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Hand-Held Ultrasound Scanners in Medical Education: A Systematic Review

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Abstract

Purpose: Ultrasound imaging devices are becoming popular in clinical and teaching applications, but there is no systematic information on their use in medical education. We conducted a systematic review of hand-held ultrasound (HHU) devices in undergraduate medical education to delineate their role, significance and limitations.

Methods: We searched Cochrane, PubMed, Embase and Medline using the strategy: ((Hand-held or Portable or Pocket or "Point of Care Systems") and Ultrasound) and (Education or Training or Undergraduate or "Medical Students" or "Medical School"). We summarised the patterns of HHU use, pooled and estimated sensitivity and specificity of HHU for detection of left ventricular dysfunction.

Results: We retained 12 articles focusing on undergraduate medical education. Features reported were heterogeneous: Training time (1-25 hours), number of students involved (1-a whole year's intake), number of subjects scanned (27-211), type of learning (self-directed vs. traditional lectures +hands-on sessions). Most studies reported cardiac HHU examinations, but other areas were examined, e.g. abdomen and thyroid. Pooled sensitivity -0.88 (0.83-0.92) - and specificity -0.86 (0.81-0.90) -were high for the detection of LV systolic dysfunction.

Conclusion: Data on hand-held ultrasound devices in medical education is scarce and incomplete, but students can be trained to high standards of diagnostic accuracy in a limited number of (mainly cardiac) pathologies. There is no consensus on protocols best-suited to the educational needs of medical students, nor data on the long-term impact or on the financial implications of deploying HHU in this setting.

Keywords: Hand-held ultrasound; Undergraduate medical education; Sensitivity; Specificity; Echocardiography

Introduction

Recent advances in ultrasound technology have led to the miniaturization of machines initially to the size of a laptop computer and more recently to that of a mobile phone. In the hands of a trained user the hand-held ultrasound (HHU) device allows a more accurate examination [1,2] augmenting the standard physical examination [3,4], often sufficiently to change clinical management [4,5]. It is also quicker and more accessible than standard transthoracic echocardiography (sTTE) [1,2], offering a more cost-effective patient assessment [6]. As the use of bedside ultrasound becomes common place [7], becoming familiar with this imaging technique in medical school might be beneficial. Ultrasound can be used together with simulation techniques and interactive web-based resources to present complex concepts in multiple modalities [8]. HHU devices are cheaper, portable and more accessible than formal ultrasound machines making them suitable for a 'hands-on' approach to teaching.

Medical schools have already incorporated ultrasound teaching into their curricula. The USA "national ultrasound curriculum" outlines areas for which ultrasound examination should be taught [9]. Although difficulties in integrating such changes are anticipated [9,10], there is evidence that ultrasound imaging improves medical students' knowledge of living anatomy and physiology [10,11] and increases their motivation to learn [12]. Many programmes use high-end machines and little work exists about the use of HHU despite a statement from the European Association of Echocardiography [13] which supports the use of HHU devices for teaching medical students, and recognises its utility in everyday practice.

We conducted a novel systematic literature review focused on undergraduate medical education in order to document patterns of usage of HHU devices, evaluate teaching techniques, and define the examination protocols taught to medical students. We hope it will stimulate further systematic research leading to a rigorous definition of the place of HHU in medical school curricula.

Methods

We searched four on-line medical literature databases (Cochrane, PubMed, Embase and Medline) on the 08/01/2017 using the search strategy: ((‘Hand-held’ or ‘Portable’ or ‘Pocket’ or “Point of Care Systems”) and ‘Ultrasound’) and (‘Education’ or ‘Training’ or ‘Undergraduate’ or “Medical Students” or “Medical School”). “Point of care systems” was the only Medical Subject Heading (MeSH) term used; other terms were part of the search as keywords. We screened Open Grey for unpublished studies using the key words (‘Hand-Held’ or ‘Portable’ or “Point of Care Systems”). The search was to limited “Human” studies and to those available in English but not by date of publication.

Eligibility and data collection

The search yielded a large number of studies. Two authors (AI and VG) selected those featuring 1) medical students who were 2) trained/educated using a 3) genuinely hand-held device (as opposed to cart- or laptop-based). We included primary and secondary research literature but not conference abstracts. A flow diagram for the search is displayed in Figure 1. References in relevant papers were searched manually to identify additional studies of interest.

Results

Studies included

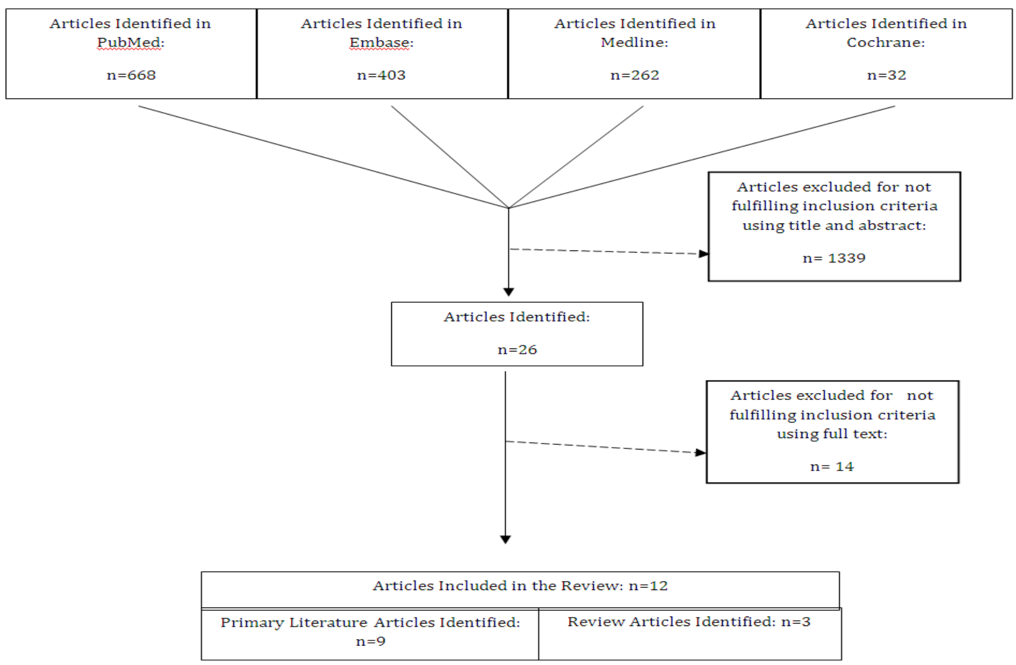

Figure 1: Flow chart of the study selection process.

Data extraction and analysis

Table 1: Data used to produce the forest plots in supplementary figures 1a, 1b & 1c.

Study	Sensitivity	Specificity	Diagnostic OR
Stokke et al. [14]	0.90 (0.80-0.96)	0.57 (0.41-0.71)	12.35 (4.44-34.37)
Andersen et al. [15]	0.99 (0.92-1.00)	0.91 (0.85-0.95)	683.85 (87.62-5337.48)
Panoulas et al. [16]	0.75 (0.61-0.85)	0.94 (0.85-0.98)	46.13 (14.19-149.82)
Ahn et al. [17]	0.85 (0.74-0.92)	0.93 (0.68-1.00)	78.40 (9.25-664.65)
Pooled	0.88 (0.83-0.92)	0.86 (0.81-0.90)	62.32 (12.79-303.76)
Inconsistency	85.00%	90.50%	77.90%

The following items were extracted from the papers selected for analysis: type of HHU device used; intensity, type and duration of HHU-specific training offered; setting (clinical, e.g. ward-based or out-patient, or laboratory setting); pathologies detected/body areas scanned; metrics for the detection of LV dysfunction; number of medical students involved and their year of medical studies, and any metrics reflecting student performance before and after the introduction of HHU-based scanning. We extracted sensitivity and specificity parameters, and calculated a diagnostic odds ratio for the detection of LV dysfunction using the HHU device. Data was collated and analysed using MetaDisc, a freely available statistical package designed for the meta-analysis of diagnostic data. The results were represented as forest plots and analysis of heterogeneity was performed (Appendix: Table 1) [14-17].

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We screened 1365 abstracts and identified 26 papers that fulfilled the inclusion criteria. Analysis of full texts led to the removal of fourteen of these studies, which included 5 abstracts for which full text was not available. We therefore retained nine primary literature articles for which full text articles were available [14-16,18-23]. Three relevant non-systematic reviews were also identified [24-26], containing information on HHU use in undergraduate medical education, yielding a total of 12 studies (Figure 1).

Studies were published between 2010 and 2014, three from USA [18-20] and six from Europe [14-16,21-23]. The mean number of medical student participants (standard deviation (SD)), based on studies where this information was available, was 18 (15.5), (range 1-45). In one study [19] all students in four years of medical school participated.

Trainees

While all studies included medical students, 2 also included other healthcare professionals (medical residents [16] and pharmacy residents [20], and did not separate the findings by type of participant in their final analyses. However, none of the participants had previous experience in ultrasonography thus qualifying as genuine "novices".

Setting

Most studies were carried out on unselected patients in the hospital [14-16,20-23]. Two studies were primarily classroom based, utilising volunteers [18,21] with some inpatient scanning. The mean number (SD) of patients scanned, based on 6 studies for which the information was available, was 96(65), range 27-211.

HHU devices used

Studies reported using 2 types of HHU device: Vscan (GE Vingmed Ultrasound AS, Horten, Norway) used in 6 studies, and Acuson P10 (Siemens Ultrasound, Surrey, UK) used in 3 studies. One of the studies did not report the model of HHU used [19]. In all studies results obtained by HHU examinations were compared to formal, comprehensive ultrasound examinations performed by an expert using high-end scanners in the local ultrasound department. We also noted some confusion in the literature as to what a hand-held device is, with some of the hand-carried devices (such as the OptiGo and MicroMaxx) being referred to hand-held [26].

Training to use HHU

All studies reported hands-on, skills-teaching sessions, complemented by didactic teaching (7 studies) or by self-directed learning resources (1 study), or a combination of the two (3 studies). One study had purely self-directed learning groups [18], while others utilised radiologists [15], sonographers [18], cardiologists and senior cardiology trainees [15] and even senior medical students as teachers [19]. When self-directed echocardiography simulators were used to teach image interpretation efficacy was lower than for a traditional lecture-based approach [18]. The teaching itself varied in length and the mean (SD) duration of training was 9.8 (7.5) hours, range from 1 hour [20] to 25 hours [23]. There was no correlation between length of training and diagnostic accuracy, but this would have been difficult to detect due to the heterogeneity of the data and small sample size (Appendix: Figures 1a-1c).

Fox et al. [19] used on-line self-directed teaching material and Apple iTunes-based podcasts to support learning. Another study compared the efficacy of the traditional lecture-based approach to online self-directed e-modules for the purposes of HHU education. The learning efficacy for theoretical aspects of ultrasonography was equivalent for both methods [18].

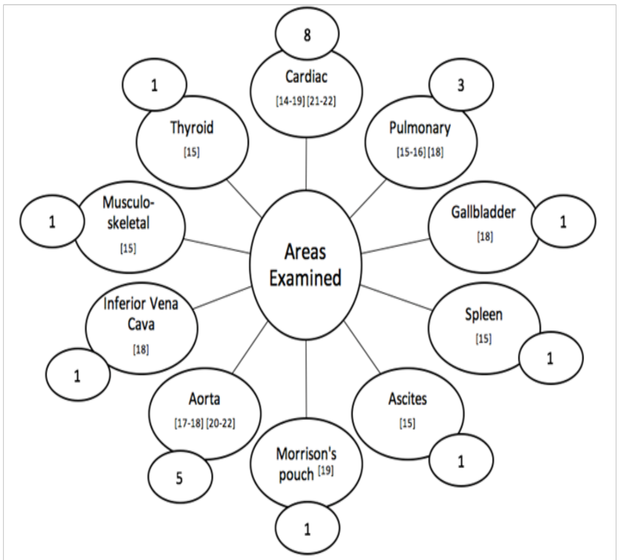

Figure 2: Structures examined with HHU (with number of studies for each structure and with references in brackets).

Medical students were taught to obtain and interpret ultrasound images of a variety of anatomical structures and organs (Figure 2), others were trained to carry out the focused assessment with sonography for trauma (FAST) scan [21]. The most widely application was imaging of the heart, featuring in 8 of the 9 primary literature articles. Medical students reported feeling confident to use the HHU device even after short (5 hours) training sessions [21].

A medical student trained to use a HHU device can achieve superior diagnostic accuracy compared with physical examination [14]. Moreover, after only short training sessions (<1hr), novices can be guided 'in real time' to perform a focused cardiac examination under off-site expert guidance, with image quality comparable to that achieved by experienced sonographers [20]. However, HHU devices achieve lower diagnostic accuracy than larger, more sophisticated scanners [23]. When medical students are given a cart-based ultrasonography device and a HHU, they are able to obtain better quality images using the larger device and are more comfortable using it than the HHU [21].

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Effects of training

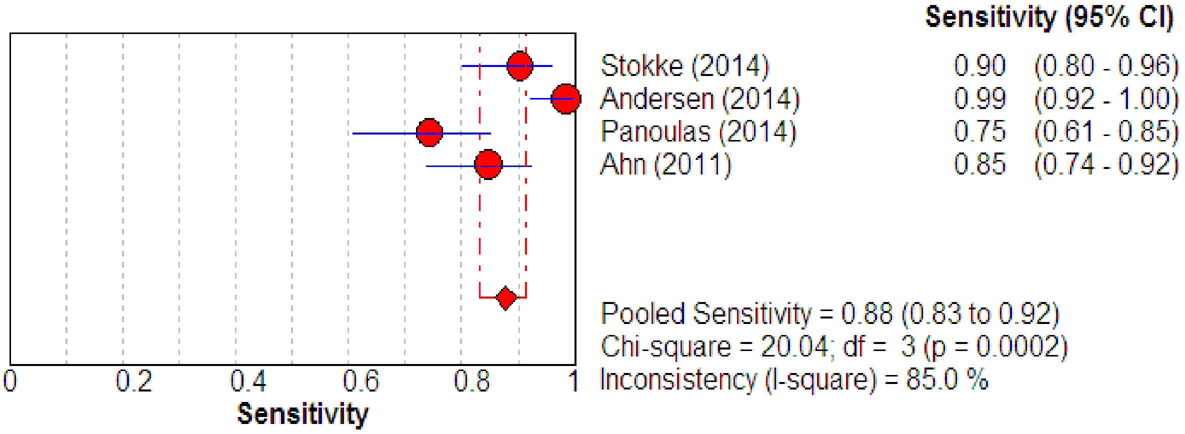

Figure 1a: Sensitivity for LV dysfunction across all five papers, displaying considerable heterogeneity of data.

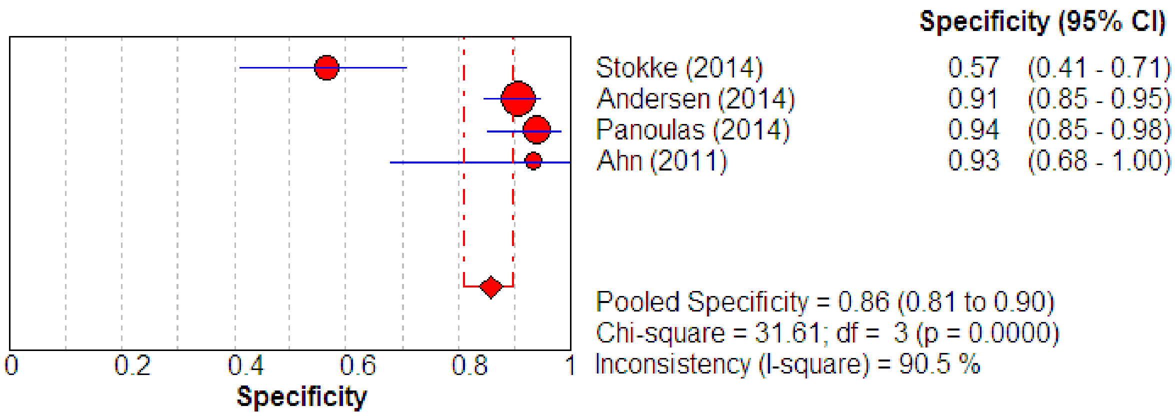

Figure 1b: Specificity for LV dysfunction across all five papers, displaying considerable heterogeneity of data.

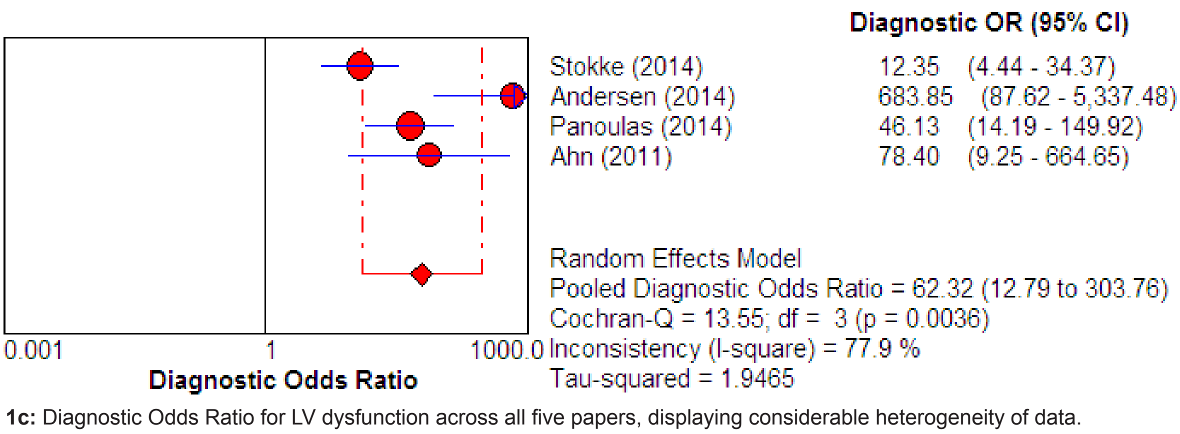

Figure 1c: Diagnostic Odds Ratio for LV dysfunction across all five papers, displaying considerable heterogeneity of data.

Assessment of the short-term effects of training varies between studies, making head-to-head comparison of results difficult. The most consistently detected pathology across the studies was LV systolic dysfunction. Sensitivity and specificity for the detection of LV dysfunction from four studies is summarised in the Appendix: Figure 1a-1c. The SROC curve (Appendix: Figure 2) demonstrates high diagnostic accuracy for detection of LV dysfunction. Although pooled sensitivity and specificity (confidence intervals) for LV dysfunction reached 0.88 (0.83-0.92) and 0.86 (0.81-0.90) respectively, the data was heterogeneous (I2 values of 85.0% and 90.5% respectively). The diagnostic odds ratio (CI) for the detection of LV dysfunction was 62.3 (12.8-303.8).

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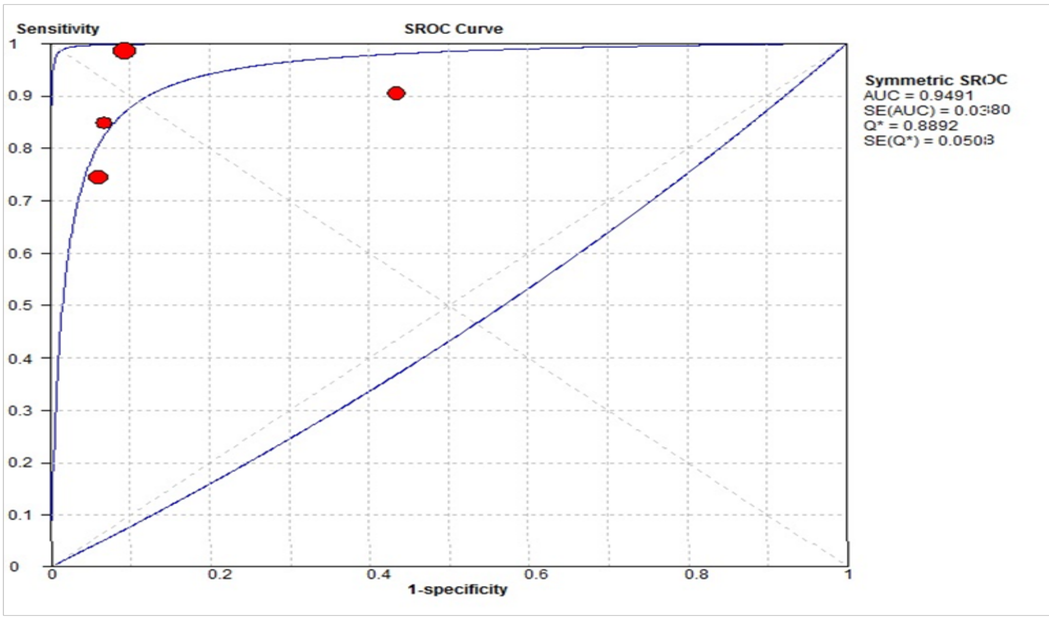

Figure 2: The SROC curve showing the diagnostic accuracy for detection of LV dysfunction.

The sensitivity for the detection of pericardial effusions was variable, with one study reporting 100% [16], while the other reporting 40% [14]. Similarly sensitivities for valvular regurgitation and stenosis varied (Table 1) [14-16,19,21-23], but were consistently >70% [14,26], aside from aortic regurgitation where one report demonstrates sensitivity to be 43% [14]. Aortic root dilatation detection had the lowest specificity at 25% with a specificity of 88% [14]. Diagnostic accuracy reached 100% for measurement of the abdominal aorta or for detection of ascites, and was at its lowest for detecting gallstones or cholecystitis [15].

Table 1: Findings from studies available in full text format.

Reference	Device	Students, Year of Study	Patients, Setting	Training	Study Design	Areas and Structures Examined	Results	Comments
Stokke et al. [14]	Vscan	21, last 2 years	72 patients attending for routine echo*	4 hours	Diagnostic accuracy in 2 scenarios: History + physical examination, with and without HHU	Cardiac: LV, RV, LA, RA, aortic root, AV, MV, TV, pericardial effusion	• Addition of HHU achieved sensitivity of: -69% for MR (Improved from 26%, p<0.001) - 70% for moderate AS* - 43% for AR* 90% for LV dysfunction - 79% for RV dysfunction - 53% for dilated LA - 49% for dilated RA - 40% for pericardial effusion - 25% for dilation of the aortic root *p =NS vs. physical exam.	• HHU improved sensitivity for mild AR (19% vs. 77%) and mild AS (72% vs. 97%), • Mean duration of HHU exam = 17 minutes

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Andersen et al. [15]	Vscan	30, 5th year	211 patients in the hospital (including in-patients and out-patient clinics)	9 hours	Diagnostic accuracy in 2 scenarios: Physical examination, with and without HHU	•Cardiac: LV function, pericardial effusion •Lung: Pleural effusion, lung comets •Renal: Hydron-ephrosis, bladder distension •GI: Gallstones, abdominal free fluid, cholecystitis •Vascular: Diameter of abdominal aorta and inferior vena cava	• Acceptable image quality in 74% of cardiac scans and in 88% of abdominal scans • Sensitivity and specificity for detection of pathology: - CVS-96% and 92% - Lung-91% and 95% - Abdominal aorta-92% and 100% - Renal system-90% and 93% - Gallbladder-94% and 86% - Free abdominal fluid-100% and 100%	• Acceptable image quality in 74% of cardiac scans and in 88% of abdominal scans • Sensitivity and specificity for detection of pathology: - CVS-96% and 92% - Lung-91% and 95% - Abdominal aorta-92% and 100% - Renal system-90% and 93% - Gallbladder -94% and 86% - Free abdominal fluid-100% and 100%
Fox et al. [19]	HHU*	Number not reported; all years	N/A	•1h/ week x16 weeks;	Ultrasound curriculum taught using HHU	Eye, thyroid, neck, pulmonary, cardiac, liver, ascites, spleen, musculo-skeletal and peripheral IV insertion	Detailed description of how the Stanford Medicine 25 examination can be augmented using HHU	• HHU across all 4 years of medical school across many organ systems • Student-to-instructor ratio 4:1
Bonnafy et al. [22]	Vscan	Not reported	56 unse-lected in-patients	9 hours	Aortic diameter measured by students using HHU vs. experts using HHU and formal echo with high-end scanners	Abdominal aorta	• Mean difference between measurements by experts using conventional ultrasound and medical students using HHU was <4mm in 92% of cases • Intra-class correlation coefficient between the medical students using HHU and the experts using conventional ultrasound was >0.90 (0.84-0.94)	• Only 2 patients in the study had AAA • Briefly trained medical students can reliably measure the diameter of the abdominal aorta

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<table>
<tr><td>Panoulas et al. [16]</td><td>Vscan</td><td>5, final year

3 junior doctors</td><td>122 in-patients</td><td>2 hours</td><td>Diagnostic accuracy in 2 scenarios: History + physical examination + 12-lead ECG, with or without HHU</td><td>Cardiac : LV, RV, aorta, pericardial effusion, valvular abnormal-ities</td><td>
<table>
<tr><th>Path-ology</th><th>HHU</th><th>Sensit-ivity</th><th>Specificity</th></tr>
<tr><td rowspan="2">LV Dysfu-nction</td><td>No</td><td>26</td><td>85</td></tr>
<tr><td>Yes</td><td>74</td><td>94</td></tr>
<tr><td rowspan="2">Valve lesions</td><td>No</td><td>46</td><td>94</td></tr>
<tr><td>Yes</td><td>70^
86*</td><td>98^
100*</td></tr>
</table>
^ - regurgitation; *- stenosis

• Pericardial effusion was detected with 100% sensitivity and specificity using HHU</td><td>53% of examin-ations were performed by medical students and 47% were performed by junior doctors</td></tr>
<tr><td>Filipiak-Strzecka et al. [23]</td><td>Acu-son P10</td><td>2; years 4 and 5</td><td>90 unse-lected patients referred to cardiac intensive care unit and 30 out-patients</td><td>25 hours</td><td>Direct comparison between HHU findings by students and formal compre-hensive echo by experts</td><td>Cardiac : LV, RV, LA, aorta, mitral and aortic valves and pericardial effusion</td><td>• Agreement between standard echo and HHU: fair (kappa 0.29-0.57) to very good (kappa 0.73-1.00),

• 10% of HHU examinations reported spurious WMAs</td><td>• 89% of patients had abnorm-alities on standard echo

• Agreement with standard echo was better in outpatients than in ITU</td></tr>
<tr><td>Gogal-niceanu et al. [21]</td><td>Acu-son P10,

Acu-son 300PE,

Acu-son x150</td><td>25, years 3 and 5</td><td>Case-based discus-sions, volu-nteer, simu-lators</td><td>5 hours</td><td>• Assessment of the ability of students to learn and perform a FAST scan;

• A score was calculated for the performance of a FAST scan and the students' ability to interpret images on a simulator in an OSCE setting</td><td>FAST Scanning: Morrison's pouch, splenorenal recess, A4C view of the heart, peric-ardium, bladder and pelvis</td><td>• 85% of students completed the FAST scan in <6 minutes to an adequate level

• Mean assessment score was 86%;

• 88% of correctly diagnosed the presence or absence of free abdominal fluid on the simulator</td><td>• Trained students were able to perform FAST Scanning (OSCE assess-ment).

• Students preferred the cart-based machines, for better image quality ease of use</td></tr>
</table>

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<table>
<tr>
<td>Mai et al. [20]</td>
<td>Vscan, Acuson P10</td>
<td>3 subjects: 1 medical student, 1 intern, 1 pharmacy resident</td>
<td>27 (22 out-patients and 5 normal volunteers)</td>
<td><1 hour</td>
<td>Assess- ment of the ability of novice operators to obtain adequate images with continuous, real-time audio guidance from off-site experts who had access to the 'live' images, compared to standard echo by expert sonographers</td>
<td>Cardiac limited ultrasound exam (CLUE): LVD, LA size, interstitial lung oedema, elevated central venous pressure</td>
<td>
• Novices obtained adequate views in 90% of cases, sonographers in 96%
• Novice' HHU scan sensitivity and specificity were:
- 80% and 95% for LVD
- 69% and 82% for LA enlargement
- 40% and 100% for lung comets
- 100% and 96% for elevated central venous pressure
</td>
<td>• Novice operators can perform high-standard CLUE examinations with live guidance from off-site expert.</td>
</tr>
<tr>
<td>Cawthorn et al. [18]</td>
<td>Vscan</td>
<td>12; first year 45; third year</td>
<td>Training mainly in the classroom; 2 hours were spent examining hospital in-patients Classroom based training</td>
<td>16 hours (2 hours for 8 weeks)
•Program 1 (lecture-based) -8 hrs;
• Program 2 (E-module and sonographer - guided training) – 14hrs;
• Program 3 (self-directed E-module and cardia-cultrasound simulator training)- 12 hrs</td>
<td>Students were evaluated on their ability to interpret images as part of online questionnaire and their abilities to acquire images were examined whilst performing an examination on a health volunteer Direct comparison of effect of 3 types of training on the ability of medical student to interpret HHU recordings of cardiac pathology.</td>
<td>Cardiac: LV dysfunction, LVH, stenosis or regurgitation of the aortic and mitral valves and pericardial effusion Cardiac: LV dysfunction, LVH, stenosis or regurgitation of the aortic and mitral valves and pericardial effusion</td>
<td>
• Students improved their ability to interpret ultrasound scans for mitral regurgitation, LV hypertrophy and recognition of absence of pathology as compared to the pre-test values, not for the other pathologies
• Mean scanning score assessing imagine acquisition was 2.14 (on a four point scale, 1=excellent , 4=poor)
Mean Image Interpretation Score
<table>
<tr><th>Group</th><th>Mean post-intervention score</th><th>Improvement</th><th>p value</th></tr>
<tr><td>Program 1</td><td>85%</td><td>125%</td><td><0.001</td></tr>
<tr><td>Program 2</td><td>82%</td><td>141%</td><td><0.001</td></tr>
<tr><td>Program 3</td><td>81%</td><td>148%</td><td><0.001</td></tr>
</table>
No significant difference in image interpretation among the three educational programs (p=0.65)
Mean Image Acquisition Score
<table>
<tr><th>Group</th><th>Mean scanning accuracy (i.e. probe positioning)</th><th>Mean quality score (0-9; 0-unreadable, 9- excellent)</th><th>p value</th></tr>
<tr><td>Program1</td><td>82%</td><td>3.87</td><td><0.001</td></tr>
<tr><td>Program 2</td><td>85%</td><td>3.15</td><td><0.001</td></tr>
<tr><td>Program 3</td><td>81%</td><td>2.58</td><td><0.001</td></tr>
</table>
</td>
<td>• Students have not yet had their core cardiology teaching
• Students had the availability to about 10 hours of e-modules
• Students had the ability to use HHU units in their own time to gain extra practice</td>
</tr>
</table>

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A4C: Apical Four-Chamber; AAA: Abdominal Aortic Aneurysm; AS: Aortic Stenosis, ASD-Atrial Septal Defect; AV: Aortic Valve; AVD: Aortic Valve Disease; CVS: Cardiovascular System; GI: Gastro-Intestinal; IVC: Inferior Vena Cava; LA: Left Atrium; LV: Left Ventricle; LVH-Left Ventricular Hypertrophy; MR: Mitral Regurgitation; MS: Mitral Stenosis; MV: Mitral Valve; PLAx: Parasternal Long-Axis; RA: Right Atrium; RHD: Rheumatic Heart Disease; RV: Right Ventricle; VSD: Ventricular Septal Defect; WMAs: Wall-Motion Abnormalities

To add to the heterogeneity, some students were assessed using an Objective Structured Clinical Examination (OSCE) in a controlled environment, using written cases and a normal volunteer examination [21], while others were assessed based on a log of selected examinations, performed on non-standardised (authentic) patients on hospital wards [15]. All studies confirmed that using HHU devices produced an improvement of the performance parameters monitored. The results are summarised in Table 1[14-16,19,21-23].

Discussion

Research into the use of HHU in medical education is scarce and highly heterogenous. Studies focus on teaching medical students to identify pathology, mostly pertaining to the heart, rather than teaching anatomy and physiology. Nevertheless, we have found that teaching medical students the basics of ultrasound using novel HHU devices is feasible and effective. Many investigators recognise the use of self-directed learning packages to aid ultrasound learning and recognition of pathology. HHU is 'the stethoscope of the future' and may have multiple uses in the hands of the physician [2,17,27]. While formal scanning with 'full-blown' ultrasound machines [11,12] has been shown to increase the understanding of anatomy and physiology in undergraduate medical education, whether HHU has a similar effects has not yet been evaluated.

Benefits and effects of HHU training of medical students

Improved diagnostic accuracy: HHU is not a substitute for clinical examination, but rather an extension of it, improving diagnostic accuracy for a range of conditions [3,14,28]. Although, the data is inconsistent, high sensitivities are achieved for a number of cardiac and non-cardiac pathologies, which may not be detected on physical examination alone. Even with limited training, medical students across the studies demonstrated relatively high sensitivities (88%) and specificities (86%) for the detection of LV systolic dysfunction.

Procedural guidance: The National Institute for Health and Care Excellence (NICE) in the UK recommends ultrasound guidance for central venous access [29], as it reduces complication rates and improves success rates of invasive procedures [30,31]. HHU training represents a good starting point for teaching ultrasound-guided central venous access, a core competency of a junior doctor. Although not reported yet, HHU could be useful for targeting pleural drains.

Management of emergencies: Students perform well when asked to complete a FAST scan and are able to detect free fluid on simulators as part of an OSCE, despite receiving only 5 hours of training [21]. Abdominal aortic diameters [22] can be measured accurately by novices, while the accuracy for the detection of pericardial effusions is still uncertain [14,16].

HHU can change patient management in emergencies when used by an expert [5]. It is unlikely that a novice would be able to achieve the same accuracy. Nevertheless, familiarity with HHU could help triage the urgency of performing a standard echocardiogram, which may be an argument for the inclusion of HHU in the curriculum of medical schools.

Uses beyond medical school: Ability to use HHU is beneficial for recognition and early management of the acutely ill patient (e.g. differentiating between LV dysfunction vs. acute exacerbation of COPD [17]). HHU may also have a role in general practice, particularly in rural settings [32]. Formal accreditation early in the career, with the provision of evidence for ongoing use [33] may be an effective way to maintain competence in the long term.

Barriers to the widespread adoption of HHU in undergraduate medical education

Poor quality of available data to guide policy: There is marked variation across the literature of all the parameters we extracted. There is no consensus on the features that define the appropriate use of HHU in medical education, and until a position statement from the relevant bodies is adopted, it is likely that penetration of HHU will remain patchy and inconsistent.

Lack of consensus on the desirable level of competence: There is no consensus about a minimal level of competence or a standard set of skills that should be taught. It may be possible to certify medical students in focused ultrasound scanning, but this approach has not been reported. Criteria and pathways for accreditation need to be developed and monitored to ensure clinical governance.

Limited availability of qualified teachers/trainers: Cardiologists and accredited cardiac sonographers are the 'gold standard' for teaching HHU of the heart, and are not readily available. Alternatives may be considered, such as non-clinical instructors, specially trained students with an interest in imaging [19], junior doctors, and this may represent a fertile area for research and development. The most important factor for the success of integration of HHU teaching into the curriculum is a good team to drive the change [34]. Free on-line HHU learning resources such as podcasts [19], i-books [35] and e-modules [18], may have an important part to play.

Uncertainty about long-term retention of skills: Any systematic attempt at disseminating HHU across the medical curriculum needs to be synchronised with a similar drive

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in the postgraduate arena. A recent study by Kimura et al. [36] conducted on physician graduates shows that cardiac ultrasound skills decline within 2 years of non-use. Therefore, unless doctors have opportunities to maintain the ability to use HHU it can be argued that undergraduate training is not worth the trouble. A profound 'cultural shift' needs to take place across the profession if HHU is to be accepted as a valid contributor to medical education.

Limitations

This review was limited to studies published in English. The studies were markedly in homogeneous, which prevented rigorous comparisons. Most students included in the studies were volunteers, presumably with a specific interest in the topic, so results cannot be generalised to a situation where HHU would be 'rolled-out' to all students in a cohort.

Conclusion

It is possible to teach medical students how to use hand-held ultrasound scanners, and this enhances their diagnostic accuracy, especially for cardiac conditions. Current data on integrating HHU with medical curricula is suboptimal and highly heterogeneous. Further study is required to assess the longevity of skills retention for HHU, their precise role in the curriculum and in the development of medical careers, the financial impact of a HHU-based approach to medical curricula, pathways to accreditation, and to inform the development of consensusamong educators and clinical leaders about the use of HHU.

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