



Focus cardiac ultrasound: the European Association of Cardiovascular Imaging viewpoint

Aleksandar N. Neskovic^{1*}, Thor Edvardsen², Maurizio Galderisi³, Madalina Garbi⁴, Giuseppe Gullace⁵, Ruxandra Jurcut⁶, Havard Dalen^{7,8}, Andreas Hagendorff⁹, and Patrizio Lancellotti¹⁰, for the European Association of Cardiovascular Imaging Document Reviewers: Bogdan A. Popescu, Rosa Sicari and Alexander Stefanidis

¹Clinical Hospital Center Zemun, Faculty of Medicine, University of Belgrade, Belgrade, Serbia; ²Department of Cardiology, Oslo University Hospital and University of Oslo, Oslo, Norway; ³Department of Translational Medical Sciences, Federico II University Hospital, Naples, Italy; ⁴King's Health Partners, King's College Hospital NHS Foundation Trust, London, UK; ⁵Cardiovascular Department of Azienda Ospedaliera della Provincia di Lecco, Lecco, Italy; ⁶Department of Cardiology, University of Medicine and Pharmacy 'Carol Davila', Emergency Institute of Cardiovascular Diseases, Bucharest, Romania; ⁷MI Lab and Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, Trondheim, Norway; ⁸Department of Internal Medicine, Levanger Hospital, Nord-Trøndelag Health Trust, Levanger, Norway; ⁹Department of Cardiology-Angiology, University of Leipzig, Leipzig, Germany; and ¹⁰Department of Cardiology, University of Liège Hospital, GIGA Cardiovascular Sciences, Heart Valve Clinic, CHU Sart Tilman, Liège, Belgium

Received 6 April 2014; accepted after revision 10 April 2014

The concept of point-of-care, problem-oriented focus cardiac ultrasound examination (FoCUS) is increasingly applied in the settings of medical emergencies, including cardiac diseases. The European Association of Cardiovascular Imaging (EACVI) recognizes that cardiologists are not the only medical professionals dealing with cardiovascular emergencies. In reality, emergency cardiac diagnostics and treatment are also carried out by a wide range of specialists. For the benefit of the patients, the EACVI encourages any medical professional, sufficiently trained to obtain valuable information from FoCUS, to use it in emergency settings. These medical professionals need to have the necessary knowledge to understand the obtained information entirely, and to use it correctly, thoughtfully and with care. In this document, the EACVI underlines major differences between echocardiography and FoCUS, and underscores the need for specific education and training in order to fully utilize advantages and minimize drawbacks of this type of cardiac ultrasound examination in the critically ill patients.

Keywords EACVI • Viewpoint • Focus cardiac • Ultrasound

“Truth is one, paths are many” - Mahatma Gandhi

“The truth is rarely pure, and never simple” - Oscar Wilde

Introduction

There is a trend of rapidly growing use of echocardiography in emergency settings by non-cardiologists or cardiologists without specific expertise. Therefore, the European Association of Cardiovascular Imaging (EACVI) has been urged to address this important issue and set the standards for adequate education and training, for the safe and efficient use of echocardiography in emergency care.¹ It has been recognized that performing echocardiographic examinations in emergency situations is challenging and that both interpretation errors and missed findings are likely to occur more frequently. Consequently, the position of the EACVI is that the level of competence in echocardiography required for emergency cases is at least the

same as for elective cases. Accordingly, the EACVI recommended competence requirements for emergency echocardiography are the same for cardiologists and non-cardiologists, i.e. anaesthesiologists, emergency physicians, intensive care specialists, cardiac surgeons, cardiac physiologists (individuals owing a cardiac physiology degree and subsequent appropriate echocardiography training and certification, working in team with cardiologists and cardiac surgeons). It was proposed that non-cardiologists should reach the same level of expertise through a training programme similar with the training programme for general cardiologists, with additional theoretical learning on certain cardiovascular diseases/conditions.¹

We are also witnessing an evolving trend of using cardiac ultrasound examination as a bedside, point-of-care diagnostic test in emergency settings, examination named ‘Focus Cardiac Ultrasound’ (FoCUS).

Current EACVI recommendations refer to emergency echocardiography and not to FoCUS.¹ Therefore, the EACVI, as the reference

* Corresponding author. Tel: +381 641216359; Fax: +381 112107057, Email: neskovic@hotmail.com

Published on behalf of the European Society of Cardiology. All rights reserved. © The Author 2014. For permissions please email: Journals.permissions@oup.com.

European echocardiographic community representative, should briefly address this issue.

Of note, this document is not a systematic review of current FoCUS practice.

Purpose

The purpose of this document is to outline the position of the EACVI on the use of FoCUS in the emergency settings, to underline major differences between echocardiography and FoCUS, and to reinforce the need for specific education and training in order to fully utilize advantages and minimize drawbacks of this type of cardiac ultrasound examination in the critically ill patients.

Terminology

Echocardiography is a comprehensive investigation, requiring maximum technical skills along with expertise in cardiovascular pathophysiology and cardiovascular diseases. Thus, the term *echocardiography* refers to comprehensive standard echocardiography in emergency settings, i.e. emergency echocardiography, which always represents a full echocardiographic investigation of cardiac morphology and function, using fully equipped echocardiographic machines, performed by a sufficiently trained operator who is able to independently perform and interpret the study.¹

The term *FoCUS* defines the point-of-care cardiac ultrasound examination, performed according to standardized but restricted scanning protocol to add information to the physical examination, by an operator not necessarily fully trained in echocardiography but appropriately trained in FoCUS, who is at the same time usually responsible for immediate decision-making and/or treatment.^{2,3}

Both cardiologists and non-cardiologists can perform either echocardiography examinations or FoCUS, depending on clinical circumstances, existing equipment, and expertise. FoCUS is typically used by non-cardiologists who underwent minimal training, but can also be performed by fully trained cardiologists or cardiac physiologists in emergency settings.

Imaging devices

The whole spectrum of echocardiographic machines, from high-end, fully equipped platforms to pocket-size imaging devices, can be used for FoCUS.

However, due to logistics as well as to the narrow scope of the FoCUS examinations, smaller, especially hand-held and pocket-size imaging devices are used more frequently. Current pocket-size imaging devices offer diagnostic-quality two-dimensional and, in part, colour Doppler cardiac imaging in real-time providing the ability to measure only linear dimensions.⁴ The small size makes them attractive for all operators performing FoCUS examinations. Purely, qualitative assessment performed with pocket-size imaging devices has demonstrated good level of diagnostic accuracy for both experienced and non-experienced operators.^{5–8} However, it should be acknowledged that image quality is generally inferior when compared with high-end systems, and that this might be particularly important in difficult patients, resulting in technically suboptimal studies, leading to less reliable findings.^{4,6,9–11} The operator must be fully aware of these

technical limitations and examinations performed with pocket-size imaging devices must be only reported as a complement to physical examination, and not as a complete echocardiogram.⁴

Expectations and limitations of the FoCUS

The crucial difference between echocardiography and FoCUS in emergency settings, with the assumption that both are performed and interpreted in a competent manner, is the amount of information obtained. FoCUS examination provides sufficient information for mostly qualitative gross assessment of cardiac morphology and function, reported as 'absent/present', or 'yes/no' (i.e. qualitative assessment). Being an inherently limited approach, FoCUS examination carries additional risks of overlooking important abnormalities and of false readings of an incomplete dataset. Although these types of errors could certainly occur also during echocardiography, their expected rates might be considerably higher for the FoCUS, and can be especially high in situations where the operators are not fully trained in echocardiography and/or cardiology.¹ It should be emphasized that failure to appreciate the limitations of the FoCUS (Table 1) may lead to serious misinterpretation of the findings with potentially devastating clinical consequences. Recognition of these limitations, therefore, must be incorporated in any training protocol for the FoCUS.

Finally, a FoCUS operator should not overestimate his own expertise and need to refer the patient to echocardiographic examination whenever possible, particularly in situations in which FoCUS, although diagnostic, is not sufficient for accurate decision-making.

Education and training frame

The concept of point-of-care, problem-oriented FoCUS examination has been actively promoted by different professional organizations,^{12–14} with a number of initiatives aiming to set up, standardize and support education and training, and to facilitate research related to the application of this concept in in- and out-of-the-hospital emergency situations, including cardiac emergencies.

Increasing interest among a wide range of physicians of different specialities involved in managing patients in emergency settings has

Table 1 Clinically relevant limitations of the FoCUS when compared with comprehensive echocardiography

1. Technical inferiority of the imaging devices typically used for FoCUS examination compared with fully equipped high-end echocardiographic machines
2. Limited skills and experience of the operators
3. Typically unfavourable settings (emergencies, critically ill, time constraints)
4. Narrow list of detectable evidence-based targets
5. 'Absent/Present' or 'Yes/No' reporting style (related to 1–4)
6. Subtle/complex cardiac abnormalities (i.e. regional asynergy) difficult to assess (related to 1–4)

been driven further by the availability of high-quality small or pocket-size imaging devices. On the other hand, there is an obvious shortage of cardiologists fully trained in echocardiography at all locations where medical emergencies occur. Therefore, we believe that the EACVI should encourage any medical professional, sufficiently trained to obtain valuable information from FoCUS, to use it in emergency settings. Thus, all attempts at individual or professional organization levels, aiming to narrow this existing logistic gap between obvious needs and available human resources are praised by the EACVI.

The EACVI recognizes that cardiologists are not the only medical professionals dealing with cardiovascular emergencies.¹ In reality, emergency cardiac diagnostics and treatment are also carried out by wide range of specialists, including emergency physicians, intensive care specialists, anaesthesiologists, and cardiac surgeons. In addition, in life-threatening scenarios, fellows in training in respective specialties and even sonographers/cardiac physiologists can find themselves in need of performing cardiac ultrasound scanning in an attempt to obtain essential diagnostic information.

There are undisputable differences between existing educational and training programmes for emergency echocardiography¹ and FoCUS.^{12,15–21} The differences are substantial, not only with regard to content and duration of echocardiographic training,^{1,22–25} but also to specific content on emergency cardiovascular disease for non-cardiologists. A variety of non-cardiology specialists perform FoCUS in a variety of specific emergency situations within specific patient populations. Being predominantly responsible for developing education and training programmes for echocardiography,^{1,22–25} the EACVI is not primarily in charge with the development and running of FoCUS educational and training programmes. The key responsibility for this lies in the hands of clinician's/operator's respective speciality organizations and/or scientific bodies, which are fully aware of respective speciality-specific FoCUS use circumstances.

Currently, a variety of recommendations, statements, and protocols for education and training in FoCUS provided by respective societies/organizations exists.^{2,3,12–21,26,27} Teaching courses for FoCUS in emergency or critical care situations have been developed in order to qualify individuals, after short, intensive and narrow scope-oriented training^{28,29} meant to allow them to identify basic but critical cardiac conditions and pathologies (Table 2). Studies have shown that these findings may beneficially modify patient management,^{30–41} and predict outcome.^{42,43,44,45,46} We believe that further expansion of the list of teaching and training targets for FoCUS (i.e. valvular abnormalities, intracardiac masses, regional wall motion analysis) would be associated with an increased risk of improper use and errors.⁸ Assessment of these conditions in the vast majority of cases requires significantly higher level of expertise and should indicate referral for echocardiographic evaluation.

Recently, the EACVI has provided a list of emergency cardiovascular diseases/conditions to be included in additional learning programmes for non-cardiologists in training on emergency echocardiography.¹ We believe that this list should be incorporated in the theoretical/didactic part of the FoCUS training programmes for non-cardiologists. To which extent the listed conditions¹ will be addressed in particular training programmes for FoCUS should be decided by each respective speciality responsible for running the programme. Such specific theoretical knowledge will aid physicians

Table 2 Evidence-based targets of FoCUS examination and related emergency cardiovascular scenarios/conditions that might be addressed

Targets
Global LV systolic function and size
Global RV systolic function and size
Pericardial effusion
Intravascular volume assessment
Scenarios
Circulatory compromise/shock
Cardiac arrest
Chest pain
Chest/cardiac trauma
Respiratory compromise
Conditions
Ischaemic LV/RV Dysfunction
Cardiomyopathies (i.e. DCM, HCM, Takotsubo)
Myocarditis
Cardiac tamponade
Pulmonary embolism
Hypovolaemia

DCM, dilated cardiomyopathy; HCM, hypertrophic cardiomyopathy; LV, left ventricular; RV, right ventricular.

who perform the FoCUS to integrate cardiac ultrasound findings in clinical context, for the best possible patient management.

Knowing the complexity of the topic and diversity of medical professionals who undergo training in FoCUS, it seems unlikely that strictly predefined minimal number of hours of hands-on image acquisition training or the number of personally performed and/or interpreted cases, would ever fit for all. The available literature clearly reflects this diversity.^{2,3,12–21} However, since the competency in FoCUS should be the minimal net result of the training process, the number of required hours/studies might be adjusted for each trainee according to the results of the competency evaluation incorporated into the ongoing training process. General tools for the assessment of competency in FoCUS currently do not exist and each respective speciality should be encouraged to work on defining and implementing them in the training process.

It appears logical to recommend that a significant number of FoCUS examinations should be performed with the same imaging device and under similar real-life clinical scenarios as for the ones encountered when using FoCUS,³ instead of practising on stable patients using fully equipped echocardiographic machines. This is very important, since higher technical skills may be needed for optimal image acquisition in unfavourable emergency settings comparing to echo scanning in stable, elective conditions.¹

It is also important that the case mix of performed FoCUS examinations during the training process covers the full range of critical/life-saving scenarios representative for the trainee's scope of practice.

Finally, we recommend that FoCUS training programmes ensure that the operators are aware of their own capacity and limitations, given the specific equipment and different situations. Only in this

way, it is ensured that FoCUS can improve diagnostics. The use of FoCUS or simplified ultrasound devices should never deprive the patient of the opportunity of a better diagnostic test.

Supervision, quality control, echocardiographic service

Considering all features of FoCUS, referral for echocardiographic examination must follow FoCUS as soon as possible, in all cases with abnormal findings or non-diagnostic studies, and continuous supervision and quality control are essential. Established emergency echocardiography service in the hospital¹ may provide professional, educational, and training support for non-cardiologists performing FoCUS, through 24 h availability of second opinion/consultative or on-call service, team work (professional help, consultations, regular reviewing of cases), and continuous supervision. Accredited echocardiography laboratories should preferably be the hub for quality control and supervision, where FoCUS cases should be reviewed, re-evaluated, and discussed together with fully trained and/or expert cardiologists.

Reporting and storage

As recommended for emergency echocardiography,¹ FoCUS examination should be well and retrievably stored, including both the report and the acquired images/cine-loops. These data should be stored permanently to be used for case reviews, consultations, quality control purpose, and as evidence of findings in acute setting for medico-legal purposes.

Since the time available to elaborate a FoCUS examination report may be extremely brief, a concise report (written and/or verbal), concentrating on critical findings and integrated into the decision-making process may be issued. However, this must be followed by a final written report, interpreted, approved, and signed by the operators with adequate formal education.

Co-operation

Both reference echocardiography community representatives and respective speciality societies/organizations currently involved in FoCUS educational and training activities have the common aim to expand and improve cardiac ultrasound examination practice for the benefit of patients. Although approaches and proposed standards to reach this aim may not always be the same, differences should be debated and positions harmonized whenever possible.

The EACVI position is that all current and future activities related to FoCUS should be done in close co-operation between respective speciality societies/organizations already engaged in FoCUS educational and training activities, and the reference echocardiography community representatives. This could be done by means of preparing recommendations and consensus documents,^{2,3} endorsing documents, adjusting educational and training programmes, running research projects, and organizing joint professional and scientific meetings.

This approach would certainly provide the *milieu* for true partnership and the basis for future developments in the field.

Table 3 Summary of the EACVI viewpoint on FoCUS

FoCUS should only be used as a point-of-care cardiac ultrasound examination, aimed to detect limited number of critical cardiac conditions
FoCUS may provide key clinical information regarding the presence of pericardial effusion/cardiac tamponade, left and right ventricular size and function, intravascular volume status, and may aid decision-making during cardiopulmonary resuscitation
FoCUS should never be considered or reported as echocardiographic examination
Educational curriculum and training programme for FoCUS should be designed and conducted by the specialty professional organizations/societies involved in treating medical emergencies, including cardiac, with continual collaboration with reference echocardiographic communities
FoCUS should only be used by the operators who have completed appropriate education and training programme, and who fully understand and respect its scope and limitations
All patients with cardiovascular abnormalities detected by FoCUS should be referred to echocardiographic examination as soon as appropriate
If the underlying cardiovascular disease could not be definitively ruled out in critically ill by FoCUS, echocardiography should be considered
FoCUS examinations should be recorded and permanently stored and reports issued in a timely manner
Continual supervision and quality control of the FoCUS examinations are essential, provided preferably by accredited echocardiographic laboratories and emergency echocardiography services
Reference echocardiographic community representatives should actively follow developments in the field and, whenever appropriate, work on improving educational and training curricula in concert with respective specialities professional societies/organizations, to deliver the best possible care for the patients

Conclusions

The viewpoint of the EACVI on FoCUS is summarized in Table 3. The EACVI fully acknowledges the efforts and achievements of individuals and professional organizations that dedicate their activities to improve emergency cardiac care using point-of-care FoCUS. At the same time, the EACVI believes that only full implementation of education and training requirements for all professionals performing FoCUS, will secure the accuracy and quality of the information obtained with cardiac ultrasound in emergency settings. These requirements should be defined by the respective specialty professional organizations/regulatory bodies in collaboration with the reference echocardiography community representatives.

The EACVI promotes and strongly supports systematic training in echocardiography and emergency echocardiography, as a general pre-requisite for full competence in collecting high-quality information with cardiac ultrasound and, consequently, optimal patient management.

For critically ill patients, it is not important whether the life-saving information is acquired by non-cardiologist performing FoCUS, or by the expert cardiologist performing echocardiography. When such information is available, it has to be used. However, for the benefit of the patients, the involved medical professionals should have the

necessary knowledge to understand the obtained information entirely, and to use it correctly, thoughtfully and with care.

Conflict of interest: none declared.

References

- Neskovic AN, Hagendorff A, Lancellotti P, Guarracino F, Varga A, Cosyns B *et al*. Emergency echocardiography: the European Association of Cardiovascular Imaging recommendations. *Eur Heart J Cardiovasc Imaging* 2013;**14**:1–11.
- Labovitz AJ, Noble VE, Bierig M, Goldstein SA, Jones R, Kort S *et al*. Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. *J Am Soc Echocardiogr* 2010;**23**:1225–30.
- Spencer KT, Kimura BJ, Korcarz CE, Pellikka PA, Rahko PS, Siegel RJ. Focused cardiac ultrasound: recommendations from the American Society of Echocardiography. *J Am Soc Echocardiogr* 2013;**26**:567–81.
- Sicari R, Galderisi M, Voigt J-U, Habib G, Zamorano JL, Lancellotti P *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.
- Galderisi M, Santoro A, Versiero M, Lomoriello VS, Esposito R, Raia R *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;**26**:51.
- 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.
- Andersen GN, Haugen BO, Graven T, Salvesen O, Mjølstad OC, Dalen H. Feasibility and reliability of point-of-care pocket-sized echocardiography. *Eur J Echocardiogr* 2011;**12**:665–70.
- Mjølstad OC, Andersen GN, Dalen H, Graven T, Skjetne K, Kleinau JO *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.
- Scholten C, Rosenhek R, Binder T, Zehetgruber M, Maurer G, Baumgartner H. Hand-held miniaturized cardiac ultrasound instruments for rapid and effective bedside diagnosis and patient screening. *Journal of Evaluation in Clinical Practice* 2005;**11**:67–72.
- Liebo MJ, Israel RL, Lillie EO, Smith MR, Rubenson DS, Topol EJ. 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.
- Liu SC, Chang WT, Huang CH, Weng TI, Ma Matthew HM, Chen WJ. The value of portable ultrasound for evaluation of cardiomegaly patients presenting at the emergency department. *Resuscitation* 2005;**64**:327–31.
- Price S, Via G, Sloth E, Guarracino F, Breitkreutz R, Catena E *et al*. World Interactive Network Focused On Critical UltraSound ECHO-ICU Group. Echocardiography practice, training and accreditation in the intensive care: document for the World Interactive Network Focused on Critical Ultrasound (WINFOCUS). *Cardiovasc Ultrasound* 2008;**6**:49.
- Mayo PH, Beaulieu Y, Doelken P, Feller-Kopman D, Harrod C, Kaplan A *et al*. American College of Chest Physicians/La Societe de Reanimation de Langue Francaise statement on competence in critical care ultrasonography. *Chest* 2009;**135**:1050–60.
- American College of Emergency Physicians. Emergency ultrasound guidelines 2008. Available at: <http://www.acep.org> (20 February 2014, date last accessed).
- Hellmann DB, Whiting-O'Keefe Q, Shapiro EP, Martin LD, Martire C, Ziegelstein RC. The rate at which residents learn to use hand-held echocardiography at the bedside. *Am J Med* 2005;**118**:1010–8.
- Vignon P, Mucke F, Bellec F, Marin B, Croce J, Brouqui T *et al*. Basic critical care echocardiography: validation of a curriculum dedicated to noncardiologist residents. *Critical Care Medicine* 2011;**39**:636–42.
- Jones AE, Tayal VS, Kline JA. Focused training of emergency medicine residents in goal-directed echocardiography: a prospective study. *Acad Emerg Med* 2003;**10**:1054–8.
- Martin LD, Howell EE, Ziegelstein RC, Martire C, Shapiro EP, Hellmann DB. Hospitalist performance of cardiac hand-carried ultrasound after focused training. *Am J Med* 2007;**120**:1000–4.
- Royse CF, Seah JL, Donelan L, Royse AG. Point of care ultrasound for basic haemodynamic assessment: novice compared with an expert operator. *Anaesthesia* 2006;**61**:849–55.
- Mayo PH. Training in critical care echocardiography. *Ann Intens Care* 2011;**1**:36.
- Expert Round Table on Ultrasound in ICU. International expert statement on training standards for critical care ultrasonography. *Intens Care Med* 2011;**37**:1077–83.
- Update of the Echocardiography Core Syllabus of the European Association of Cardiovascular Imaging (EACVI). Available at: <http://www.escardio.org/communities/EACVI/education/Pages/core-syllabus.aspx> (20 February 2014, date last accessed).
- Cosyns B, Garbi M, Separovic J, Pasquet A, Lancellotti P. Education Committee of the European Association of Cardiovascular Imaging Association (EACVI). Update of the echocardiography core syllabus of the European Association of Cardiovascular Imaging (EACVI). *Eur Heart J Cardiovasc Imaging* 2013;**14**:837–9.
- Gillebert TC, Brooks N, Fontes-Carvalho R, Frasz Z, Gueret P, Lopez-Sendon J *et al*. ESC core curriculum for the general cardiologist (2013). *Eur Heart J* 2013;**34**:2381–411.
- Popescu BA, Andrade MJ, Badano LP, Fox KF, Flachskampf FA, Lancellotti P *et al*. on behalf of the European Association of Echocardiography. European Association of Echocardiography recommendations for training, competence, and quality improvement in echocardiography. *Eur J Echocardiogr* 2009;**10**:893–905.
- Gullace G, Demicheli G, Monte I, Colonna P, Carerj S, Caso P *et al*. Reclassification of echocardiography according to the appropriateness of use, function- and competence-based profiles and application. *J Cardiovasc Echogr* 2012;**22**:91–8.
- Gullace G, Demicheli G, Monte I, Colonna P, Carerj S, Caso P *et al*. Educational pathway, indication, quality process of the novel Echo classification according to appropriateness of use and application. *J Cardiovasc Med* 2014 (in press).
- Price S, Ilper H, Uddin S, Steiger HV, Seeger FH, Schellhaas S *et al*. Periresuscitation echocardiography: training the novice practitioner. *Resuscitation* 2010;**81**:1534–9.
- Jensen MB, Sloth E, Larsen KM, Schmidt MB. Transthoracic echocardiography for cardiopulmonary monitoring in intensive care. *Eur J Anaesthesiol* 2004;**21**:700–7.
- Breitkreutz R, Price S, Steiger HV, Seeger FH, Ilper H, Ackermann H *et al*. Emergency Ultrasound Working Group of the Johann Wolfgang Goethe-University Hospital, Frankfurt am Main. Focused echocardiographic evaluation in life support and periresuscitation of emergency patients: a prospective trial. *Resuscitation* 2010;**81**:1527–33.
- Rozycki GS, Feliciano DV, Ochsner MG, Knudson MM, Hoyt DB, Davis F *et al*. The role of ultrasound in patients with possible penetrating cardiac wounds: a prospective multicenter study. *J Trauma* 1999;**46**:543–51.
- Mayron R, Gaudio FE, Plummer D, Asinger R, Elsparger J. Echocardiography performed by emergency physicians: impact on diagnosis and therapy. *Ann Emerg Med* 1988;**17**:150–4.
- Tayal VS, Kline JA. Emergency echocardiography to detect pericardial effusion in patients in PEA and near-PEA states. *Resuscitation* 2003;**59**:315–8.
- Chardoli M, Heidari F, Rabiee H, Sharif-Alhoseini M, Shokoochi H, Rahimi-Movaghar V. Echocardiography integrated ACLS protocol versus conventional cardiopulmonary resuscitation in patients with pulseless electrical activity cardiac arrest. *Chin J Traumatol* 2012;**15**:284–7.
- Jones AE, Craddock PA, Tayal VS, Kline JA. Diagnostic accuracy of left ventricular function for identifying sepsis among emergency department patients with nontraumatic symptomatic undifferentiated hypotension. *Shock* 2005;**24**:513–7.
- Disney PJ, Da Costa R, Hutchison SJ. Transthoracic echocardiography to identify or exclude cardiac cause of shock. *Chest* 2004;**126**:1592–7.
- Leung JM, Levine EH. Left ventricular end-systolic cavity obliteration as an estimate of intraoperative hypovolemia. *Anesthesiology* 1994;**81**:1102–9.
- Zengin S, Al B, Genc S, Yildirim C, Ercan S, Dogan M *et al*. Role of inferior vena cava and right ventricular diameter in assessment of volume status: a comparative study: ultrasound and hypovolemia. *Am J Emerg Med* 2013;**31**:763–7.
- Feissel M, Michard F, Faller JP, Teboul JL. The respiratory variation in inferior vena cava diameter as a guide to fluid therapy. *Intensive Care Medicine* 2004;**30**:1834–7.
- Barbier C, Loubières Y, Schmit C, Hayon J, Ricôme JL, Jardin F *et al*. Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. *Intens Care Med* 2004;**30**:1740–6.
- Moore CL, Rose GA, Tayal VS, Sullivan DM, Arrowood JA, Kline JA. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. *Academic Emergency Medicine* 2002;**9**:186–93.
- Blaivas M, Fox JC. Outcome in cardiac arrest patients found to have cardiac standstill on the bedside emergency department echocardiogram. *Acad Emerg Med* 2001;**8**:616–21.
- Salen P, O'Connor R, Sierzenski P, Passarello B, Pancu D, Melanson S *et al*. Can cardiac sonography and capnography be used independently and in combination to predict resuscitation outcomes?. *Acad Emerg Med* 2001;**8**:610–5.
- Prosen G, Križmaric M, Završnik J, Grmec S. Impact of modified treatment in echocardiographically confirmed pseudo-pulseless electrical activity in out-of-hospital cardiac arrest patients with constant end-tidal carbon dioxide pressure during compression pauses. *J Int Med Res* 2010;**38**:1458–67.
- Plummer D, Brunette D, Asinger R, Ruiz E. Emergency department echocardiography improves outcome in penetrating cardiac injury. *Ann Emerg Med* 1992;**21**:709–12.
- Tomruk O, Erdur B, Cetin G, Ergin A, Avcil M, Kapci M. Assessment of cardiac ultrasonography in predicting outcome in adult cardiac arrest. *J Int Med Res* 2012;**40**:804–9.