and produce output based on the results. Sonographers should be able to recognize when AI is reliable and when its conclusions should be disregarded. Over-reliance on AI – referred to as *automation bias* – can be dangerous, while excessive feedback may confuse the sonographer. Therefore, the application of AI must be approached with a degree of caution to prevent and mitigate risks associated with its limitations [46].

Guidelines for sonographer practice

Newly qualified sonographers are advised to meet several prerequisites to support the continued development of US services. All practitioners should complete training to the undergraduate or master's level. Examinations must be conducted following written protocols that are regularly updated, and the service must be supported by radiologists, clinicians, and senior hospital management. Formal training in report writing would also help reduce the need for radiologists to rephrase or revise content in terms of wording or style [6].

A key factor in the future growth of the sonographic workforce is the development of sustainable educational solutions. Given the already mentioned shortage of healthcare professionals in this field, work-integrated learning (WIL) could become a core component of the future of the sonography profession. WIL is an educational approach that allows students to combine academic education with simultaneous workplace experience. Students typically engage in internships that build on their university-acquired knowledge while simultaneously developing professional skills. WIL is therefore recognized as an effective model for preparing students for the workforce, as it helps bridge the gap between the workplace and academic education, bringing the two closer together [47].

The primary philosophy of WIL should focus on student learning and the development of a sustainable workforce. It is therefore essential that all US students have access to quality education. To achieve this, internships and clinical placements must be carefully and precisely organized and supported with sufficient resources to ensure that workforce availability, workload, and learning opportunities are ultimately balanced. It is vital to invest in building clinical education capacity by offering opportunities for clinical education and mentor training. Financial support serves to increase the capacity for clinical placements and simultaneously alleviates financial burdens for students, ensuring equal educational opportunities for all. Such funding may be provided by multiple stakeholders in the education process, most notably the government, academic institutions, or professional associations [47].

At all levels of practice, sonographers should adhere to the following professional guidelines:

- Practice and perform duties within their scope of competence.
- Comply with local clinical protocols.
- Ensure that practice is in line with current professional standards.
- Develop into competent and safe sonographers who are able to independently perform, interpret, and report on US examinations.

- Possess foundational knowledge that supports the development of leadership and educational skills for training future stakeholders in US services.
- Support colleagues to ensure safe practice and meet the needs and expectations of patients [2].

Conclusion

US today represents an indispensable component of diagnostic medicine. Radiologic technologists have significant potential to take on the role of sonographers. High-quality education and continuous professional development, combined with strict adherence to established guidelines, form the foundation for the accurate and safe performance of US examinations. The integration of AI into US diagnostics introduces new challenges, but also offers opportunities to enhance the efficiency of diagnostic processes. This paper confirms the importance of ongoing education and the need for international harmonization of practice standards. In conclusion, with the support of modern technologies, US has a clear trajectory for continued growth and advancement. Radiologic technologists are expected to increasingly assume independent roles in the performance of these examinations in the future.

All data in this paper are part of the results of the undergraduate thesis " Education of radiologic technologists in the workplace of sonographers in different countries" written at the Faculty of Health Sciences, University of Split [48]. ■

Obrazovanje radioloških tehnologa na radnom mjestu sonografera u različitim zemljama

Sažetak

Ultrazvuk je jedna od najčešće korištenih slikovnih metoda. Jedna je od najvažnijih neinvazivnih dijagnostičkih metoda u suvremenoj medicini. U radu su analizirani temeljni pojmovi ultrazvuka, kao i uloga sonografera u svakodnevnoj kliničkoj praksi. Detaljno su opisane edukacijske smjernice potrebne za stjecanje kompetencija sonografera kako bi se osigurala standardizacija rada i zadovoljila kontrola kvalitete. U mnogim zemljama ulogu sonografera preuzimaju radiološki tehnolozi s dodatno potrebnim edukacijama te tako rasterećuju već dovoljno opterećeno zdravstveno osoblje. Ovaj rad pruža pregled obrazovanja radioloških tehnologa na radnom mjestu sonografera u različitim zemljama te se također analiziraju ključna područja njihove prakse, od kojih su najistaknutija: kardiološki ultrazvuk, ultrazvuk u opstetriciji i abdominalni ultrazvuk. Također se stavlja naglasak na primjenu umjetne inteligencije, čijom se primjenom postavljaju razna etička pitanja, kao i nova pitanja oko stjecanja kompetencija. Temeljem međunarodnih primjera, istaknuta je potreba za zakonskom i formalnom edukacijom radioloških tehnologa na radnom mjestu sonografera.

Ključne riječi: kompetencije; obrazovanje; radiološki tehnolozi; sonograferi; ultrazvuk

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