Ultrasound in undergraduate medical education: a systematic and critical review

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Abstract

Introduction

Point-of-care ultrasound (POCUS) use in clinical care is growing rapidly, and advocates have recently proposed the integration of ultrasound into undergraduate medical education (UME). The evidentiary basis for this integration has not been evaluated critically or systematically. In this study, we conducted a critical and systematic review framed by the rationales enumerated by advocates of ultrasound in UME in academic publications.

Methods

This research was conducted in two phases. First, the dominant discursive rationales for the integration of ultrasound in UME were identified using techniques from Foucauldian critical discourse analysis (CDA) from an archive of 403 academic publications. We then sought empirical evidence in support of theses rationales, using a critical synthesis methodology also adapted from CDA.

Results

We identified four dominant discursive rationales, with different levels of evidentiary support. Ultrasound was not demonstrated to improve students' understanding of anatomy. The benefit of ultrasound in teaching physical examination was inconsistent, and rests on minimal evidence. With POCUS, students' diagnostic accuracy was improved for certain pathologies, but findings were inconsistent for others. Finally, the rationale that ultrasound training in UME will improve quality of patient care was difficult to evaluate.

Discussion

Our analysis has shown that the frequently repeated rationales for the integration of ultrasound in UME are not supported by a sufficient base of empirical research. The repetition of these dominant discursive rationales in academic publications legitimizes them and may preclude further primary research. Since the value of clinical ultrasound use by medical students remains unproven, educators must consider whether the associated financial and temporal costs are justified or whether more research is required.

Introduction

Advocates of point-of-care ultrasound (POCUS) propose the integration of ultrasound into undergraduate medical education (UME), driven by a belief "that expanded training in the use of ultrasound will lead to better health care for both individuals and populations" [1]. With the expectation that POCUS will be viewed by future physicians "as an extension of their senses, just as many generations have viewed the stethoscope", educators are encouraged to "embrace and incorporate the technology throughout the curriculum" [2]. Some institutions have begun to do just that [3-5].

The use of POCUS in clinical care has expanded across medical specialties in recent years [6]. There is evidence to support the improved safety of certain procedures with POCUS [7-9]. POCUS has also been shown to assist with certain diagnoses at the bedside, and can rapidly and accurately identify anatomic pathology [10-13]. However, there remains a lack of sufficient evidence to support any clear clinical benefit of even the longest-studied diagnostic application of POCUS (i.e. the FAST examination in blunt abdominal trauma) [14]. Kim et al. [15] question the "uncritical acceptance" of the diagnostic role of POCUS, which they believe is "spurred by enthusiasm, not science".

It is this environment of proliferating POCUS use, with an evolving evidence base for different applications, in which advocates have promoted incorporation of ultrasound training into the curricula of medical schools. Curricular changes might best be judged on their ability to influence patient outcomes, but because it is difficult to demonstrate how educational interventions achieve these outcomes, such studies are rare [16-18]. Educators are left to weigh other sources of evidence when choosing to implement curricular changes.

There exists no clear evidence of improved patient outcomes as a result of incorporating ultrasound in UME. Several rationales are suggested by proponents; for example, in a recent article, educators in California suggested four main justifications:

> "(1) it can enhance traditional learning; (2) it can train future physicians to improve their diagnostic and procedural skills; (3) it can promote coordinated and efficient patient care; and (4) it can serve as a template for advanced, specialty-specific, or interdisciplinary ultrasound training in graduate medical education and continuing medical education." [19]

Two reviews have been published on ultrasound in UME. Mircea et al. [20] described the findings of nearly three dozen publications, asserting that "ultrasonography should be always the choice as an ideal support tool in medical education". Similarly, Lane et al. [21] described the history of clinical ultrasound and ultrasound in medical education, citing fifty publications, concluding that "ultrasound in medical education is ingrained and will grow exponentially in the coming years" and calling for the allocation of further resources. Neither of these reviews approached the literature systematically or critically.

The body of literature focusing on ultrasound in medical education is growing, and many medical schools have begun to implement ultrasound-integrated curricula [22]. It is imperative to understand the rationale for the integration of ultrasound in UME, and the evidence supporting this trend, given the temporal and financial costs and uncertain clinical role in the hands of medical students [23]. In order to critically evaluate taken-for-granted assumptions about the benefits of ultrasound in UME, we used a systematic approach to explore the evidence found in academic publications.

Methods

We conducted our research in two phases. First, we identified dominant discursive rationales for the integration of ultrasound in UME by analyzing a large corpus of academic literature. Second, we critically and systematically reviewed the literature for empirical evidence in support of the identified discursive rationales. We followed the STORIES statement as a guide to the reporting of our systematic review of the evidence [24].

We employed techniques from Foucauldian critical discourse analysis (CDA) to identify the dominant discursive rationales. Foucauldian CDA examines relationships between language, practices, and power to identify taken-for-granted assumptions about ideas that appear natural or inevitable and reveal the power relationships that support dominant ways of viewing the world [25, 26]. Discursive rationales are *statements of truth*, the "surface manifestations" of discourse: "strongly articulated arguments about what is true/untrue, just/unjust, legitimate/illegitimate, permitted/forbidden in a given place or time" [27]. The dominant discursive rationales were identified from an archive of academic publications related to ultrasound in medical education. This archive consisted of 403 texts published in academic journals between 1980 and 2016, located through searches in MEDLINE and Google Scholar (most recent update April 1, 2016) using the search terms 'ultrasound', 'ultrasonography', and 'medical education'. Relevant titles found in reference lists and citing articles identified using Google Scholar were also explored; 1395 articles were reviewed for relevance. We conducted an iterative textual analysis using Foucauldian CDA techniques focusing on frequently recurring truth statements, especially those that cited research evidence, to identify dominant discursive rationales for the integration of ultrasound in UME [28-30].

We used these dominant discursive rationales as a framework to guide our review. We chose to frame our review in this way to achieve two ends: 1) in order to directly problematize dominant arguments as articulated by advocates; and 2) in order to approach the literature broadly as readers without content expertise in ultrasound education by allowing advocates' arguments to guide us.

For each rationale, we systematically searched the literature to identify supporting evidence. To locate relevant studies, we began by exploring the references cited by authors in support of their arguments. Next, we identified relevant articles in the archive described above. Finally, we searched the literature again using MEDLINE in order to identify any articles relevant to the rationales that might have otherwise been missed. The literature is highly heterogeneous, with few studies reporting on learning outcomes such as knowledge outcomes or behaviour/practice outcomes, and even fewer reporting on patient care outcomes. Because of this, our specific inclusion and exclusion criteria were relatively broad to allow for a large enough sample of literature to review; we included studies reporting on students' perceptions of curricular interventions, and comparative effectiveness using knowledge outcomes. Details regarding the standardized search strategies and the specific inclusion and exclusion criteria for searches associated with each rationale can be found in the associated appendix (Supplemental Table 1). Figure 1 illustrates the different sources of references used in the different parts of this paper.

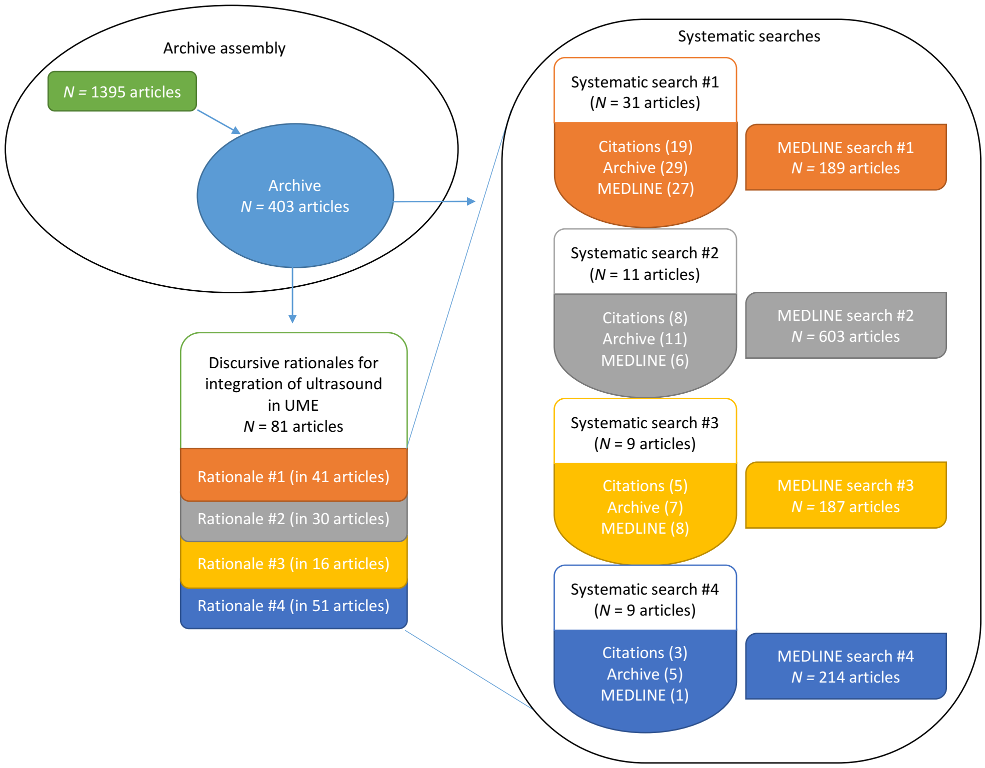

Figure 1. Schematic of the different sources and collections of references analyzed. In the first phase of research, an archive was assembled of academic publications related to ultrasound in medical education. From this archive, four discursive rationales were identified. These discursive rationales served as a framework to guide a systematic review of the evidence for the integration of ultrasound in undergraduate medical education (UME). Four separate systematic searches were conducted, with articles obtained from references cited by authors in support of their rationales, articles identified in the archive, and from systematic searches of MEDLINE.

The use of CDA techniques within a methodology for a critical literature review is relatively novel. A recent article by Wall et al. [31] describes the adaptation of Habermasian CDA as a systematic review method that can help expose strongly- and commonly-held assumptions within a research community. Our approach to data extraction and qualitative data synthesis fits within the category of content analysis [32] and focuses on the validity claims as described by Wall et al. [31] and adapted from Cukier et al. [33]. Unlike these authors, because we are working in a different field, we first categorized publications by the outcomes (learning or otherwise) reported and summarized the relevant findings. In our synthesis, we concentrated on the 'truth' ("Is evidence and reasoning provided sufficient?") and 'sincerity' ("Is what is said consistent with how it is said?") claims within this CDA-oriented schema [31, 33]. This data extraction and synthesis approach, to be clear, does not search for "conscious hegemonic participation"; it does not attempt to 'incriminate' authors as individual deceptive actors falsifying data due to conflicts of interest or ulterior motives [31]. We chose to focus on these validity claims to inform our understanding of the body of literature "to uncover unconscious hegemonic participation in academic research", critically focusing on dominant ideas and concepts that authors and research communities take for granted [31]. This critical review method is best served to answer our key questions about the availability of evidence for undergraduate ultrasound training while highlighting unquestioned assumptions within this domain of medical education research.

Our choice of approach in this review is necessarily informed by our individual and collective perspectives. Reflexively examining our own positions as readers of this literature and education researchers, we note first that none of us have conducted any prior research work related to POCUS. We are all physicians, three in medical subspecialties and one a primary care physician. As well, we are all involved in medical education research predominantly from a critical theoretical perspective. By adopting a critical method of systematic review rather than a traditional method employing statistical calculations and strenuously avoiding biases, we acknowledge the impact of our subjective positions, and how this figures into the interpretation of our results [34].

Our research was not conducted on any human subjects; rather, our research materials exist in the public domain (academic publications). As such, and in consultation with the Office of Research Ethics at the University of Toronto, we did not seek ethical approval.

Results

Identifying discursive rationales

We identified 81 publications within our archive that contained rationales for the integration of ultrasound in UME published between 2005 and 2016. The recentness of publication is notable: 8 articles were published in the first quarter of 2016, 25 in 2015, and 20 in 2014, leaving only 28 published between 2005 and 2013. Four dominant discursive rationales emerged from our analysis. These are described below accompanied by a critical synthesis of the literature related to each rationale.

Rationale #1: Ultrasound allows medical students to see inside a living body, leading to better understanding of anatomy

Because ultrasound can be used to ‘see’ inside the body, ‘living anatomy’ can supplement the traditional cadaver-based and cross-sectional anatomy teaching most medical students received. This is asserted to lead to a better understanding of anatomy. This rationale is found in 41 articles within the archive (e.g., [1, 2, 19, 35, 36, 37]). A typical example of this rationale: "Ultrasound facilitates the learning of anatomy, aids in understanding the physiology and pathophysiology of numerous organs and systems" [38].

We identified a total of 31 articles that informed this rationale. From the 40 different references cited by authors in support of their statements, 19 were relevant. We identified 29 articles as relevant from the 403 in our archive. Finally, our MEDLINE search yielded 189 articles, of which 27 were deemed relevant after review of titles and abstracts (see Supplemental Table 1 for search details). After removing duplicates, the 31 articles were categorized by outcomes. Positive student perceptions were reported as an outcome in 22 articles, and as the sole outcome in 10 articles. Improved ultrasound skills were reported in 8 articles. Increased self-reported knowledge was reported in 8 articles. Finally, increased anatomy knowledge, as measured by pre- and post-tests, was reported in 8 articles (Figure 2).

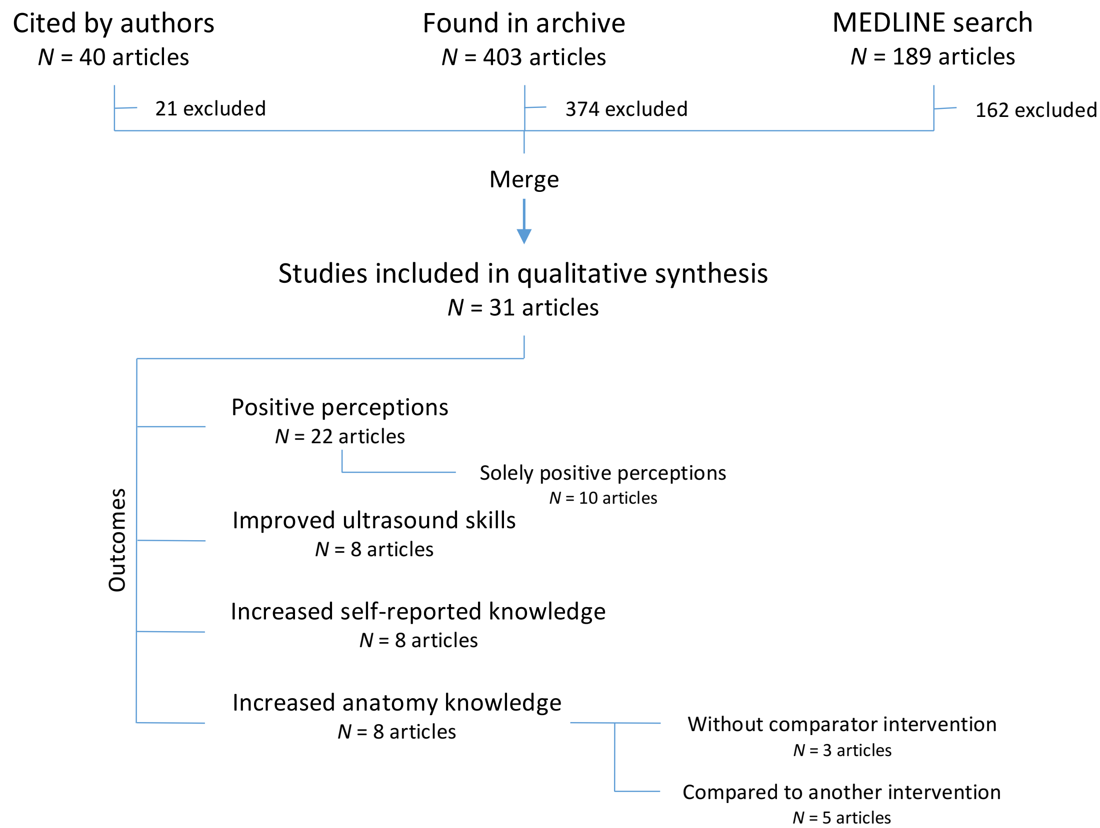

Figure 2. Derivation of study set for systematic review of evidence for Rationale #1 (ultrasound improves anatomy learning), with division of articles by outcomes evaluated.

Definitive evidence of the effectiveness of ultrasound-based anatomy teaching would come from comparison to another method of instruction, evaluating knowledge outcomes. We identified 5 such articles, in which cadaver-based dissection was usually the comparator condition [39-43]. These were mostly brief interventions (30 minutes to 3 hours), excepting the report by Kondrashov et al. [43], and all used multiple choice tests of anatomy knowledge, with Knobe et al. [42] also measuring differential performance on a clinical skills examination. These 5 articles demonstrated no difference in knowledge gains as measured between ultrasound-based anatomy teaching and cadaver-based anatomy teaching. Knobe et al. [42] demonstrated that arthroscopy-based teaching of shoulder anatomy led to improved post-test scores compared with ultrasound- or cadaver-based teaching.

We analysed the validity claims within the 31 articles selected for this review (Supplemental Table 2). We found a number of violations of truth claims, with over-reliance of self-report methods, conflation of improved self-reported knowledge with improved knowledge, and confounding of improved ultrasound skills with improved anatomy knowledge. The literature prominently relies on positive perceptions as a measure of utility, which is an insubstantial reason for curriculum change, especially given its susceptibility to desirability bias [44, 45]. We also found violations of sincerity claims, wherein connotative language is used to persuade the reader of interpretations beyond what is demonstrated. Inferences about the mechanism of the benefit of ultrasound (e.g., “an ultrasound-based lesson could be more effective because the professor could show what is happening inside the human body right in that moment” [46]) and the concreteness of conclusions (e.g., “ultrasound can augment the student’s knowledge of anatomy acquired through traditional teaching methods while improving understanding of the clinical relevance of anatomical principles” [44]) stretch interpretations beyond the studies’ designs.

Rationale #2: Ultrasound improves medical students' ability to learn physical examination techniques

By providing additional information while learning physical examination manoeuvres, ultrasound is claimed to be a useful teaching tool that will lead to improved physical exam technique. This rationale is found in 30 articles within the archive e.g., [20, 47, 48-53]. A typical phrasing: "Many advantages to early ultrasound education exist, including improvement in physical examination techniques" [54].

We identified 11 articles that were relevant to this rationale. Only 8 of 33 papers cited by authors in support of this rationale were relevant. Some of the other articles cited by authors to support the claim that ultrasound training improves the learning of physical examination techniques in fact evaluated students' diagnostic accuracy with ultrasound [55], or described undergraduate clinical ultrasound training [56]. The archive, which included those 8 articles, contributed 3 more, and no additional articles were discovered from our MEDLINE search (see Supplemental Table 1 for search details). The 11 studies were again categorized by the reported outcomes. Positive student perceptions were reported most commonly, as an outcome in 7 of the articles. Improved ultrasound skills were reported in 2 articles, and self-reported improvement in physical examination skills was reported as an outcome in 3 articles. Finally, physical examination skills were directly evaluated after ultrasound-augmented instruction in 6 articles (Figure 3).

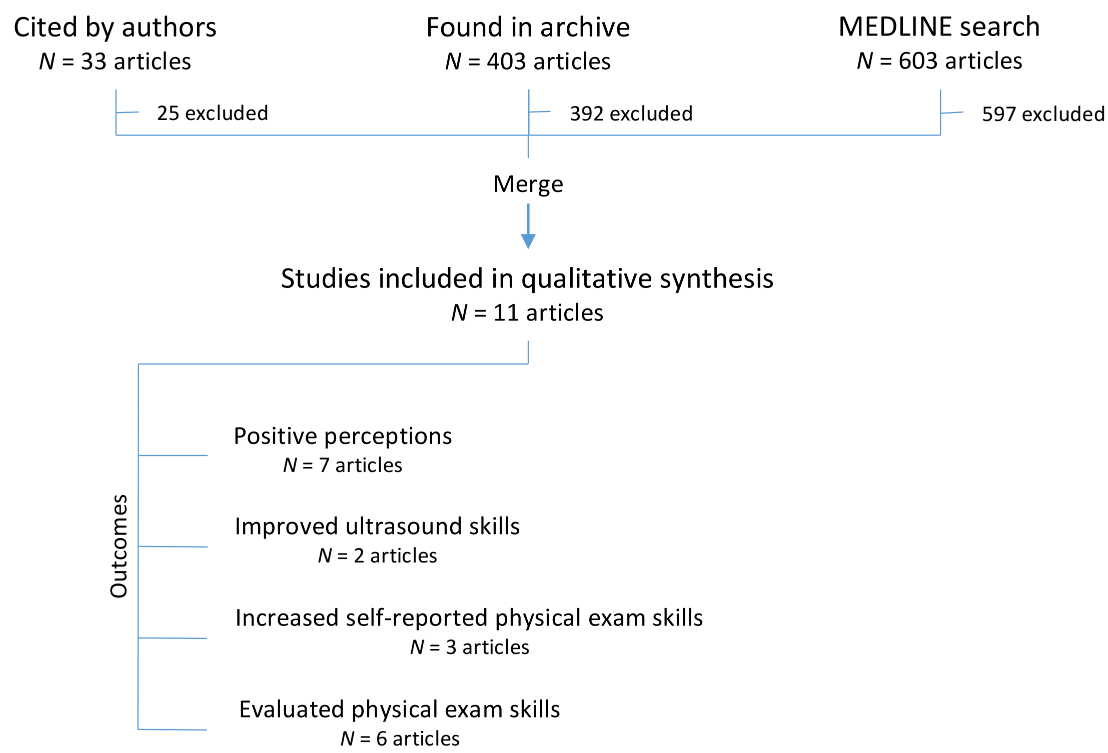

Figure 3. Derivation of study set for systematic review of evidence for Rationale #2 (ultrasound improves physical examination learning), with division of articles by outcomes evaluated.

In these 6 studies, ultrasound was used as a teaching technique to visualize internal anatomy, after which physical examination skills were evaluated either directly as part of a pseudo-experimental study design, or via results on a structured clinical skills examination that was part of the students' standard evaluation [57-62]. Some of the methodological choices were unable to support inferences of benefit. For example, Am Dinh et al. [58] compared standardized clinical skills examination results between two separate cohorts of students (one of which received an ultrasound-integrated clinical skills course); further, of the three 'organ systems' that the post-ultrasound cohort passed more successfully, one was ‘blood pressure’ and another was ‘professionalism’, which ultrasound could not have influenced. In another widely cited paper, Fodor et al. [61] evaluated students’ ability to identify multiple surface anatomy points, after some were provided ultrasound-augmented instruction. These surface anatomy points were seldom identified correctly by either group, but slightly more consistently, for some points, by students in the ultrasound condition. Notably, the students were tested on the same patient upon whom they had practised. Overall, the results were mixed and inconsistent, with positive findings in one study (improved accuracy estimating vertical liver span noted by Barloon et al. [59]) being imperfectly replicated (improved accuracy identifying the inferior liver margin, but not the superior shown by Fodor et al. [61]) or not replicated at all when re-examined (Butter et al. [60] found no gains in accuracy estimating vertical liver span). One study reported a negative effect of ultrasound-assisted gastrointestinal anatomy learning on performance in a clinical skills examination when comparing different cohorts [62].

Our analysis of validity claims within this body of literature again did not support some dominant conceptions within this research community (Supplemental Table 3). We found violations of truth claims including over-reliance on comparisons of different cohorts of students [58] and continued reliance on self-reported gains [63]. The use of multiple measurements and statistical tests that may obscure the educational relevance of statistically significant findings is also problematic [60, 61]. We found some violations of sincerity claims, including exaggerated interpretations of modest findings [64], and the minimization of negative findings (e.g., casting doubt on the veracity of negative findings due to inherent flaws of comparing different cohorts, while ignoring how those flaws might affect interpretation of positive findings [62]).

Rationale #3: Ultrasound improves medical students' diagnostic accuracy

The demonstration that students armed with ultrasound machines can 'out-diagnose' traditionally trained peers (or superiors) is asserted to be a compelling reason to ensure that medical students, incorrigibly poor diagnosticians, are taught this new skill. This rationale is found in 16 articles (e.g., [65, 66-69]). A typical statement of this rationale: "several studies show that medical students and junior trainees using ultrasound are able to more reliably diagnose diseases than cardiologists and surgeons" [19].

There were 5 relevant articles out of the 21 articles that were cited to support different phrasings of this rationale. We identified 7 relevant articles within our archive, and 8 articles were added from the 187 retrieved through our MEDLINE search (see Supplemental Table 1 for search details). The removal of duplicate references left 9 articles. All 9 articles compared medical students' diagnostic accuracy using POCUS with a standard diagnostic test. In 2 articles, medical students' accuracy using POCUS was also compared with the clinical examination conducted by an attending clinician, and in

3 articles, authors evaluated the incremental benefit of POCUS when added to medical students' clinical examination (Figure 4).

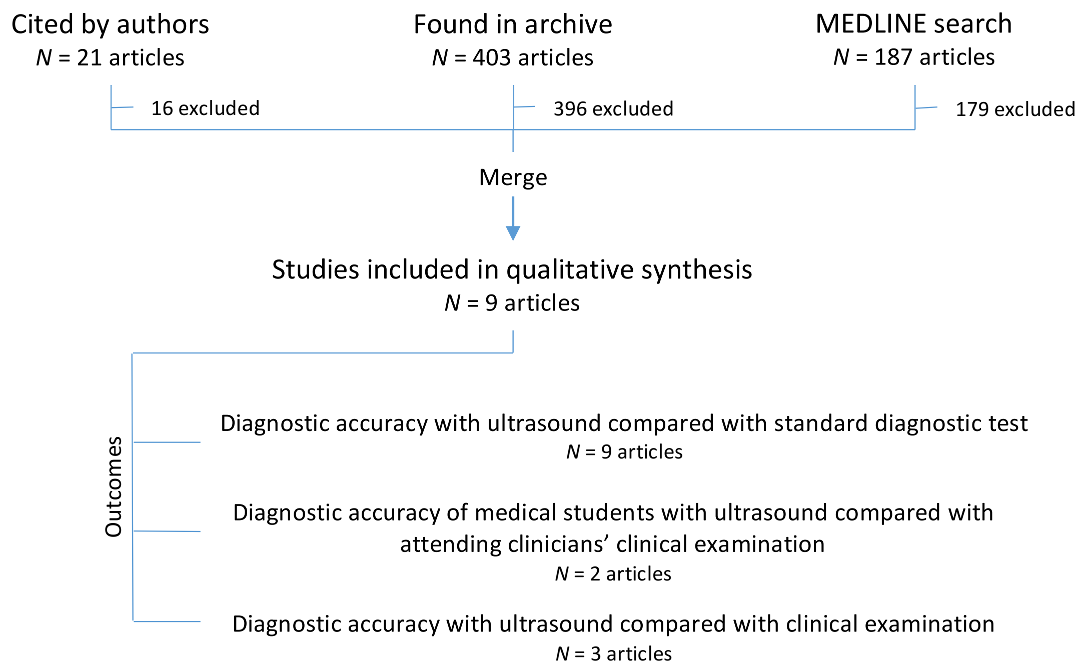

Figure 4. Derivation of study set for systematic review of evidence for Rationale #3 (ultrasound improves students' diagnostic accuracy), with division of articles by outcomes evaluated.

In these 9 studies evaluating medical students' diagnostic accuracy with POCUS, relatively few students were trained and evaluated (a range of 2 to 30 subjects, median 10). Trained medical students performed POCUS with acceptably proficient accuracy compared to the diagnostic standard [10, 70-72]. Medical students' diagnostic accuracy using ultrasound was found to be superior to that of the clinical evaluation of attending physicians in the 2 studies evaluating this outcome [36, 55]. Results were mixed for the incremental benefit outcome; while one study reported significant improvement in diagnostic accuracy with the addition of POCUS [73], for some diagnoses, diagnosis rates were not always improved by the addition of ultrasound (e.g., for mitral stenosis and regurgitation, students demonstrated poor performance with or without ultrasound in one study [74]; in another, medical students' ability to detect aortic valvular pathology did not improve with the use of ultrasound [75]).

We analyzed the validity claims of these 9 articles, identifying certain dominant conceptions (Supplemental Table 4). The most common violations of truth claims related to argumentation regarding the necessity of diagnostic ultrasound due to a deterioration of physical examination skills (e.g., "the interest and expertise of professionals in physical examination has declined substantially in recent decades" [71]; "The decline in physical examination skills during the past 2 decades is well documented and occurs at all levels of training" [10]) and reliance on results from small numbers of motivated subjects [55, 74]. Claims of the decline in physical examination skills cite references that do not compare diagnostic accuracy over time. The main violation of sincerity claims relates to the consistent conclusion, where negative or equivocal findings were produced, that more extensive training in POCUS skills would rectify the lack of success with this tool [74, 75]. While many concluded that future research would be required to determine the clinical utility of training students or residents in diagnostic ultrasound, some conclusions made a conceptual jump from improved diagnostic accuracy to improved clinical outcomes that were not demonstrated [36, 71].

Rationale #4: Undergraduate ultrasound training ensures a minimum ultrasound skill level, improving patient safety, and allowing for advanced training during residency

Concerned that POCUS is currently being used without adequate training, and convinced that POCUS will inevitably become part of the core clinical skill set of modern physicians, many authors assert that ultrasound training must become part of the undergraduate medical curriculum. Training all medical students in ultrasound skills will purportedly lead to improved healthcare outcomes – initially of patients cared for by these newly-skilled medical students, but ultimately of all patients [1]. Related justifications include the following: 1) as an 'operator-dependent' imaging technology, ultrasound skills are difficult and time-consuming to learn; 2) clinicians in practice may find the acquisition of a new skill more difficult due to time constraints or different learning needs; and 3) post-graduate programs may not have the capacity to provide basic ultrasound training and also teach advanced applications. Variations of this rationale are found in 51 articles (e.g., [3, 5, 22, 23, 35, 46, 53, 56, 76-81]). A typical expression: "Given its growing importance, it is time for the medical education community to debate whether the lack of ultrasound training is a disservice to future generations of medical students by depriving their opportunity to learn the clinical skills of the twenty-first century" [82].

Through our systematic search process, we found 9 articles that were relevant to this rationale. In the majority of articles containing some formulation of this rationale, no references were cited to support the relevant statements; only 10 articles were cited, of which 3 were relevant. We identified 5 relevant articles within our archive, and 1 article was found to be relevant of the 214 retrieved through our MEDLINE search (see Supplemental Table 1 for search details). Of the 9 articles, 4 described changes in patient management following the use of POCUS by attending clinicians, 5 described similar changes with use of POCUS by post-graduate trainees, and 1 described improved procedural safety when medical students used POCUS (Figure 5).

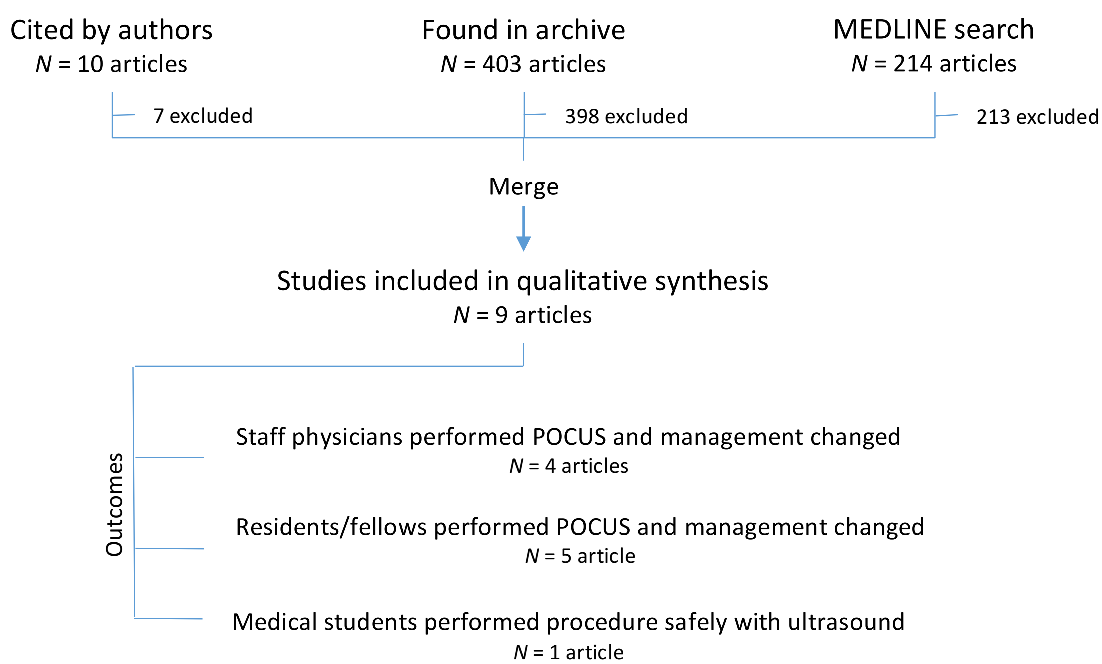

Figure 5. Derivation of study set for systematic review of evidence for Rationale #4 (undergraduate ultrasound training improves patient safety), with division of articles by outcomes evaluated.

Among the studies reporting on the effects of training attending clinicians to perform POCUS, the application of POCUS was adjudicated to contribute to a change in management in 16-37% of cases in different clinical contexts [83-86]. Studies reported similar findings after training residents or fellows, with POCUS contributing to management changes in 16-40% of clinical applications [84, 87-90]. Only one study evaluated any impact on patient-relevant outcomes of training medical students to perform POCUS, demonstrating improved safety of simulated central venous catheter placement using ultrasound [91].

We analyzed the validity claims of the literature relevant to this rationale (Supplemental Table 5). The major truth claim violation involves the paucity of relevant evidence. As the rationale relates to undergraduate ultrasound training and the articles analyzed largely present findings related to post-graduate trainees or practicing clinicians, the translation of these findings to the undergraduate context remains untested. Furthermore, justifications regarding the inability of practicing clinicians to learn new skills and the lack of available room in post-graduate curricula are difficult to evaluate on the basis of any evidence beyond opinion. The studies analyzed rely on methodologies potentially subject to falsification (with self-collected data), and seldom question the relevance to patient care of improved pathology detection. In terms of sincerity claims, the most important conceptual issue relates to the inference frequently made between early learning and patient safety (e.g., “ultrasound technology is, of course, operator dependent and can be difficult to use, misleading at times, and prone to misinterpretations by the novice user. Consequently, early and comprehensive sonology education is a must" [81]). Finally, in concluding improved quality of care with the implementation of POCUS training, the implications of false negative results are seemingly ignored.

Discussion

We identified four dominant discursive rationales underpinning calls for the integration of ultrasound in UME which were used as a frame for a critical and systematic review. There is minimal evidence supporting assertions of the utility of ultrasound in teaching anatomy of physical examination skills. A small number of studies provide evidence to support the position that POCUS can improve students' diagnostic accuracy. However, there is a lack of empirical support for the rationale that links POCUS training in UME to improved patient safety. Analysis of validity claims revealed violations of truth claims related to methodological choices, as well as violations of sincerity claims related to hyperbolic and connotative language.

These discursive rationales are increasingly repeated by advocates of integrating ultrasound into UME, contributing to the legitimacy of the position. Two institutional bodies have issued policy statements in support of widespread ultrasound integration [53, 92]. Across North America and worldwide, medical schools are implementing ultrasound-integrated curricula, encouraged by publication of 'ultrasound competencies' [93]. The incorporation of ultrasound in UME would require financial investment (for the purchase and maintenance of ultrasound machines), and temporal sacrifices (a reduction in the time available for other topics in the curriculum). Our results raise concerns that there is as yet insufficient evidence to support further integration of ultrasound in UME curricula.

Each discursive rationale relies on a logic of accepted truths, some of which may similarly be unsupported. For example, the second rationale relies on the premise that clinical examination skills are insufficiently accurate and are deteriorating over time. Skilled clinicians may in fact be more accurate with clinical examination than supposed [94]. Conversely, ultrasound may be less useful, less accurate, and may lead to more testing than otherwise assumed [23]. Furthermore, training medical students in ultrasound skills may lead to missed diagnoses due to “greater faith in ‘high tech’ information” [2]. Thus, the incremental benefit of adding POCUS to a clinician’s skill set may not be as large as seems implicit to proponents.

The other rationales rely on similar logics; the third rationale, emphasizing the improved diagnostic accuracy of ultrasound, ignores the possibility that increased diagnostic accuracy may not have a significant impact on patient outcomes [95]. Finally, evidence for the clinical use of diagnostic POCUS remains limited. Even the FAST protocol for identifying internal bleeding in patients who have suffered blunt trauma is not sufficiently sensitive to justify its use [14].

Medical education research is often conducted by interested and enthusiastic education researchers, such that there is a consistent bias towards the studied intervention [96]. These researchers participate in the 'unconscious hegemony' of the dominant discourses in their respective fields of academic research. This may hamper their ability to seek, or even perceive, potential unintended consequences of the educational intervention studied. Thus, we rarely have evidence of harms or shortcomings until after the implementation of curricular change; decisions are sometimes made based on a small volume of evidence.

From clinical medicine, cautionary tales of the broken promises of encouraging preliminary research are easy to find. Until 2002, observational data and scientific plausibility suggested a cardiovascular benefit to hormone replacement therapy for post-menopausal women, when a larger randomized controlled trial demonstrate opposite effects [97]. Relevant to the discussion of ultrasound as a more accurate diagnostic tool, pulmonary artery catheters were in widespread use in the care of critically ill patients before evidence emerged suggesting a lack of benefit and potential harms [98, 99].

Research questions in medical education research may not be as amenable to the methodologies used to determine the utility of clinical treatments or diagnostic techniques in these examples. However, there is an opportunity to learn from the ongoing experiences of schools where ultrasound has been integrated across the undergraduate curriculum [3-5]. Data regarding relevant knowledge outcomes, behaviour/practice outcomes, and even patient care outcomes could be collected prospectively.

Limitations

In conducting our review, we chose to frame our approach using the arguments put forth by advocates of ultrasound in UME as expressed in academic publications. Because of this, we have not systematically evaluated every possible rationale. A significant proportion of earlier literature on ultrasound in medical education was interested in delineating 'learning curves' for the acquisition of specific ultrasound skills in order to empirically determine the appropriate number of procedures to establish competence [100-102]. The general consensus from this research concludes that a moderately large number of procedures (usually 50-75) must be performed to achieve proficiency [103]. We did not include this body of research in our systematic review, though it might inform the fourth rationale, in part because none of this evidence was cited by authors as reasons for early training of ultrasound skills, and in part because of the unclear relevance to UME (all of these studies included post-graduate or attending clinician participants). Furthermore, the studies evaluated in assessing the third rationale demonstrated reasonable accuracy after brief training periods; this would suggest that perhaps there is no need for lengthy training and a high volume of practice.

Conclusions

Using dominant discursive rationales as a framework, a systematic review of the literature demonstrates mostly absent or mixed evidence in support of rationales for the integration of ultrasound in UME. Our research problematizes the proliferation of ultrasound-integrated undergraduate curricula, and highlights some of the dominant concepts taken for granted by this research community which undermine the validity claims of the research within this field.

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