Author’s response to reviews

Title: Feasibility and accuracy of point-of-care pocket-size ultrasonography performed by medical students

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Version: 2
Date: 22 May 2014

Author’s response to reviews: see over
COVER LETTER
Submission of revised manuscript:
“Feasibility and accuracy of point-of-care pocket-size ultrasonography performed by medical students”

We hereby submit this original and revised manuscript in hope of it being of interest to the BMC Medical Education. We would also like to thank the reviewers for their valuable input and suggestions, which has contributed to the improvement of our manuscript.

Below is a copy of each reviewer’s response and our reply. In addition we have taken the liberty of including a draft version of the manuscript at the end of this cover letter. This draft has the “track changes” function of WORD included so as to highlight the actual changes made to the manuscript. The manuscript has also been submitted as a “clean” manuscript were changes are no longer visible.

We firmly believe that the incorporation of routine bedside pocket-size ultrasound by non-experts as well as experts has the potential to greatly improve inpatient workflow and diagnostic accuracy at a low financial cost. Starting training with point-of-care ultrasonography in medical school will contribute to this goal.

With regards, on behalf of the authors,

Andersen, Garrett Newton, MD.
Annja Viset, MD.
Mjølstad, Ole Christian, MD.
Øyvind Salvesen Ph.D.
Reviewer’s report

Title: Feasibility and accuracy of point-of-care pocket-size ultrasonography performed by medical students

Version: 1 Date: 4 April 2014

Reviewer: Daniel J van Hoving

Reviewer’s report:

Thanks for allowing me to review this manuscript. This manuscript describes the use of point-of-care pocket-size ultrasonography performed by medical students. Although the scientific rigor of the study methods are questionable, I do believe that this manuscript add to the scientific body of knowledge regarding the use of ultrasound in everyday practice.

- Major Compulsory Revisions

1. A significant amount of bias (diagnostic review bias) were possible introduced. Specialists were used as ‘gold standard’ to interpret the students’ images. Please describe the qualification of these specialists and whether they were blinded to the students interpretation.

Author’s reply: The specialists, one board certified radiologist and 2 board certified cardiologists with special interest in ultrasonography and echocardiography, were not blinded to the students stipulated set diagnosis, but their responsibility was rather to answer whether the recordings were acceptable for interpretation and if the set diagnosis of the acceptable images were correct or incorrect.

This has been further addressed in Materials and Methods > Accuracy. A further comment on this has also been added to the Discussion section.

- Minor Essential Revisions

2. Please clarify how students were selected if more than 30 volunteered?

Author’s reply: The first 30 students that volunteered were allocated to participate in the study. This has been clarified and added to the section Materials and Methods > Medical
3. A significant amount of bias is present in the study:

- **Selection bias**: Number of patients scanned per student ranged from 1 – 27. Nine students didn’t do any scans and were excluded.

- **Spectrum bias**: Students selected which patients to scan.

- **Partial verification bias**: Students selected which images to be interpreted.

This was acknowledged by the authors in the Limitations section, however, the authors only listed reasons for selection bias but didn’t discuss the estimated effect of it on the results.

*Author’s reply*: *We cannot accurately estimate the effects of these biases on the study results, but we do agree that it probably has had some effect on the results (overestimation) and this has been added under Limitations.*

The selection and spectrum bias present in this study is inline with other similar studies involving inexperienced users (such as residents and nurses). These articles have been added to our references in the manuscript.


Furthermore selection bias is an integrated part of point-of-care ultrasound, as opposed to patients referred for formal imaging. That is it is to a larger degree the clinician’s decision which patients to examine, conversely this may have the positive effect of selecting appropriate patients for examination.

Regarding partial verification bias; the operator is not able to review an image loop until it is stored on the specific PSID device used (Vscan). All imaging procedures have similar selection bias here, including higher order imaging hardware such as MRI and CT machines. Keeping substandard images when better images are available does not enhance diagnostic accuracy. The fact that the students did not select images of poor quality is, in our opinion, a strength and not a concrete bias. The aim of the study was to assess whether the students could acquire and subsequently analyze the selected ultrasound images. It would however have been a bias if we were to study how large a proportion of all stored images were of acceptable quality.

4. Another limitation that should be addressed is the fact that the diagnostic accuracy only included acceptable images. There were a 25% loss of patients in the cardiovascular group and 15% loss in the radiological structures group, this would most
likely dilute the true diagnostic accuracy and should be discussed or mentioned.

Author’s reply: The lack of a gold standard/reference made the basis for this, as assessing accuracy in non-acceptable images is useless when no reference is available. However, we do agree that this may have diluted the true diagnostic accuracy to some extent. We have added this to our article under Discussion.

5. The writing style are acceptable, but please correct the following: • P1 para 2 line7 – Inappropriate use of semi-colon• P5 para 3 line3 – Should be Clopper-Pearson• P7 para4 line10 – Double word (a)

Author’s reply: This has been edited as suggested.

- Discretionary Revisions

6. Numbers under ten are usually written out

Author’s reply: This has been edited as suggested.

☐ Level of interest: An article of importance in its field

Quality of written English: Acceptable

☐ Statistical review: No, the manuscript does not need to be seen by a statistician.

Declaration of competing interests: I declare that I have no competing interests

Reviewer’s report

☐ Title: Feasibility and accuracy of point-of-care pocket-size ultrasonography performed by medical students

Version: 1 Date: 14 April 2014

Reviewer: Somashekhar Nimbalkar

Reviewer’s report:

Specific Points:

1. Sentence 2 and 3 are not well supported by recent references.
2. References number 1 and 2 are almost three decades old. They do show that clinical skills are deficient. It is possible that they have improved in the meantime rather than decreased. Inappropriate references.

3. Reference 3 is a comparison of three English speaking countries. It does show that there is a reduction of skills but does not show it over a period of time.

4. Reference number 4 – is not relevant. It describes a comparison of emergency medicine residents and internal medicine residents. Paper is published in 1995 and thus does not provide support to decline in clinical skills with evolution of medicine.

Author’s reply: Reference nr 1-5 have been removed and along with the first 2 lines in the introduction.


5. Reference number 6 – is not well quoted. It refers to a Lancet article which is a review on autopsies. The reference to 30% missed diagnosis is a cross-reference in the review article and hence this reference is not correct.


6. Reference number 7 – quotes a misdiagnosis of about 10-12% and the era is from 1960 to 1990. Hence this reference is not contextual as the rates have not changed and the current paper is almost 25 years since this study was conducted.

Author’s reply: Despite the advent of newer technologies misdiagnosis continues to plague medical practice. This is an important point and highlights the need for increasing diagnostic accuracy. One might expect diagnostic errors to have decreased over the last 6 decades, but this article shows that it seemingly has not. In our opinion that makes this reference highly contextual. We have added an additional autopsy study conducted
from 1999-2005 with similar results that further supports our statement.


If the editor prefers we will be happy to change this.

7. In introduction there are many references used for two statements. 10-18 and 19-25 references are one too many for two lines. They have not been utilized in discussion except for 14 and 10-13, 16 and 18. Here again the references are used for support to a single statement.

Author’s reply: In an attempt to be succinct we have in a single sentenced summarized important findings of several different articles, each of which has addressed a separate topic pertaining to the clinical use of pocket-size ultrasound and similarly so when with regards to education of medical students. We have removed references nr. 11, 19 and 22 from the manuscript, but find that removing further references may reduce the importance of the manuscript.


8. Study Population:- lack of consent cannot be an exclusion criteria. Minor Compulsory Revision

Author’s reply: This as been edited.

9. 3 evenings – Scientific documents require that numbers 1-9 be written in words preferably. Mention of hours is sufficient. Evenings or mornings is not moot for this paper. Minor Compulsory Revision

Author’s reply: Numbers have been written out. We have specifically written evenings as this underlines the fact that this was an extracurricular activity for the students and to most accurately describe our methods of education. If the editor prefers we will be happy to change this.

10. Methods - more details on the training process and what assessment methods were
used to ensure that their training was of same quality. The study is about medical students achieving the ability to use PSID. Hence more details on the process of selection and the quality of students needs to be given.

Author’s reply: Students were volunteers and selected on a first come, first serve principle. This has been clarified in Materials and Methods > Medical students. The quality of the medical students were not assessed prior to study inclusion and nor were students or authors familiar with each other prior to study start. All students received the same education/training. The medical students had all undergone a brief introductory ultrasound course (2 hours) in their first year of medicine, apart from which they were ultrasound naïve.

11. Results – “They were able to correctly acquire and interpret these bedside-ultrasound images in 74-88 % and 93% of cases, respectively” – missing systems. Minor Compulsory Revision.

Author’s reply: This has been edited.

The characteristics of the students that participated and did not participate needs to be shown as this has the capability of letting the reader know which students are more likely to more use PSID. This would allow the reader to understand the various biases that may be prevalent. It is possible that the 21 students that ultimately used PSID were more techno savvy and the remaining 9 were less so. Since the students had volunteered it may be helpful to know why they volunteered. Major Compulsory Revision

Author’s reply: Unfortunately we have no information on why the medical students volunteered, why some performed well and others not or any other student specific characteristics. This was not the aim of our study. We do however agree that the difference in use of PSID may be partly explained by the degree of techno savviness, but this would be pure speculation on our part.

In general, proficiency in ultrasound is user dependent. This is seen even in fields of ultrasound expertise such cardiology and radiology. Why some radiologists or cardiologists are more adept at using ultrasound is not known, similarly why some students performed well and others not has not been the focus of our study. The variation in the amount of exams performed by each student is in line with previous publications on the use of pocket-size ultrasound by inexperienced users (such as residents and nurses). We have added further comments on the selection and spectrum bias under Limitations, including references listed below.


12. Discussion is very poor, almost nonexistent. The last two lines in discussion cannot be derived from the study. The study does not show increasing proficiency with increasing use. Neither does the study make a case for starting PSID use early. What the study shows is that PSID can be used by medical students.

Author’s reply: The discussion and limitations section has been elaborated.

Several studies have shown increasing accuracy with increasing levels of experience including those already referenced in the discussion. We have added a further recent reference just published in JASE which may “…contribute to and further guide the establishment and integration of competency-based handheld ultrasound device training in medical schools” according to an editorial comment by Mulvagh et al.


One can therefore expect increased proficiency in point-of-care ultrasonography at an earlier stage in a clinician’s career if training starts earlier. When to start PSID training is a matter of debate, but we have shown that PSID can be used by 5th year medical students, therefore making it plausible to start PSID education at an earlier stage in a clinician’s career than is currently practiced at most universities.

1. Is the question posed by the authors well defined?

There can be a better introduction with lesser references. The introduction can be more crisper which lands smoothly on the hypothesis. The hypothesis is well defined. However the case for action is weak. Major Compulsory Revision

Author’s reply: References have been altered and cut down as stated above. In our opinion the case for action is strong and we feel it is well supported by our references.

2. Are the methods appropriate and well described?

The methods are more focused on technology rather than the students. This is a research looking at how students can acquire newer competencies. There are no cognitive competences that are defined and what should be the essential skill requirements for students is not stated. Elaborating on this will allow others to replicate this study. Major Compulsory Revision

Author’s reply: This is addressed in Materials and Methods > Training and education of medical students. The specific skill requirements were; “Students were specifically trained to assess for pathology relevant in the immediate emergency care of patients. They were instructed to assess for reduced left ventricular (LV) function defined as mitral annular excursion (MAE) < 10 mm, pericardial effusion, pleural effusion, lung comets, inferior vena cava (IVC) diameter and variation, hydronephrosis, bladder distension, gallstones, signs of cholecystitis, diameter of abdominal aorta (AA) and abdominal free-fluid.” The students were evaluated on their ability to perform these tasks in clinical
practice when they returned their ultrasound machines for analysis. The results are presented in the study. A comment regarding their experience with ultrasound has been added to Materials and Methods> Medical Students

3. Are the data sound?

Data related to students is lacking entirely. Data related to technology is well shown.

Author’s reply: As the students are included as an heterogenous population based on willingness only we unfortunately have no further data on the medical students. A comment regarding their experience with ultrasound has been added to Materials and Methods> Medical Students

4. Does the manuscript adhere to the relevant standards for reporting and data deposition?

Data are well reported. The graphs are fair.

5. Are the discussion and conclusions well balanced and adequately supported by the data?

Discussion as written above is poor. The focus is more on the technology in the methods and the results while the focus needs to be on the students and their skill acquisition. For a paper being submitted to a journal focused on medical education these are glaring deficiencies. The conclusions in the last two lines of discussions are not based on the study findings. Major Compulsory Revision

Author’s reply: See previous reply above regarding the same concerns.

6. Are limitations of the work clearly stated?

These are well stated. However data related to limitations could have been obtained and presented.

Author’s reply: Unfortunately we have no further data regarding the limitations of the study.

7. Do the authors clearly acknowledge any work upon which they are building, both published and unpublished?

No

Author’s reply: We have attempted to reference several articles as a base for this study. As requested by reviewer nr 2 we have now shortened this reference list, in addition we have added a few selected references for further clarification. Further reduction in our reference material would result in a reduced quality of work. In total we find this work well positioned based on the referenced work by others as well our own group.
8. Do the title and abstract accurately convey what has been found?

Yes

☐ 9. Is the writing acceptable?

Can be improved

Summary: It appears that the study has been conducted rigorously but not much effort has been made in the writing of the manuscript. References have been used up to pad up the introduction. It seems that the references have not been read as they are not in context of the statements of the manuscript. The heart of any manuscript is the discussion section and this is extremely poor.

Level of interest: An article whose findings are important to those with closely related research interests

Quality of written English: Needs some language corrections before being published

Statistical review: Yes, but I do not feel adequately qualified to assess the statistics.

Declaration of competing interests:
I declare that I have no competing interests

Feasibility and accuracy of point-of-care pocket-size ultrasonography performed by medical students

Authors:
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Background: Point-of-care ultrasound performed by clinicians is a useful supplement in the treatment and assessment of patients. We aimed to investigate whether medical students with minimal training were able to successfully acquire and interpret ultrasound images using a pocket-size imaging device (PSID) as a supplement to their clinical practice.
Methods: Thirty 5th year (of six) medical students volunteered to participate. They were each given a personal PSID device to use as a supplement to their physical examination during their allocated hospital terms. Prior to clinical placement the students were given three evenings of hands-on training with PSID by a board certified radiologist/cardiologist, including three short lectures (<20 min). The students were shown basic ultrasound techniques and taught to assess for basic, clinically relevant pathology. They were specifically instructed to assess for the presence or absence of reduced left ventricular function (assessed as mitral annular excursion < 10 mm), pericardial effusion, pleural effusion, lung comets, hydronephrosis, bladder distension, gallstones, abdominal free-fluid, cholecystitis, and estimate the diameter of abdominal aorta and inferior vena cava.

Results: A total of 211 patients were examined creating 1151 ultrasound recordings. Acceptable organ presentation was 73.8% (95% CI 63.1-82.6) for cardiovascular and 88.4% (95% CI: 80.6-93.6) for radiological structures. Diagnostic accuracy was 93.5% (95% CI: 89.0-96.2) and 93.2% (95% CI: 87.4-96.5) respectively.

Conclusion: Medical students with minimal training were able to use PSID as a supplement to standard physical examination and successfully acquire acceptable relevant organ recordings for presentation and correctly interpret these with great accuracy.

Keywords: Echocardiography, Point-of-care ultrasound, Bedside, Medical student, Hand-held

Introduction

We are increasingly reliant upon expensive and time-consuming biochemical and radiologic diagnostics to aid us in our evaluation of patients. Unfortunately this still results in major diagnostic errors in up to 30% of patients at autopsy[1-3]. Furthermore the increasing age and
chronicity of the western population highlights the need for improved out of hospital diagnosis and treatment.

Point-of-care ultrasonography allows for the near instantaneous acquisition of real-time dynamic images, which can be correlated directly to the patient’s signs and symptoms [4, 5]. It has been shown to increase diagnostic accuracy, rapidly and cost effectively in the hands of experts and non-experts [6-13]. Furthermore, portable ultrasonography is a valuable teaching tool in medical anatomy and physiology as well as physical examination [14-18]. Despite this most medical students are not routinely educated in the clinical use of point-of-care ultrasonography, as they are in more widely accepted and traditional techniques, such as the stethoscope. This may in part be due to the lack of evidence regarding the bedside use of pocket-size ultrasound by medical students.

We aimed to investigate whether medical students with minimal training were able to successfully acquire and interpret ultrasound images using a pocket-size imaging device (PSID) as a supplement to their clinical practice.

**Materials and methods**

**Medical Students**
The fifth year (of six) medical students eligible to participate in the study based on planned hospital rotations received verbal and written information from the authors regarding the study. Participation in the study was not part of the students’ curriculum and all participating students were volunteers. The first 30 students whom volunteered were included in the study. There were no further inclusion or exclusion criteria. The number of participating students was limited to the number of available PSID. The medical students had similar limited experience in ultrasound.

**Study population**

All patients over 18 years of age, encountered in-hospital and at outpatient clinics during the students’ clinical placement periods were eligible for inclusion. The patients were included from a total of seven regional hospitals between January-May 2012. There were no exclusion criteria, and all participating patients provided informed consent.

**Training and education of medical students**

The medical students received three evenings (nine hours) of combined theoretical and practical training in the use and interpretation of ultrasound images. The theoretical training was given as short didactical lectures by relevant specialists (cardiologists and radiologists) and focused on basic ultrasound physiology, anatomy and examples of normal and pathological ultrasound images. Students were specifically trained to assess for pathology relevant in the immediate emergency care of patients. They were instructed to assess for reduced left ventricular (LV) function defined as mitral annular excursion (MAE) < 10 mm [19-21], pericardial effusion, pleural effusion, lung comets, inferior vena cava (IVC) diameter and variation, hydronephrosis, bladder distension, gallstones, signs of cholecystitis, diameter of abdominal aorta (AA) and abdominal free-fluid. Practical hands-on training was given by relevant specialists and senior
registrars, with students using their personal PSID. Students were encouraged to perform at least 75 examinations prior to placement.

Written informed consent was obtained from all patients. The Regional Committee for Medical and Health Research Ethics had no objections to the study’s conduction, which was conducted according to the Declaration of Helsinki.

**Pocket-size ultrasound examination**

The ultrasound examination was performed bedside with a PSID, Vscan (GE Vingmed Ultrasound, Horten, Norway). The device measures 135 × 73 × 28 mm and weighs 390 g, including the phased-arrayed probe. Two-dimensional grey scale and live colour Doppler imaging are offered. The image sector for echocardiographic imaging is 75°. The bandwidth ranges from 1.7 to 3.8 MHz and is automatically adjusted. Storage and looping of a cardiac cycle are possible without ECG signal and looping of other structures is predefined and limited to 2 seconds. The device has separate modes optimized for cardiac and abdominal examinations. All images and recordings were saved on the device’s micro-SD card and later transferred to a computer by commercial software (Gateway; GE Vingmed Ultrasound).

The bedside (point-of-care) cardiovascular ultrasound examination was performed with patients in the left-lateral decubitus and/or supine position. Assessment of LV global function was done from the apical four-chamber view using MAE, where MAE < 10 mm was classified as decreased LV function. Pericardial effusions were classified as present or not. The AA and IVC were assessed from the subcostal position. The AA diameter was assessed proximally to the bifurcation and if exceeding 35 mm classified as an abdominal aortic aneurysm (AAA). IVC diameter was measured end-expiratory within two cm from the right atrium orifice. All
measurements of dimensions were done on the PSID. With patients in a supine or upright position, the pleura was assessed from left and right thoracic dorsolateral views, and assessed for the presence of pleural effusions and comet tails.

Other abdominal structures and spaces were assessed from a supine position looking specifically for hydronephrosis, bladder distension, gallstones, and signs of cholecystitis, and abdominal free-fluid.

**Accuracy**

The students were required to hand-in a log of selected examinations including their own set diagnosis based upon PSID examination. The specialists, one board certified radiologist and 2 board certified cardiologists with special interest in ultrasonography and echocardiography, were asked to categorize the image acquisition of relevant organ as acceptable or unacceptable for clinical interpretation and then determine whether the set diagnosis of the acceptable images were correct or incorrect. The specialists were not blinded to the set diagnosis.

**Statistics**

Data not following a normal distribution were presented as median and (interquartile) range. For sufficiently large samples logistic mixed model with random intercepts for students was used to examine estimate proportions. Clopper-Pearson estimates were used for small sample analyses. Sensitivity and specificity, negative and positive predictive value calculations were performed using relevant specialists as “gold standard”.

All the statistical analyses were performed using SPSS for Windows/Mac (version 20.0, SPSS, Inc.) or R version 2.13.1.

**Results**
Thirty 5th year (of six) medical students volunteered to participate in the study. At the end of the study period and their clinical placement, 21 (70%) medical students had performed exams using PSID and recorded their results. A total of 211 patients were examined (43% male, 38% female and 18% unrecorded sex), creating 1151 ultrasound recordings. Each student examined a median of 9 (±8, range 1-27) patients, producing a median of 49 (±49, range 5-169) ultrasound recordings. Acceptable organ presentation (fig 1.) was estimated to 73.8% (95% CI 63.1-82.6) for cardiovascular (heart, lungs and IVC) and 88.4% (95% CI: 80.6-93.6) for radiological (AA, renal system, gallbladder and abdominal free fluid) structures. Specifically, students performed best when acquiring images of the lungs and renal system (> 93 % (95% CI: 84.3-98.2) and found it most difficult to acquire acceptable images of the heart (71.2% (95% CI: 58.7-81.5)) and free fluid (73.2% (95% CI: 41.4-92.7)). The other categories (AA, IVC and gallbladder) had acceptable presentation in >80% (95% CI: 65.2-92.9) of cases. Diagnostic accuracy (fig 2.) was estimated at 93.5% (95% CI: 89.0-96.2) for cardiovascular structures and 93.2% (95% CI: 87.4-96.5) for radiological structures. The specific diagnostic accuracy was on a whole excellent. Diagnostic accuracy was close to 100% for AA (98.6% (95% CI: 92.7-100)) and free abdominal fluid (100% (95% CI: 76.8-100)) and lowest for gallbladder at 87.6% (95% CI: 73.7-95.1). The remaining categories showed diagnostic accuracy > 93% (95% CI: 83.3-99).

The estimated values for sensitivity, specificity, negative and positive predictive values of PSID are presented in table 1.

**Discussion**

Medical students, with a limited amount of training, successfully incorporated the use of point-of-care ultrasonography in their clinical placements. They were able to correctly acquire bedside
ultrasound images of cardiovascular and radiological structures in 74 and 88% of their patients and correctly interpret these images in 93% of cases.

An attempt to simulate real life scenarios was done when determining the feasibility and accuracy. In our experience, when non-experts use pocket-size ultrasound at the patients point-of-care they may have the need to clarify or present their ultrasound findings to a specialist for review or guidance. The specialists were in this setting used as the gold standard with regards to statistical analysis and were not blinded to the set diagnosis. Optimally this would have been done by higher order, formal imaging, but that was beyond the scope of this study in terms of logistics and economy.

Other studies have shown that medical students are able to quickly acquire ultrasound recordings of good quality on normal test subjects, in optimal conditions with a standard ultrasound machine after a brief period of training[22]. For the assessment of diagnostic accuracy in our study, only acceptable organ images were used. This may have diluted the true diagnostic accuracy to some extent. However the lack of a formal gold standard/reference made the basis for this, as assessing accuracy in non-acceptable images is useless when no reference is available.

A recent, though smaller study with five final year medical students has shown encouraging results using pocket-size cardiac ultrasonography as an adjunct to standard physical examination in cardiology patients [9]. We have broadened the field, looking at several different organ systems and included diverse groups of hospital and emergency room patients.

The European Association of Echocardiography published a position statement in 2010 regarding with the use of PSID[23]. It supports the use of PSID as a teaching tool in medical schools, as a tool for a fast initial screening in the emergency setting, and as a complement to the standard physical examination.
Previous studies have shown increased accuracy, efficacy and diagnostic impact of pocket-size point-of-care ultrasonography in the hands of experts versus non-experts[6-8, 11, 13, 24]. Thus the benefits of bedside PSID exams increase with increasing proficiency in its use and proficiency has been shown increase with increasing use [25]. Therefore standardized training in the routine use PSID as an adjunct to standard physical examination should start as early as possible.

**Limitations.**

The main limitation of this study is the inability to exclude for selection bias. With the use of their logbooks, students were able to select which ultrasound loops were eligible for review. This selection and spectrum bias may have lead to some overestimation of the results for feasibility and accuracy, however the degree of selection bias is in line with similar studies involving unselected residents and nurses [26, 27]. Furthermore 1 student did not hand in a completed logbook and a further 8 students did not perform any examinations with PSID and were therefore excluded from the study. The number of students not performing any examinations was probably influenced by several factors. Firstly the use of PSID in their clinical placement was not a mandatory exercise for the medical students. Secondly, as this was a trial of the use of PSID the students received specific instructions not to let the trial come in the way of their other academic responsibilities. Thirdly, the inclusion of patients was performed by the medical students themselves, which may have created a further barrier for its use. Lastly the use of ultrasound imaging is operator dependant, enthusiastic students will likely acquire more and better images reflecting a more realistic picture of it´s clinical use, i.e. those skilled in ultrasound will also be the ones using it the most.
Conclusion

Medical students with minimal training were able to use PSID as a supplement to standard physical examination and successfully acquire acceptable relevant organ images for presentation and correctly interpret these with great accuracy. Incorporating training of point-of-care ultrasound in medical student education may be one step further towards a more widespread use of ultrasound and a faster and more accurate diagnosis for patients.

Abbreviations

PSID: pocket-size imaging device; LV: left ventricular; MAE: mitral annular excursion; IVC: inferior vena cava; AA: abdominal aorta; AAA: abdominal aortic aneurysm;

Competing interests

GE Healthcare provided 20 of the 30 PSID devices used during this study as a loan. No financial support was received.

Authors’ contributions

GNA participated in the study design and coordination, education of medical students, data processing, performed the statistical analysis and drafted the manuscript. AV participated in the coordination of the study, education of the medical students and review of relevant images. OCM participated in the coordination of the study, education of the medical students and review of relevant images. ØS participated in the design of the study and performed the statistical analysis. HD participated in the design of the study, performed the statistical analysis and helped to draft the manuscript. BOH conceived of the study and participated in its design and coordination,
education of the medical students and review of relevant images and helped to draft the manuscript. All authors read and approved the final manuscript.

Acknowledgements

We thank all the participating medical students for their invaluable assistance with the inclusion and data collection for this study. The Norwegian University of Science and Technology (NTNU) and Nord-Trøndelag Health Trust, both Norway, funded this study. GNA, OCM, HD and BOH hold positions at the Medical Imaging Laboratory, NTNU, a Centre of Research-based Innovation that is funded by the Research Council of Norway and industry. One of the industry partners is GE Vingmed Ultrasound. The Centre has a total budget of app. 124 million NOK for the 8 year period 2007–2014, and the contribution from GE Vingmed Ultrasound to this budget is app. 7 million NOK (app. 6%).

References


Figure Legends

Fig 1. Acceptable Organ Presentation
Cardiovascular all; heart, IVC and Lungs, IVC; Inferior vena cava, Radiological all; includes AA, Renal system, Gallbladder and Abdominal free fluid. AA; Abdominal aorta

Fig 2. Correct Diagnosis
Cardiovascular all; heart, IVC and Lungs, IVC; Inferior vena cava, Radiological all; includes AA, Renal system, Gallbladder and Abdominal free fluid. AA; Abdominal ao

Table 1. Sensitivity, specificity, positive and negative predictive values.

<table>
<thead>
<tr>
<th>Pathology to detect</th>
<th>N Pathology (N total)</th>
<th>Sensitivity % (95% CI)</th>
<th>Specificity % (95% CI)</th>
<th>PPV % (95% CI)</th>
<th>NPV % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cardiovascular</td>
<td>156 (468)</td>
<td>95.5 (90.9-97.9)</td>
<td>92.4 (83.7-96.9)</td>
<td>87.0 (75.3-93.4)</td>
<td>97.6 (95.0-98.8)</td>
</tr>
<tr>
<td>Cardiac only</td>
<td>115 (338)</td>
<td>98.3 (93.9-100) *</td>
<td>90.8 (78.8-96.7)</td>
<td>84.5 (62.6-95.6)</td>
<td>99.0 (96.4-99.9) *</td>
</tr>
<tr>
<td>IVC</td>
<td>20 (71)</td>
<td>84.5 (57.2-96.3)</td>
<td>100 (93.0-100) *</td>
<td>100 (80.5-100)*</td>
<td>94.8 (82.9-98.7)*</td>
</tr>
<tr>
<td>Lungs</td>
<td>21 (59)</td>
<td>90.5 (68.8-97.6)</td>
<td>94.7 (82.2-99.4)*</td>
<td>90.5 (69.6-98.6)*</td>
<td>94.7(82.2-99.2)*</td>
</tr>
<tr>
<td>All abdominal</td>
<td>104 (453)</td>
<td>92.6 (83-97.1)</td>
<td>92.2 (82.9-96.9)</td>
<td>80.1 (63.3-91.0)</td>
<td>97.5 (92.6-99.2)</td>
</tr>
<tr>
<td>AA</td>
<td>12 (74)</td>
<td>91.7 (61.5-98.6)*</td>
<td>100 (94.2-100)*</td>
<td>100 (71.3-100)*</td>
<td>98.4 (91.5-99.6)*</td>
</tr>
<tr>
<td>Renal System</td>
<td>48 (282)</td>
<td>89.9 (77.2-95.9)</td>
<td>93.3 (82.5-98.0)</td>
<td>73.1 (48.4-89.6)</td>
<td>97.5 (85.7-99.7)</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>35 (84)</td>
<td>94.3 (80.8-99.1)*</td>
<td>85.6 (71.5-93.4)</td>
<td>82.4 (63.7-93.1)</td>
<td>95.5 (84.5-99.3)*</td>
</tr>
<tr>
<td>Abdominal free fluid</td>
<td>9 (14)</td>
<td>100 (66.2-100)*</td>
<td>100 (48.0-100)*</td>
<td>100 (66.2-100)*</td>
<td>100 (48.0-100)*</td>
</tr>
</tbody>
</table>

N; number, CI; confidence interval, PPV positive predictive value, NPV; negative predictive value, IVC; inferior vena cava, AA; abdominal Aorta. * Clopper-Pearson CI