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REVIEW

# Pocket-sized focused cardiac ultrasound: Strengths and limitations

## *Échoscopie à l'aide d'échographe de poche : avantages et inconvénients*

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**Summary** Focused cardiac ultrasound (FCU) has emerged in recent years and has created new possibilities in the clinical assessment of patients both in and out of hospital. The increasing portability of echocardiographic devices, with some now only the size of a smartphone, has widened the spectrum of potential indications and users, from the senior cardiologist to the medical student. However, many issues still need to be addressed, especially the acknowledgment of the advantages and limitations of using such devices for FCU, and the extent of training required in this rapidly evolving field. In recent years, an increasing number of studies involving FCU have been published with variable results. This review outlines the evidence for the use of FCU with pocket-echo to address specific questions in daily clinical practice.



*Abbreviations:* ESC, European Society of Cardiology; FCU, Focused cardiac ultrasound.

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**Résumé** L'avènement de l'échoscopie a ouvert des possibilités diagnostiques nouvelles ces dernières années, à la fois en pré-hospitalier et à l'hôpital. Les échographes de poche sont des appareils de la taille d'un téléphone portable. Ils permettent une grande mobilité ouvrant l'éventail d'utilisateurs potentiels, allant du cardiologue expérimenté à l'étudiant en médecine. De nombreuses questions demeurent néanmoins sans réponse à ce jour. Une attention particulière doit être portée aux avantages et aux limites de l'utilisation de ces appareils pour l'échoscopie afin d'en assurer une bonne utilisation. Les modalités de formation restent aussi à préciser. De nombreuses études ont été publiées ces dernières années avec des résultats variables. Cette revue résume le niveau de connaissances actuelles de l'échoscopie à l'aide d'échographes de poche.


## Introduction

History taking and clinical examination alone do not always allow precise cardiac diagnoses. Point-of-care echocardiography ultrasounds, using portable devices, has emerged as a bedside tool in many specialities, from trauma to neonatology [1]. However, a particularly challenging area is likely to be focused cardiac ultrasound (FCU) because a wide variety of patients need assessment of ventricular function and estimation of filling pressures in different settings. Several studies have shown incremental benefit when FCU is added to the general physical examination, and investigators have suggested that FCU will someday become an integral part of the physical examination and could even replace the stethoscope [2—8].

Technological advances have led to the miniaturization of echocardiographic machines, with gradually smaller portable devices. Pocket-echocardiography is defined by the size of the devices: small enough to fit into a coat pocket, slightly larger than a smartphone. The use of pocket-echo necessarily implies FCU due to the limited functions of these devices. The relatively low cost and high portability of these devices make them accessible to a wide range of practitioners in different settings: at the bedside, in or out of hospital, from the outpatients' cardiology clinic to the intensive care unit. Before rapid and uncontrolled proliferation of these devices, there is an urgent need to address indications, protocols, limitations and training for the optimal use of pocket-echocardiography [9].

When assessing the accuracy and feasibility of pocket-echocardiography for FCU, three components are particularly important:

- image quality and technical limitations due to the device;
- the expectations practitioners have of FCU;
- expertise of the user/reader.

Some studies have addressed these issues separately and others in combination. In this review, we explore the current level of evidence for the use of different pocket-echo devices for FCU in daily clinical practice.

## Reliability of FCU with pocket-echocardiography in different clinical scenarios

In experienced hands, pocket-echocardiography may be of significant diagnostic value when used in conjunction with physical examination [2—8]. Systematic use of FCU may lead to a change of management and/or diagnosis in up to 20% of patients for whom comprehensive echocardiography was not requested after traditional clinical assessment [3,5,8].

### Left ventricular size and function

FCU by pocket-echocardiography enables the user to answer several simple questions of importance in daily practice (Table 1). One of the most reproducible measurements across studies is semi-quantitative left ventricular ejection fraction, with a sensitivity to detect left ventricular systolic impairment of 74—97% and a specificity of 94—99% when compared to comprehensive echocardiography [4,6,10—18]. Left ventricular dilatation (Fig. 1A) may also be assessed with sensitivity and specificity of 71—94% and 97—100%, respectively [11,15—19]. Regional wall motion abnormalities may not be as accurately assessed as left ventricular ejection fraction or left ventricular dilatation [10,19]. However, FCU by pocket-echocardiography would miss many cases of heart failure with preserved ejection fraction due to the lack of pulsed-wave Doppler and tissue Doppler [20].

### Lung ultrasound: assessment of extravascular lung water

Extravascular lung water results in some comet-tail reverberation artefacts, called B-lines or ultrasound lung comets. The absence of multiple bilateral B-lines excludes cardiogenic pulmonary oedema with a negative predictive value close to 100% [21] (Table 1). In the presence of breathlessness, ultrasound lung comets may also be readily visualized by non-experienced users, and are of prognostic value [22]. Lung ultrasound may also be helpful to detect pleural effusion (Fig. 1B) and identification of pneumothorax, pulmonary consolidations and acute respiratory distress syndrome [23].

### Filling pressure estimation

It is also of interest to be able to estimate the loading conditions in patients with breathlessness or circulatory failure. The inferior vena cava diameter (Fig. 2A) and its respiratory variation may be useful to guide appropriate medical treatment [24—26]. However, the sensitivity and specificity to accurately assess this parameter by FCU vary considerably from one study to another [4,11,13,15,27] (Table 1). This may partly be explained by difficulties in

**Table 1** Accuracy of parameters assessed by pocket-echo.

| Parameters | Accuracy[a] |
|---|---|
| Left ventricular size | Good [11,15–19] |
| Left ventricular systolic function | Good [4,6,10–18] |
| Regional wall motion abnormalities | Good [10,19] |
| Ultrasound lung comet | Good [21,22] |
| Pleural effusion | Good [23] |
| Inferior vena cava | Variable [4,11,13,15,27] |
| Left atrial size | Fair [28] |
| Pericardial effusion | Excellent [4,5,10,11,15–19] |
| Aortic valve disease presence/severity | Fair [10,13,16,30] |
| Mitral valve disease presence/severity | Fair [10,13,16,30] |
| Abdominal aortic aneurysm | Good [10,32,33] |
| Right ventricle | Variable [4–6,10,16] |

[a] Accuracy is defined as a compromise between sensitivity and specificity. Excellent: sensitivity $\geq$ 90%, specificity $\geq$ 95%, including by non-experts. Good: sensitivity > 90%, specificity > 90% by experts. Fair: sensitivity $\approx$ 80%, specificity $\approx$ 80%. Variable: figures vary across studies.

visualizing this structure in approximately 15% of patients, due to limited image width and depth [5,10]. Another explanation for the variability of this measurement with pocket-echocardiography may be the delay between the FCU and the ''gold standard'' high-end echocardiography with the possibility of rapidly changing loading conditions between examinations. In most cases, left atrial dilatation can also be accurately assessed using pocket-echocardiography when performed by experts and reflects left ventricular filling pressure [28] (Table 1).

### Pericardial effusion

Pocket-echocardiography enables a quick rule in/out of pericardial effusion (Fig. 2B) with excellent accuracy (Table 1): sensitivity of 89–91% and specificity of 96–99% [4,5,10,11,15–19].

### Valve disease

Pocket-echocardiography may be of significant value to rule out valve regurgitation (Fig. 3) or stenosis in patients referred for a murmur by a general practitioner, or to guide the management of anaesthetics in elderly patients at risk of aortic stenosis [3]. The use of FCU may facilitate triage of patients and increase delivery of echocardiography for the detection of moderate or severe valve disease [29]. In contrast, grading the severity of valve disease is not indicated with pocket-echocardiography. Results vary considerably from one study to another and may depend on the definition of significant valve disease and on the operator's experience [10,13,16,30] (Table 1). The overestimation of regurgitation may be due to the sensitivity of colour Doppler. There is also a trend towards underestimation of, but not missing, aortic stenosis due to the lack of spectral Doppler.

### Right ventricle

The assessment of the right ventricle has been less well studied, although some studies have addressed right ventricular dilatation or systolic function [4–6,10,16]. Use of FCU has been assessed as a tool in addition to clinical criteria for suspected pulmonary embolism [31]. However, the dropout of the right ventricular free wall and the limited image width with pocket-echocardiography pose major issues when assessing right ventricular dilatation or systolic impairment [16].

### Abdominal aortic aneurysms

Screening for abdominal aortic aneurysms in elderly patients may be integrated into the clinical examination performed by cardiologists [10,32], and is accessible after a short period of training [33]. Accuracy with pocket-echocardiography is generally good [10,32,33] (Table 1).

## Protocol of image acquisition and training scheme for non-experts

The number of non-cardiologists performing FCU is likely to increase dramatically in the coming years [34]. An integrated approach – including four views to look for left ventricular dysfunction, left atrial enlargement, inferior vena cava dilatation and ultrasound lung comet-tail artefacts – may be one simple protocol strategy [35]. Indeed, several questions can be accurately assessed by ''non-experts'' provided users are aware of their own and the device's limitations. Some parameters amenable for interpretation by non-experts include left ventricular systolic function, left ventricular dilatation and pericardial effusion, either in the emergency department or by students/residents in the intensive care or internal medicine wards [4,11,12,14,15,36].

The easier operation of small devices does not obviate the need for training to acquire and interpret cardiac images. As outlined in the European Society of Cardiology (ESC) statement, there are different degrees of expertise among pocket-echocardiography users that perform FCU

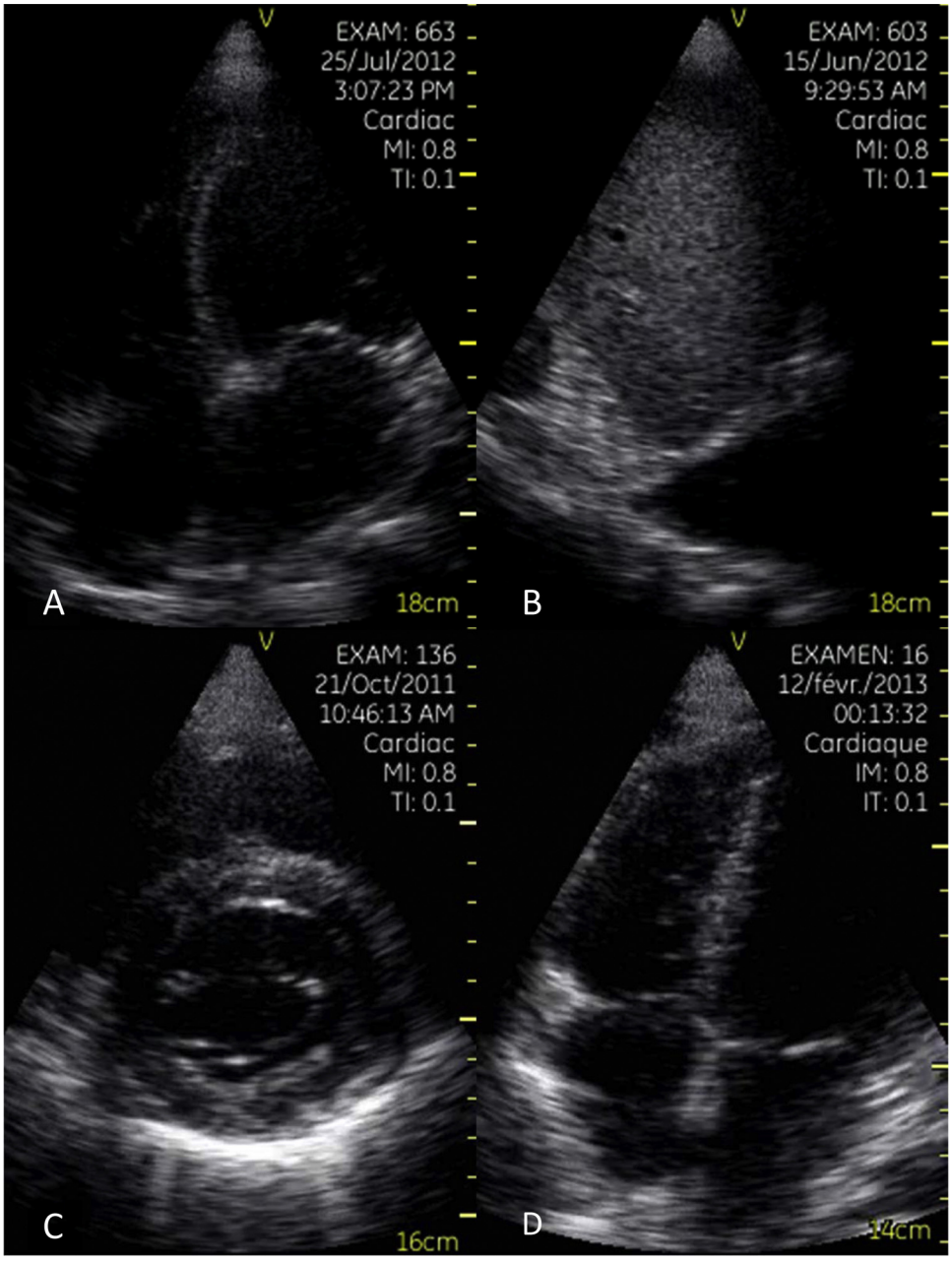


**Figure 1.** Images acquired in patients admitted with breathlessness showing (A) left ventricular dilatation, (B) pleural effusion, (C) hypertrophic cardiomyopathy, and (D) normal FCU. FCU: focused cardiac ultrasound.

[37], with a significant impact on the accuracy of diagnosis. In contrast to FCU, emergency echocardiography is defined as a fully comprehensive examination and should require training according to the ESC curriculum (i.e. a minimum of 150 supervised scans) [38]. Training programmes for FCU range from 2 h to over 3 months [4,6,36,39,40]. It is important to note that even cardiology fellows are not proficient if no specific training is provided [19]. However, the accuracy of FCU by residents increases over time, provided education is pursued [41]. Trainees' proficiency may also vary in different settings. Charron et al. recently showed that FCU used by non-experts after a 2-day training scheme is suboptimal in emergency settings [40], but this contradicts a previous report [42]. National guidelines have issued requirements in the curriculum of non-cardiologists for FCU [43]. Some universities have already integrated FCU into their critical care and internal medicine training programmes [44,45]. However, no study has yet specifically addressed the comparison of educational programmes for FCU and the recent position paper from the ESC does not provide any specific training guidelines [46].

## Devices and their accuracy

Instruments for FCU have been miniaturized to improve portability for use at the bedside. The compromise of smaller devices is loss of features, particularly

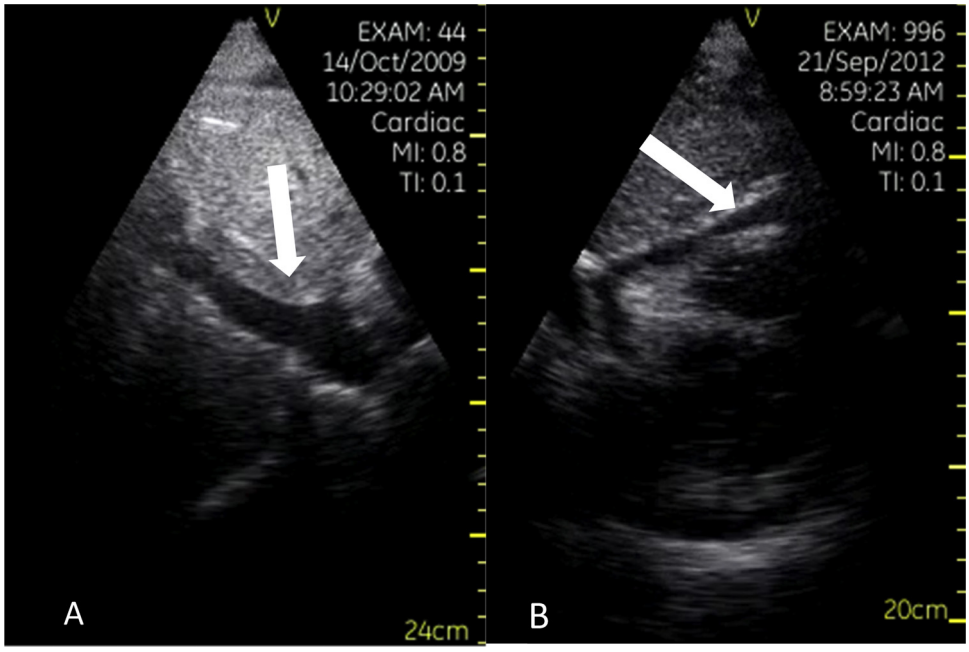


**Figure 2.** Images acquired in patients with circulatory failure — subcostal view — showing (A) normal inferior vena cava diameter (arrow) and (B) pericardial effusion (arrow).

cardiac-applicable spectral Doppler, tissue Doppler, strain and three-dimensional imaging.

There are currently four pocket-echo machines available on the market: Acuson P10™ (Siemens, Mountain View, CA, USA); Vscan V1.2 (GE Healthcare, Milwaukee, WI, USA); MobiUS™ SP1 (MobiSante, Redmond, WA, USA); and SignosRT (Signostics, Thebarton, Australia). Characteristics and capabilities of these devices are summarized in Table 2. To date, all published studies have tested either Acuson P10™ or Vscan V1.2 machines. Briefly, both devices are switched on by lifting the hinged display and include depth and gain controls. The Acuson P10 has tissue greyscale harmonic imaging but provides no colour Doppler. The Vscan V1.2 device has a dual probe that enables cardiac imaging and vascular Doppler.

Although pocket-echocardiography cannot yield the same image quality as more sophisticated machines, it has been assessed as ''good'' in most patients [13,17,47]. Left heart

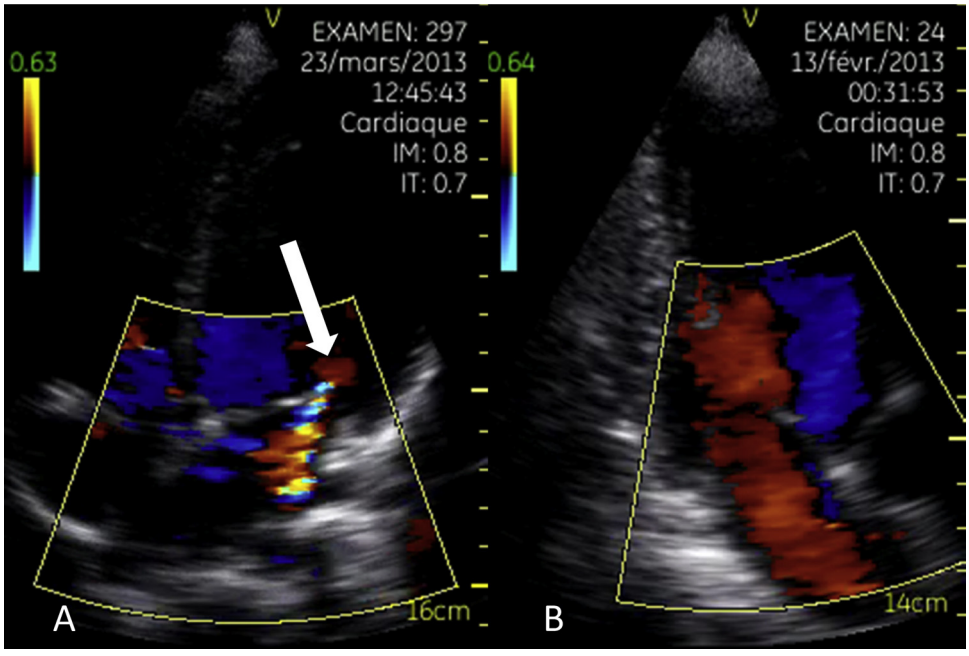


**Figure 3.** Images acquired in patients referred for a murmur in the outpatient's clinic showing (A) pathological mitral regurgitation (arrow) and (B) normal FCU with no valve disease on colour Doppler. FCU: focused cardiac ultrasound.

**Table 2** Summary of the technical characteristics of the four commercially available pocket-echo devices for FCU.

| | Acuson P10™ | Vscan V1.2 | MobiUS™ SP1 | SignosRT |
|---|---|---|---|---|
| |  |  |  |  |
| Company | Siemens | GE Healthcare | MobiSante | Signostics |
| Size[a] (cm) | 5.4 × 9.7 × 14.2 | 13.5 × 7.3 × 2.8 | 13 × 7 × 0.99 | 11.5 × 15 × 6 |
| Total weight (g) | 725 | 390 | 329 | 304 |
| Transducer (MHz) | 2—4 | 1.7—3.8 | 3.5—5.0 | 3.0—5.0 |
| Screen dimension (cm) | 9.4 | 8.9 | 8.0 | 11.5 |
| Image resolution (pixels) | 640 × 480 | 240 × 320 | 480 × 480 | 250 (M-Mode) |
| Grey scale | Yes | Yes | Yes | Yes |
| Colour Doppler | No | Yes | No | No |
| Measurements | Distance, area | Distance | — | Distance, area, circumference, volume |
| Digital storage | Still frames | Still frames, loop, voice recording | Loop | Still frames, patient ID |
| Means to download to a PC | Specific software | 4 GB microSD card | USB sync | 4 GB microSD card |
| M-Mode | No | No | No | Yes |
| Continuous/pulsed Doppler | No/No | No/No | No/No | No/Yes |
| Battery, scanning time (min) | 60 | 90 | 60—330 | 48 |
| Price[b] (USD/€) | 8100/6508 | 8410/6760 | — | 7995/— |

FCU: focused cardiac ultrasound; ID: identification; PC: personal computer; SD: secure digital; USB: universal serial bus; USD: United States dollars.

[a] Includes the largest size of each component, as ultrasound probe, display unit or touch screen if available.

[b] The commercial prices of MobiUS™ SP1 and SignosRT devices are not available in the European zone. The SignosRT price is available in the US.

dimensions measured with Acuson P10™ and Vscan V1.2 devices are accurate when compared to high-end echocardiography performed by experienced cardiologists [13,48]. Exportation of images to a full-size screen does not improve the accuracy of measurements or diagnosis, and real-time interpretation increases efficiency [16]. There has been no peer-reviewed published evidence to date assessing the image quality of MobiUS™ SP1 or SignosRT (according to a systematic search of PubMed and Embase).

## Advantages, limitations and perspectives of FCU by pocket-echocardiography

Pocket-echocardiography is convenient for daily practice. It is readily available and protocols of image acquisition only take 2—5 min [3,8,11,49]. Pocket-echocardiography allows for immediate diagnosis as the same person acquires and interprets the images. The systematic use of pocket-echocardiography for FCU may be cost effective [50]; and the workflow of sonographers and cardiologists could be improved by the use of pocket-echocardiography [18,51]. Use of FCU may also reduce length of stay in patients admitted for heart failure [52]. However, there are two main issues that have limited the widespread use of pocket-echocardiography. Firstly, the lack of reimbursement by social security systems in different countries may have played a role. Secondly, legal responsibility of FCU has not been clearly defined, as FCU is not 100% accurate and will not replace comprehensive echocardiography nor will it detect incidental abnormalities that could impact on patient prognosis. Setting training requirements and certification in FCU would probably — at least partly — address these issues.

Pocket-echocardiography may also emerge as a potential screening tool for population-based surveillance programmes or in specific target groups [53]. Rheumatic heart disease is a potentially preventable disease in low-income countries and echocardiography based active surveillance has emerged as a potential alternative to cardiac auscultation [54—58]. Also, systematic screening for hypertrophic cardiomyopathy (Fig. 1C) in young athletes by FCU performed by sports medicine physicians may be an attractive solution for the possible prevention of sudden death [59].

## Conclusions

FCU is an emerging field that may be enhanced by the use of pocket-echocardiography. There is now sufficient evidence to support its use by experts, provided the questions are circumscribed and within the technical capacities of the device. Non-experts may also accurately answer a number of simple questions that may impact on patient care. Awareness of the technical limitations of these devices, validation of standardized training schemes, evaluation of accuracy of diagnoses and cost-effectiveness are pivotal issues in determining the future of FCU by pocket-echocardiography.

## Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

## References

[1] Moore CL, Copel JA. Point-of-care ultrasonography. New Engl J Med 2011;364:749—57.
[2] Kimura BJ, Demaria AN. Empowering physical examination: the ''laying on'' of ultrasound. JACC Cardiovasc Imaging 2008;1:602—4.
[3] Cardim N, Fernandez Golfin C, Ferreira D, et al. Usefulness of a new miniaturized echocardiographic system in outpatient cardiology consultations as an extension of physical examination. J Am Soc Echocardiogr 2011;24:117—24.
[4] Galderisi M, Santoro A, Versiero M, et al. Improved cardiovascular diagnostic accuracy by pocket-size imaging device in non-cardiologic outpatients: the NaUSiCa (Naples Ultrasound Stethoscope in Cardiology) study. Cardiovasc Ultrasound 2010;8:51.
[5] Mjolstad OC, Dalen H, Graven T, et al. Routinely adding ultrasound examinations by pocket-sized ultrasound devices improves inpatient diagnostics in a medical department. Eur J Intern Med 2012;23:185—91.
[6] Panoulas VF, Daigeler AL, Malaweera AS, et al. Pocket-size hand-held cardiac ultrasound as an adjunct to clinical examination in the hands of medical students and junior doctors. Eur Heart J Cardiovasc Imaging 2013;14:323—30.
[7] Shmueli H, Burstein Y, Sagy I, et al. Briefly trained medical students can effectively identify rheumatic mitral valve injury using a hand-carried ultrasound. Echocardiography 2013;30:621—6.
[8] Skjetne K, Graven T, Haugen BO, et al. Diagnostic influence of cardiovascular screening by pocket-size ultrasound in a cardiac unit. Eur J Echocardiogr 2011;12:737—43.
[9] Spencer KT, Kimura BJ, Korcarz CE, et al. Focused cardiac ultrasound: recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr 2013;26:567—81.
[10] Andersen GN, Haugen BO, Graven T, et al. Feasibility and reliability of point-of-care pocket-sized echocardiography. Eur J Echocardiogr 2011;12:665—70.
[11] Biais M, Carrie C, Delaunay F, et al. Evaluation of a new pocket-echoscopic device for focused cardiac ultrasonography in an emergency setting. Crit Care 2012;16:R82.
[12] Razi R, Estrada JR, Doll J, Spencer KT. Bedside hand-carried ultrasound by internal medicine residents versus traditional clinical assessment for the identification of systolic dysfunction in patients admitted with decompensated heart failure. J Am Soc Echocardiogr 2011;24:1319—24.
[13] Prinz C, Dohrmann J, van Buuren F, et al. Diagnostic performance of hand-held echocardiography for the assessment of basic cardiac morphology and function: a validation study in routine cardiac patients. Echocardiography 2012;29:887—94.
[14] Mjolstad OC, Andersen GN, Dalen H, et al. Feasibility and reliability of point-of-care pocket-size echocardiography performed by medical residents. Eur Heart J Cardiovasc Imaging 2013;14:1195—202.
[15] Liebo MJ, Israel RL, Lillie EO, et al. Is pocket mobile echocardiography the next-generation stethoscope? A cross-sectional comparison of rapidly acquired images with standard transthoracic echocardiography. Ann Intern Med 2011;155:33—8.
[16] Testuz A, Muller H, Keller PF, et al. Diagnostic accuracy of pocket-size hand-held echocardiographs used by cardiologists in the acute care setting. Eur Heart J Cardiovasc Imaging 2013;14:38—42.
[17] Prinz C, Voigt JU. Diagnostic accuracy of a hand-held ultrasound scanner in routine patients referred for echocardiography. J Am Soc Echocardiogr 2011;24:111—6.
[18] Reant P, Dijos M, Arsac F, et al. Validation of a new bedside echoscopic heart examination resulting in an improvement in echo-lab workflow. Arch Cardiovasc Dis 2011;104:171—7.

[19] Giusca S, Jurcut R, Ticulescu R, et al. Accuracy of hand-held echocardiography for bedside diagnostic evaluation in a tertiary cardiology center: comparison with standard echocardiography. Echocardiography 2011;28:136—41.
[20] Penicka M, Vanderheyden M, Bartunek J. Diagnosis of heart failure with preserved ejection fraction: role of clinical Doppler echocardiography. Heart 2014;100:68—76.
[21] Gargani L. Lung ultrasound: a new tool for the cardiologist. Cardiovasc Ultrasound 2011;9:6.
[22] Mai TV, Shaw DJ, Amundson SA, Agan DL, Kimura BJ. Learning to apply the pocket ultrasound device on the critically ill: comparing six ''quick-look'' signs for quality and prognostic values during initial use by novices. Crit Care 2013;17:448.
[23] Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med 2012;38:577—91.
[24] Goonewardena SN, Gemignani A, Ronan A, et al. Comparison of hand-carried ultrasound assessment of the inferior vena cava and *N*-terminal pro-brain natriuretic peptide for predicting readmission after hospitalization for acute decompensated heart failure. JACC Cardiovasc Imaging 2008;1:595—601.
[25] Yavasi O, Unluer EE, Kayayurt K, et al. Monitoring the response to treatment of acute heart failure patients by ultrasonographic inferior vena cava collapsibility index. Am J Emerg Med 2014;32:403—7.
[26] Tchernodrinski S, Lucas BP, Athavale A, et al. Inferior vena cava diameter change after intravenous furosemide in patients diagnosed with acute decompensated heart failure. J Clin Ultrasound 2014, http://dx.doi.org/10.1002/jcu.22173 [Epub ahead of print].
[27] Lafitte S, Alimazighi N, Reant P, et al. Validation of the smallest pocket-echoscopic device's diagnostic capabilities in heart investigation. Ultrasound Med Biol 2011;37:798—804.
[28] Gianstefani S, Catibog N, Whittaker AR, et al. Pocket-size imaging device: effectiveness for ward-based transthoracic studies. Eur Heart J Cardiovasc Imaging 2013;14:1132—9.
[29] Arden C, Chambers JB, Sandoe J, et al. Can we improve the detection of heart valve disease? Heart 2014;100:271—3.
[30] Abe Y, Ito M, Tanaka C, et al. A novel and simple method using pocket-sized echocardiography to screen for aortic stenosis. J Am Soc Echocardiogr 2013;26:589—96.
[31] Mansencal N, Vieillard-Baron A, Beauchet A, et al. Triage patients with suspected pulmonary embolism in the emergency department using a portable ultrasound device. Echocardiography 2008;25:451—6.
[32] Dijos M, Pucheux Y, Lafitte M, et al. Fast track echo of abdominal aortic aneurysm using a real pocket ultrasound device at bedside. Echocardiography 2012;29:285—90.
[33] Bonnafy T, Lacroix P, Desormais I, et al. Reliability of the measurement of the abdominal aortic diameter by novice operators using a pocket-sized ultrasound system. Arch Cardiovasc Dis 2013;106:644—50.
[34] Haji DL, Royse A, Royse CF. Review article: clinical impact of non-cardiologist-performed transthoracic echocardiography in emergency medicine, intensive care medicine and anaesthesia. Emerg Med Australas 2013;25:4—12.
[35] Kimura BJ, Yogo N, O'Connell CW, et al. Cardiopulmonary limited ultrasound examination for ''quick-look'' bedside application. Am J Cardiol 2011;108:586—90.
[36] Vignon P, Dugard A, Abraham J, et al. Focused training for goal-oriented hand-held echocardiography performed by non-cardiologist residents in the intensive care unit. Intensive Care Med 2007;33:1795—9.
[37] Sicari R, Galderisi M, Voigt JU, et al. The use of pocket-size imaging devices: a position statement of the European Association of Echocardiography. Eur J Echocardiogr 2011;12:85—7.
[38] Neskovic AN, Hagendorff A, Lancellotti P, et al. Emergency echocardiography: the European Association of Cardiovascular Imaging recommendations. Eur Heart J Cardiovasc Imaging 2013;14:1—11.
[39] Stokke TM, Ruddox V, Sarvari SI, et al. Brief group training of medical students in focused cardiac ultrasound may improve diagnostic accuracy of physical examination. J Am Soc Echocardiogr 2014;27:1238—46.
[40] Charron C, Templier F, Goddet NS, Baer M, Vieillard-Baron A. Difficulties encountered by physicians in interpreting focused echocardiography using a pocket ultrasound machine in prehospital emergencies. Eur J Emerg Med 2015;22:17—22.
[41] Prinz C, Dohrmann J, van Buuren F, et al. The importance of training in echocardiography: a validation study using pocket-echocardiography. J Cardiovasc Med (Hagerstown) 2012;13:700—7.
[42] Jensen MB, Sloth E, Larsen KM, Schmidt MB. Transthoracic echocardiography for cardiopulmonary monitoring in intensive care. Eur J Anaesthesiol 2004;21:700—7.
[43] Pelliccia F, Palmiero P, Maiello M, Losi MA. Italian Chapter of the International Society of Cardiovascular U. Italian chapter of the International Society of cardiovascular ultrasound expert consensus document on training requirements for non-cardiologists using hand-carried ultrasound devices. Echocardiography 2012;29:745—50.
[44] Beraud AS, Rizk NW, Pearl RG, Liang DH, Patterson AJ. Focused transthoracic echocardiography during critical care medicine training: curriculum implementation and evaluation of proficiency*. Crit Care Med 2013;41:e179—E181.
[45] Solomon SD, Saldana F. Point-of-care ultrasound in medical education—stop listening and look. N Engl J Med 2014;370:1083—5.
[46] Neskovic AN, Edvardsen T, Galderisi M, et al. Focus cardiac ultrasound: the European Association of Cardiovascular Imaging viewpoint. Eur Heart J Cardiovasc Imaging 2014;15:956—60.
[47] Culp BC, Mock JD, Chiles CD, Culp Jr WC. The pocket-echocardiograph: validation and feasibility. Echocardiography 2010;27:759—64.
[48] Fukuda S, Shimada K, Kawasaki T, et al. Pocket-sized transthoracic echocardiography device for the measurement of cardiac chamber size and function. Circ J 2009;73:1092—6.
[49] Frederiksen CA, Juhl-Olsen P, Larsen UT, et al. New pocket-echocardiography device is interchangeable with high-end portable system when performed by experienced examiners. Acta Anaesthesiol Scand 2010;54:1217—23.
[50] Kitada R, Fukuda S, Watanabe H, et al. Diagnostic accuracy and cost-effectiveness of a pocket-sized transthoracic echocardiographic imaging device. Clin Cardiol 2013;36:603—10.
[51] Badano LP, Nucifora G, Stacul S, et al. Improved workflow, sonographer productivity, and cost-effectiveness of echocardiographic service for inpatients by using miniaturized systems. Eur J Echocardiogr 2009;10:537—42.
[52] Lucas BP, Candotti C, Margeta B, et al. Hand-carried echocardiography by hospitalists: a randomized trial. Am J Med 2011;124:766—74.
[53] Celermajer DS, Chow CK, Marijon E, Anstey NM, Woo KS. Cardiovascular disease in the developing world: prevalences, patterns, and the potential of early disease detection. J Am Coll Cardiol 2012;60:1207—16.
[54] Marijon E, Mirabel M, Celermajer DS, Jouven X. Rheumatic heart disease. Lancet 2012;379:953—64.
[55] Marijon E, Ou P, Celermajer DS, et al. Prevalence of rheumatic heart disease detected by echocardiographic screening. New Engl J Med 2007;357:470—6.
[56] Beaton A, Aliku T, Okello E, et al. The utility of hand-held echocardiography for early diagnosis of rheumatic heart disease. J Am Soc Echocardiogr 2014;27(1):42—9.

[57] Mirabel M, Bacquelin R, Tafflet M, et al. Screening for rheumatic heart disease: evaluation of a focused cardiac ultrasound approach. Circ Cardiovasc Imaging 2015;8(1), http://dx.doi.org/10.1161/CIRCIMAGING.114.002324 [pii: e002324].

[58] Beaton A, Lu JC, Aliku T, et al. The utility of hand-held echocardiography for early rheumatic heart disease diagnosis: a field study. Eur Heart J Cardiovasc Imaging 2015 [pii: jeu296 (Epub ahead of print)].

[59] Yim ES, Gillis EF, Ojala K, et al. Focused transthoracic echocardiography by sports medicine physicians: measurements relevant to hypertrophic cardiomyopathy. J Ultrasound Med 2013;32:333—8.