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implementation, training and clinical applications

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Point-of-care ultrasound (POCUS): implementation, training and clinical applications

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Chapter 1: Introduction

Point-of-care ultrasound (POCUS) is a significant development in intensive care medicine which could be marked as a "disruptive" innovation" (*Disruptive innovation is defined as a process in which a new competitor successfully challenges an established market*). [1-3] POCUS has the following characteristics: [4]

- can be done at the bedside,
- generates real time images,
- images can be interpreted instantly,
- images correlate directly with patient's presenting signs and symptoms,
- is easily repeatable,
- can be used by various specialists in diverse situations,
- may be broadly divided in procedural, diagnostic and screening applications.

Appropriate use, point-of-care ultrasonography can decrease medical errors, provide more real-time diagnoses, and supplement or replace more advanced imaging in appropriate situations.
In 2009 we started with the implementation of POCUS in the Intensive Care Unit (ICU) of the Rijnstate hospital Arnhem. We raised three scientific questions that we thought should be answered before successful implementation:
1. How should we define POCUS, what is the essential content, are different levels possible, is there an uniform nomenclature and what are the training requirements?
2. What are the necessary steps needed for implementation of POCUS in the ICU and how do we organize POCUS training?
3. Will POCUS result in improved patient care?

1. How should we define POCUS, what is the essential content, are different levels possible, is there an uniform nomenclature and what are the training requirements?

The existing literature on these topics is highly heterogenous making it difficult to summarize the main findings. Different names were used for the same ultrasound procedures. Papers were published as recommendations, guidelines, "documents" or statements and sponsored by different organizations/societies. Content differed between cardiac POCUS only [5-8] and multiple POCUS elements (pleural, lung, abdominal and vascular) [9, 10]. Some papers based their advice on expert opinion, some used a Delphi method and some a combination of Delphi method with GRADE/RAND method for grading levels of evidence.
We review the most important recommendations focusing on basic cardiac POCUS and summarize the data in table 1.

In the 2008 the World Interactive Network Focused On Critical UltraSound (WINFOCUS) 5 described almost all elements of cardiac POCUS including different levels, training requirements, clinical scenarios in which cardiac POCUS can be used, standard views and standard recording requirements. Importantly, the authors acknowledge 4 levels for ICU echocardiography from Emergency Echo (EE) to level 3 echocardiography. Specific and detailed recommendations are given for training (level 1-3) and an extensive description of POCUS in various clinical situations is provided. The authors suggest that intensivists should at least be trained in level 1 echocardiography, without providing the number of required echocardiography exams to obtain competency. In this document the general opinion is that intensivists who want to be competent in at least level 1 echocardiography must be trained comparable to cardiology standards.

Table 1: ***Part 1. Differences in POCUS guidelines/recommendations***

Journal **Author** **Year** **(reference)** ***Number of pages***	Title	Society	Terminology	Basic level	Training basic	Number of examina-tions basic
Cardiovascular Ultrasound **Price S. et al** **2008** [5] ***35***	Echocardiography practice, training and accreditation in the intensive care: **document** for the World Interactive Network Focused on critical ultrasound (WINFOCUS)	WINFOCUS Based on recommendations by: Royal College of Radiologists British Society of Echocardiography European Society of Echocardiography American Society of Echocardiography	Emergency echo Level 1 Level 2 Level 3	Standard views (PLAX, PSAX, A4CH, S4CH and SIVC) TEE: no Color/Doppler: no Evaluation of valves: ?	Not specified	Not specified
Chest **Mayo, P.H. et al** **2009** [9] ***11***	**Statement** on competence in critical care ultrasonography	American College of Chest Physicians/ Société de Réanimation de Langue Française	Critical Care Echocardiogra phy (CCE) Basic Advanced	Standard views TEE: yes Color/Doppler: yes (for severe valvular regurgitation)	Not specified	Not specified
Intensive Care Medicine **Expert Round Table** **2011** [11] ***7***	International expert **statement** on training standards for critical care ultrasonography	European Society of Intensive Care Medicine	Critical Care Echocardiogra phy (CCE) Basic Advanced	Standard views TEE: optional Color/Doppler: yes (for severe valvular regurgitation)	10 h	30 TTE (no consensus)

Journal of the American Society of Echocardiography **Via G. et al 2014** [8] ***33***	International evidence-based **recommendations** for focused cardiac ultrasound	WINFOCUS	FOCUS Focused Cardiac Ultrasound	5 standard views TEE: no	Not specified	Not specified
Critical Care Medicine **Levitov, A. et al 2016** [12] ***22***	**Guidelines** for the appropriate use of bedside general and cardiac ultrasonography in the evaluation of the critically ill patients: part II: cardiac ultrasonography	Society of Critical Care Medicine	Basic: Bedside Cardiac Ultrasound Expert/ Advanced	Standard views TEE: no Color/Doppler: no	12 h	Not specified
Critical Care Medicine **Official statement of the Society of Critical Care Medicine** **Pustavoitau, A. et al 2017** **http://journals.lww.com/ccmjournal/Documents/Critical%20Care%20Ultrasound.pdf.*12***	**Recommendations** for achieving and maintaining competence and credentialing in critical care ultrasound	Society of Critical Care Medicine	Critical Care Echocardiography Focused cardiac ultrasound	Standard views TEE: no Color/Doppler: no	20 h	50 Interpreted 30 Personally performed

European Heart Journal **Neskovic et al** **2018** [7] ***14***	Focused cardiac ultrasound core curriculum and C**ore syllabus** of the European Association of Cardiovascular imaging	European Association of Cardiovascular Imaging in close cooperation with: European Society of Anesthesiology, European Association of Cardiothoracic Anesthesiology, Acute Cardiovascular Care Association of the European Society of Cardiology WINFOCUS	FoCUS Focused Cardiac Ultrasound	Standard views TEE: no Color/Doppler: no	Practical training followed by post course ultrasound examinations. Hours needed depending on local situation	Not specified
Critical Care **Wong a. et al** **2020** [10] ***5***	**Recommendations** for core critical care ultrasound competencies as part of specialist training in multidisciplinary intensive care: a framework proposed by the European Society of Intensive Care Medicine (ESICM)	ESICM	Core CCUS	Standard views TEE: no Color/Doppler: limited	Not specified	Not specified

Table 1: Part 2: Differences in POCUS guidelines/recommendations

Journal **Author** **Year (reference)** ***Number of pages***	ICU clinical situations specified	Level of evidence included	Expert opinion based	Delphi questionnaire used
Cardiovascular Ultrasound **Price S. et al** **2008** [5] ***35***	All levels: - ventricular function L and R - diastolic function L and R - hypovolemia - volume responsiveness - filling status - tamponade - pericardial disease - sepsis syndromes - Effects of preload and afterload - hypoxemia - acute cor pulmonale - complications of acute myocardial infarction - echocardiography after chest trauma - echocardiography in shock - failure to weaning from mechanical ventilation - hemodynamic measurements	No	Yes	No

Chest **Mayo, P.H. et al** **2009** [9] ***11***	Basic: - severe hypovolemia - left ventricle failure - right ventricle failure - tamponade - acute left sided valvular regurgitation - resuscitation (during and after)	No	No	Yes 5 residents 20 fellows 73 attendings 1 PA/NP* Other * Physician Assistant/ Nurse practitioner
Intensive Care Medicine **Expert Round Table** **2011** [11] ***7***	No (document is based on previous paper)	No	Yes 29 experts from 11 critical care societies from 5 continents	No
Journal of the American Society of Echocardiography **Via G. et al 2014** [8] ***33***	Yes - LV dimension and systolic function - RV systolic function - Volume status - Pericardial effusion, tamponade - Gross signs of chronic heart disease - Gross valvular abnormalities - Large intracardiac masses	Yes (GRADE/ RAND method)	Yes	Yes 33 experts from 16 countries
Critical Care Medicine **Levitov, A. et al** **2016** [12] **22**	- Pericardial effusion - Severe right and left ventricular failure - Regional wall motion abnormalities - Gross anatomical valvular abnormalities - Size and collapsibility of the inferior vena cava	Yes (GADE/RAND method)	Yes	Yes

Critical Care Medicine **Official statement of the Society of Critical Care Medicine** **Pustavoitau, A. et al** **2017** **http://journals.lww.com/ccmjournal/Documents/Critical%20Care%20Ultrasound.pdf.** ***12***	- Normal and abnormal right and left ventricular size and systolic function - Normal and abnormal cardiac atrial size - Estimation of central venous pressure - Pericardial effusion and signs of tamponade - Manifestations of septic shock and differentiation between severe hypovolemia and vasodilatory state - Manifestation of severe hypovolemia and understanding of the limitation of assessment of “fluid status” with ultrasound	No	Yes	No
European Heart Journal **Neskovic et al** **2018** [7] ***14***	- abnormally enlarged cardiac chambers - signs of severe left and right ventricular dysfunction - large pericardial effusion - extreme altered intravascular volume status	No	Yes	No
Critical Care **Wong a. et al** **2020** [10] ***5***	- syndromes: severe hypovolemia, LV and RV failure, tamponade, acute cor pulmonale, severe valvular abnormalities - LV: size (qualitative), systolic function (qualitative), contraction pattern (qualitative) and valvular disease (qualitative color doppler) - RV: size (qualitative), systolic function (qualitative, TAPSE, RV/LV ratio), valvular disease (qualitative color doppler) - inferior vena cava: size (qualitative), respiratory variation (qualitative)	No	Yes	Yes 32 experts

On behalf of the American college of Chest Physicians (ACCP) and their French counterpart Mayo et al. 11 described essential requirements for technical (image acquisition) and cognitive (image interpretation) skills using a Delphi method. Two levels of critical care echocardiography (CCE), basic and advanced, are described. This work served as the basis for training standards for critical care ultrasonography. [12] Nine items concerning training requirements for basic CCE were proposed including a minimum of 10 hours theoretical training and 30 transthoracic echocardiography (TTE) exams performed by the trainee. Via et al 8 provided a follow up of the 2008 WINFOCUS paper. Thirty-three experts from 16 countries participated in an evidence based methodologically rigorous consensus process on Focused cardiac ultrasound (FoCUS). They discussed 108 statements on FoCUS using the modified Delphi technique in combination with the Grading of Recommendation, Assessment, Development and Evaluation (GRADE) method to determine the quality of available evidence and the RAND appropriateness method for judgment and consensus on the following items: technique, potential benefits, clinical integration, education and certification. There was disagreement on 10 statements, 13 statements were supported with grade A evidence and 96 recommendations were marked as strong or very strong. Apart from many other recommendations they provide useful targets for basic cardiac ultrasound: LV dimension and systolic function, RV systolic function, volume status, tamponade, gross signs of chronic heart disease and valvular abnormalities and large intracardiac masses. They could not agree on specific training requirements, and these are therefore not provided. In contrast, in the 2016 guidelines published by Levitov et al in Critical Care Medicine 13 out of 45 statements on cardiac POCUS none were supported by Grade 1A evidence. Finally, the European Society for Intensive Care Medicine recently published recommendations for core critical care ultrasound (CCUS). [10]

Overall, there appears to be agreement on the fact that POCUS is an important tool for the intensivist and can be trained effectively but that apart from initial training a follow up system (portfolio) is essential to keep physicians competent and that expert ultrasound help should be asked if needed. Two levels (basic and advanced) of cardiac ultrasound should be recognized with clear boundaries between the two levels although not always distinguishable in clinical practice.

Comparable literature on other POCUS elements (lung, abdominal) is scarce. In the 2017 SCCM recommendations requirements for competence in other CCUS fields are provided. The SCCM recommends specific numbers of interpreted and personally performed ultrasound exams for pleural/lung, abdominal, vascular and procedural (vascular access, thoracentesis, pericardiocentesis and other needle guidance procedures) CCUS applications.

On the topic of recommendations for lung ultrasound the WINFOCUS initiative [14] graded twenty-nine statements (40%) with level A evidence

indicating that lung POCUS is relatively straightforward compared to cardiac POCUS.
Recommendations for abdominal POCUS in emergency and critical care settings are even more scarce.[15]
In summary, although an important topic in critical care medicine, the definition of POCUS is variable, nomenclature is not clear, essential components differ, different levels are described, training requirements vary and the level of evidence for the various recommendations and guidelines are generally poor.

2. What are the necessary steps needed for implementation of POCUS in the ICU and how do we organize POCUS training?

There is little literature available on the subject of POCUS implementation. Expert help [5] and knowledge of one's own shortcomings [16] are essential elements. More data are published on the subject of POCUS training. POCUS training is done in various ways worldwide. [17, 18] Although there is significant heterogeneity in the published POCUS training curricula, the central message is that it is possible to train residents and fellows in POCUS acknowledging the fact that the quality of published papers on this subject is rather low. [19] In the Dutch setting all internal medicine (IM) residents do a compulsory ICU rotation. The Dutch Society of Internal Medicine (NIV) recently stated that POCUS training is an obligatory component of the IM curriculum and we postulated that combining POCUS training and the start of the ICU rotation is possible and would be efficient. IM residents are highly motivated in acquiring POCUS skills. [20-25]
Gibson et al published a systematic review [25] in which the data of 23 studies on 292 learners were evaluated, with some of them on residents. A near perfect agreement (Cohen's $\kappa>0{,}8$) between novices and experts after 6 hours each of theory and hands-on training on detecting left ventricular systolic dysfunction and pericardial effusion was found. After only 3 hours of each, substantial agreement (Cohens $\kappa>0{,}6$) could be achieved. In all studies participants were able to display interpretable cardiac ultrasound scans within an acceptable amount of time.
In a previous systemic review by Kanji et al on cardiac POCUS courses it was shown that scanning competency can be achieved after minimally 30 scans. [26] Training that consists of a combination of different teaching methods including hands-on training, didactic sessions and online instruction were found to be most efficient. The highest concordance between novices and experts was achieved when the focused ultrasound was limited to a basic qualitative assessment of the global ventricle function and collapsibility of the inferior vena cava. Both systemic reviews indicate that the best results are achieved if POCUS training is limited to mastering basic cardiac POCUS goals.
Literature on training of other POCUS elements (lung, abdomen and vascular) is more scarce and specific recommendations are lacking. The SCCM recommendations on achieving and maintaining competence state

that for basic CCE a minimum of 50 interpreted cardiac POCUS exams are required and for lung, abdomen and vascular POCUS 30 interpreted POCUS exams each.
Digital POCUS simulation programs may be of additional value in POCUS training and this element could be increasingly used in the near future due to the manufacturing of lifelike ultrasound mannequins and computer based simulation solutions. [27]
It is important to realize when designing a POCUS curriculum, that acquired POCUS skills should be maintained and that motor and cognitive skills will decline in time in case of non-use. [28-30] Another issue is that a substantial number of physicians fail to attain competence after a short POCUS course, stressing the need for adequate follow up after an initial basic POCUS course. [31]
In conclusion there is little guidance in scientific literature on how POCUS can best be implemented on the ICU. Furthermore, basic POCUS courses will generally lead to acceptable basic POCUS skills also for IM residents but a follow up program to help retaining the acquired POCUS skills is important. Generating new data on both topics is warranted.

3. Will POCUS result in improved patient care?

Although the importance of POCUS use is endorsed, the question whether the use of POCUS improves patient outcome is still hard to answer [32] and the difficulty in designing clinical POCUS studies is acknowledged. [33] Literature on the impact of POCUS on endpoints like mortality is scarce but there is substantial evidence that in various acute medical settings POCUS will improve patient care in other ways.
In the ED setting multiple studies on non-traumatic hypotensive patients and dyspneic patients show that the use of POCUS substantially improves diagnostic accuracy (14-30% improvement) and also often results in changes in clinical management (in 24-47% of the cases). [34-47] In addition to this, POCUS resulted in an increase in confidence of the treating physician, narrowing of the differential diagnosis and detection of life-threatening diagnoses that would have been missed otherwise.
Likewise, in the ICU setting the use of POCUS improves patient care. In this group of patients there is also an indication that mortality is decreased when cardiac POCUS is deployed. [48] Furthermore, the application of POCUS is beneficial for patients who are newly admitted to ICU due to respiratory symptoms or hypotension, but also unselected patients benefit from it. There is an increase in diagnostic accuracy that changes the primary diagnosis in 21 to 25.6%. While less additional imaging techniques are necessary, clinical management is directly affected in the range of 39,2 to 61% of cases. [49-60]
The use of POCUS in other medical settings is less well investigated.
Routine use of POCUS in assessing general ward patients leads to better diagnostic accuracy and less additional investigations as was reported in three studies. [61-63] Studies on the use of POCUS during deployment of

Medical Emergency Teams (METs) on general hospital wards are even more scarce. POCUS could be of value in the assessment of the acutely deteriorating general ward patient comparable to ED/ICU settings. MET patients show a variety of presenting symptoms mainly acute signs of neurological and cardiorespiratory symptoms [64] and especially for cardiorespiratory deterioration POCUS could be helpful. Until 2021 only one small study evaluated the use of lung POCUS in combination with deep vein analysis during MET deployment. [65] The authors found that with the use of their POCUS protocol 84% diagnostic accuracy was reached but due to the small numbers of inclusions no statistical benefit of POCUS was found. Furthermore, in almost all mentioned ICU/ED/ward/MET studies POCUS was performed by experienced ultrasonographers and only in a few studies residents performed POCUS. [60,63] MET's are not always staffed by experienced consultants, [66] so it would be interesting to generate new data on the topic of POCUS during MET calls, including studies on MET's staffed by less experienced physicians.
Another possible positive impact of POCUS on improving patient care is that POCUS can be used to guide interventions and to improve safety of certain procedures such as the insertion of a central venous catheter. [4] The insertion of central venous catheters is one of the most common ICU procedures. [67] The use of POCUS during central line insertion is endorsed by many experts especially for the internal jugular vein. [23, 68, 69] It could well be that after a central line is inserted POCUS could also be used to look for (in)correct placement and possible complications [70] but few data are available and more data are warranted. [33] Some argue that in case of ultrasound guidance during central line insertion (internal jugular vein) there is no need for routine chest radiography at all due to the very small misplacement and complication rate. [71] This would result in fewer additional radiological exams and would also save time because POCUS control of (mal)position and complications can be done instantaneously.
One of the main advantages of ultrasound is that it is save in terms of biohazard and it is a non-invasive technique. Due to the lack of long-term side effects ultrasound examinations can be repeated frequently. It would therefore be interesting to further explore new indications for POCUS, for instance in generating continuous non-invasive hemodynamic measurements. [33] It was already shown that cardiac output (CO) measurements using transthoracic TTE can be used in managing unstable critical care patients [72] and that more continuous CO measurements could expand the utility of cardiac ultrasound. For this application smaller sized TEE probes are available. [73] It would however be interesting to explore TTE methods for continuous CO measurements for various reasons: TTE is completely non-invasive and because TTE is part of basic cardiac ultrasound it can be used by a wider range of physicians.
In summary, data from ED and ICU studies show that the use of POCUS is of benefit to the patient. In other medical settings such as MET calls there are fewer data, and this could be further explored. Furthermore, POCUS technology can also be used for procedural guidance and post-procedural

evaluation and other new POCUS technologies and applications also need further exploration.

Outline

In chapter 2 we review the main international guidelines and recommendations regarding POCUS. We suggest the use of the name POCUS as a comprehensive name for clinical bedside ultrasound for intensivists, but this term can also be used by other physicians. POCUS of heart, lungs, abdomen and blood vessels is divided in basic and advanced skills with suggestions for content and training. In this paper we have created some order in the jungle of POCUS recommendations and guidelines and offer general suggestions that can be used by clinical practitioners.

In chapter 3 we describe a manual for training in basic cardiac and lung ultrasound for the Dutch intensive care community.

In chapter 4 we describe our POCUS implementation strategy and our training program for residents.

In chapter 5 we describe the evaluation of our training program for residents. Residents participating in our course were tested (cognitive and practical skills) before, on the last day of the course and after three months. This paper serves two goals. First, we share our course content and outcome data. Second, the evaluation is used as a quality check of the POCUS course in order to make necessary improvements if needed.

In chapter 6 we make a small sidestep to IM and POCUS training and stress the need for general accepted European standards when training internists in POCUS.

In chapter 7 we describe the use of a basic thoracic POCUS protocol during medical emergency team (MET) calls, showing that the use of POCUS increases diagnostic accuracy significantly and improves MET physicians' certainty.

In chapter 8 we describe the use of POCUS after the insertion of a central line and answer the question if a routine chest X-ray after a ultrasound guided line insertion is necessary if a post insertion ultrasound protocol is used.

In chapter 9 we describe the use of an external ultrasound holder (Probefix). With this device it was possible to measure cardiac output using cardiac ultrasound in eight out of ten patients. With the use of the Probefix cardiac output measurements can be done at exactly the same body position. This opens the way to continuous cardiac output measurements using transthoracic (noninvasive) ultrasound.

In chapter 10 we summarize and discuss the main findings of this thesis.
Furthermore, we explore possible future implications.
Conlusions

Chapter 11 is the Dutch summary and future orientation

Chapter 12 apendixes
Abbreviations
List of publications
Biography
Dankwoord

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Chapter 2: A practical approach to critical care ultrasound

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1. Introduction

In the past decades there is growing interest in the use of critical care ultrasound (CCUS). For physicians in the field of acute medicine (Emergency Medicine or Critical Care Medicine) CCUS has become an indispensable tool because CCUS can be used at the bedside, can provide instant clinical information and yields no burden to the patient in terms of radiation.[1]
Literature on the positive effects of CCUS is limited. [2] It is understandably hard to design a study protocol in which the effect of CCUS can be properly evaluated in a randomized way.
Several papers discuss the influence of ultrasound on the process of diagnosis [3-5] and patient management. [6, 7] Other papers show the effect of ultrasound on the need for other imaging studies [8, 9] and on outcome. [9, 10] These studies have no "hard" endpoints like differences is mortality or length of stay.
There are no studies on negative effects of CCUS on clinical outcome or the occurrence of complications or injuries. There is however concern about the quality of CCUS from for instance cardiac ultrasound societies. They stress the need for adequate training, certification, maintenance of ultrasound skills and the need to ask for expert help if necessary. [11, 12] In a paper by Blanco et al. the common pitfalls in CCCUS are summed up but exact data on how often inappropriate use of CCUS occurs and at what costs is hard to find. [13]
We as clinicians are sometimes bewildered by the number of guidelines produced by different societies. There is no easy answer to the question: "what are the necessary ultrasound competencies that I need to evaluate an unstable patient?" In this paper we try to address this question. First, we will give a critical appraisal of the most relevant guidelines produced by several interest groups, then we will put this into perspective and look at the most pressing needs for intensivists, but our approach might also be valuable for other specialists such as internists. Writing such a paper in detail would possibly lead to a comprehensive textbook on the use of critical care ultrasound, we will try to describe what in our view can be considered to be essential in a paper that can be used by the everyday clinician. We also suggest a rational layout for CCUS training. In this way we will make small steps since the process of trying to make the care for our patients more effective, safer and cheaper, will never stop and the situation will be completely different in a couple of years.
For a start, there is consensus worldwide that despite the lack of "hard" evidence, CCUS is an irreversible development in critical care medicine and will be increasingly used as more and more critical care physicians are trained in at least basic CCUS. [14] There is also consensus that CCUS should be mandatory in the curriculum of intensive care unit (ICU) physicians.[15] The use of ultrasound can even be included in basic medical training (medical school). [16] Training in ultrasound in medical school helps the student gaining basic anatomical and physiological knowledge, during

later phases of medical training the use of ultrasound may also "mature" by training in clinical ultrasound. In our view basic CCUS could best be incorporated in residencies with forms of advanced CCUS in the later phases of resident training of for qualified specialists. Such stepwise approaches have been described in different countries.[17] Ultrasound is not only hot a topic in intensive care medicine but also in many other clinical specialties, for instance the American College of Emergency Physicians has an extensive policy statement on ultrasound guidelines (Ultrasound Guidelines: Emergency Point-of-care and Clinical Ultrasound Guidelines in Medicine 2016) or the Canadian Internal Medicine Ultrasound Group [18] for the training in internal medicine in Canada.

2. Cardiac critical care ultrasound (cardiac CCUS)

Cardiac CCUS is an important topic in critical care ultrasound and is a subject of many reviews, recommendations etc.
Cardiac CCUS is important because it can provide the intensivist with bed side information concerning many different clinical questions. The intensivist will use Cardiac CCUS predominantly in acute situations during which the ultrasound findings are integrated with other physiological and clinical findings and directly translated into therapeutic measures. This is different from the more standard out-patient clinic cardiological ultrasound examinations. Some recommend that all intensivists should be trained at least in the basics of cardiac CCUS. [19] It is possible to train non-cardiologists in performing basic cardiac CCUS. After structured training intensivists and emergency physicians are able to reliably assess left ventricular function. [20-25]

here are differences in the various basic cardiac ultrasound algorithms as shown in several papers addressing issues on training and different levels in cardiac CCUS skills.[11, 12, 15, 17, 19, 26-30]
There is no consensus on the name, levels of competence, training and certification. In Table 1 we show the main differences in terminology, aspects of basic cardiac CCUS and training aspects. Being a corner- stone in critical care ultrasound it is important that we look at these differences in more detail.
Price et al. [30] describe a relatively straight forward basic level. There is so called emergency echo using standard TTE views to recognize major causes of arrest/shock and to determine when referral for second opinion ultrasound is indicated. Emergency echo is considered to be a potential core skill for the acute physician. In this paper the required skills for emergency echo are further explained.
Beyond the emergency echo there are 3 levels of competence in Cardiac CCUS. All three levels include TEE and consist of increasing levels of skills in TTE and TEE with increasing need for training with examination and certification. Level 1 echocardiography is not the same as those required by

a cardiologist, but it comes close in required skills. An intensivist with a level 2 training will be comparable to a cardiologist. This paper was written by the WINFOCUS network (The World Interactive Network Focused on Critical Ultrasound) a scientific society committed to the development of high-quality ultrasound in the emergency and critical care setting. This publication is based on recommendations published by The Royal College of Radiologists, the British Society of Echocardiography, the European Association of Echocardiography and the American Society of Echocardiography together with input from established practitioners of ICU echocardiography.

In another consensus paper by Mayo et al. [19] a different approach is used. First of all, this paper is not restricted to cardiac ultrasound only but also includes general CCUS (pleural, lung, abdominal and vascular). Consensus was sought concerning the question about the difference be tween basic and advanced cardiac CCUS. Answers by experienced ultrasound specialists and less experienced colleagues were used to define different competence levels.

For every level, requirements for competence were noted. Concerning cardiac CCUS, two different levels are distinguished (basic and advanced). In this paper the basic level is comparable to an extensive emergency level (including some color Doppler) and includes TTE and TEE. The advanced level is used for a more comprehensive hemodynamic evaluation. This paper is the result of collaboration between the American College of Chest Physicians and la Société de Réanimation de Langue Française.

In the expert round table paper of 2011 [15] three different forms of critical ultrasound are defined. The basic levels are divided in General Critical Care Ultrasound (GCCUS) and basic critical care echocardiography (CCE). Both basic skills require 10 h of theoretical training. The amount of examinations to be performed is not mentioned and also no formal certification is required. In this paper TEE is optional for basic CCE.

For advanced CCE the requirements concerning training and certification are specified. Scientific critical care societies from all over the world contributed to this international expert statement.

Another international paper was published in JASE in 2014. [11] Again WINFOCUS was the driving force. The international consortium of scientific societies in this paper was different from the ICM paper.[15] In the view of Via et al. [11] we should speak of FoCUS. They provide us with the results of scientific discussions on 108 different subjects. FoCUS comes close to basic CCE.[19] In the elaborate paper by Via et al. almost all aspects of (learning) basic CCE are addressed.

In the paper by Neskovic et al. [12] the European Association of Cardiovascular Imaging (EACI) on behalf of the European Society of Cardiology (ESC), the position of cardiac ultrasound by non-cardiologists is discussed. The EACI recognizes the need for cardiac ultrasound in emergency situations but stresses the fact that there are concerns about the quality of ultrasound examinations done by non-cardiologists. The

EACI provides us with their viewpoints concerning FoCUS that need to be taken very seriously.
The EACI states that there are risks when echocardiography is done by colleagues who have been less trained than cardiologists in cardiac ultrasound. There are differences compared to cardiologists in terms of quality of the ultrasound examinations and the possibility of the wrong clinical implications as a result of insufficient cardiac ultrasonography. Also, because FoCUS is a limited, targeted approach it carries the risk of overlooking important abnormalities. They stress the need for the non-cardiologist ultrasonographer to fully appreciate these limitations and to refer the patient if necessary. Very recently Neskovic et al. published another paper on Focused cardiac ultrasound on behalf of the European association of cardiovascular imaging.[31] In this paper is again acknowledged that there is a place for focused cardiac ultra sound performed by non-cardiologists in certain critical care or emergency situations. This because it will not be possible to guarantee a fully trained cardiologist to be always present and because cardiologists are not always sufficiently trained in ultrasound in critical care or emergency situations. The authors further state that focused cardiac ultrasound should be combined with lung ultrasound. This paper includes proposals for minimal education/training requirements, targets for examination and related cardiovascular scenarios/conditions and includes a comprehensive syllabus with full explanation of the FoCUS training elements. Neskovic et al. state that a basic course will never be sufficient to train non-cardiologists in an adequate way so no number of training hours or number of needed ultrasound exams are given. They leave the responsibility for adequate training to local staff, but they do provide with their elaborate syllabus a framework for FOCUS training. FOCUS consists out of more elements than other basic critical care echocardiography protocols.
The American Society of Echocardiography has also published a paper with their view on cardiac ultrasound done by non-echocardiographers [32] comparable to the EACI/ESC view. In the 2016 special article by Levitov et al. [29] the latest guidelines for general and cardiac CCUS are summed up. In part 2 cardiac CCUS is discussed. The authors are physicians “proficient” in the use of ultrasound and are from North America, Europe and the Middle East, some of the authors are active WINFOCUS members. They introduce another term: BCU (bedside cardiac ultrasound) and acknowledge two levels of competence. The basic level, including standard cardiac views will help in recognizing the presence of pericardial fluid, severe right and left ventricle dysfunction, regional wall motion abnormalities, gross anatomical valvular abnormalities and assess the size and collapsibility of the inferior vena cava. The basic level can be achieved after a 12-hour training. The expert level needs far more training and will be beyond the basic skill level of the average American intensivist. The authors state that the skills of doctors in between the basic and advanced level will be hard to define and the authors do not provide guidelines for the intermediate level. This article

makes very rational recommendations concerning what should be part of basic cardiac ultrasound and what is better left to the advanced level. Although the two cardiac ultrasound levels are basic and advanced, the recommendations assume the levels basic and expert. These two formats might be the same, it adds up to the indistinctness concerning CCUS.
The article by Levitov et al. is nicely structured and provides us with reasonable recommendations. However, the strength of the given recommendations was never grade 1A (strong recommendation, high quality evidence) but with a maximum grading of 1B (strong recommendation, moderate quality evidence) indicating that there is no absolute proof available (further research is likely to have an important impact on our confidence in the estimate of effect or accuracy and may change the estimate).

3. Remaining issues in CCUS

After reading the literature there seems to be agreement on the question whether (cardiac) critical care ultrasound is an important and accepted tool for the intensivist but that there is no definite agreement on:

- the definition of critical Care Ultrasound
- what are the elements of CCUS; cardiac, lung, abdomen or a combination of different ultrasound examinations.

For Cardiac CCUS there is no agreement on:

- the correct name (CCE, FoCUS, FCCE, EE, LE, FCU).
- what levels of competence do we acknowledge (Emergency, basic, intermediate and advanced?)
- is TEE part of a basic Cardiac CCUS program or is TEE reserved for the advanced level?
- recommended training in cardiac CCUS.

Although there is lack of hard evidence to guide us through these questions we propose a practical approach for critical care ultrasound.
What is critical care ultrasound; maybe it is time to use a general accepted name?
Critical care ultrasound is a bedside ultrasound examination by the critical care physician. The results of the ultrasound examination can be directly translated to therapeutic measures.
The critical care physician will use ultrasound in a dynamic manner at the bedside. The ultrasound examination can be repeated.
Bedside ultrasound is not only used by intensivists but also by emergency physicians, doctors in pulmonary medicine, internists and many more. We endorse the name point-of-care ultrasound (POCUS). POCUS is done at the bedside, is integrated into the diagnostic and therapeutic activities of the attending clinician and is not restricted to a specific group of doctors (for instance critical care physicians).

4. What are the components of POCUS?

POCUS is more than cardiac ultrasound; it includes also lung ultrasound, abdominal ultrasound or a combination.[19,33,34]

In recent years the emphasis has been on cardiac ultrasound but there are reports that for instance lung ultrasound is important as well or that combined lung and cardiac ultrasound is also valuable. It seems therefore wrong to exclude other forms of ultrasound from POCUS.

In the literature there are also recommendations and expert panels for point-of-care lung ultrasound 35 on behalf of the International Liaison Committee on Lung Ultrasound (ILC-LUS) for the International Conference on Lung Ultrasound (ICC-LUS), WINFOCUS was the organizing society for this article. Seventy-three recommendations regarding the use and evidence for the use of lung ultrasound (LUS) were discussed. The recommendations were produced in order to help implementation, development and standardization of LUS. After extensive literature review and three conferences 73 statements on lung ultrasound were analyzed by 28 experts on lung ultrasound. On 65 statements strong recommendations were made, 2 statements received weak/conditional recommendations and for 6 statements no consensus was reached. The main items were pneumothorax, interstitial syndrome, lung consolidation, monitoring lung disease, neonatology/pediatrics and pleural effusion.

In case of the acutely dyspneic patient lung ultrasound can help the clinician to make a rapid diagnosis [26,36-40] without the use of radiation, without the need of transportation of the patient to the radiology ward and with the possibility of direct live-saving interventions.

Abdominal ultrasound has also been suggested as part of critical care ultrasound. [4, 7, 19, 41-43] Although little discussed we feel that also in abdominal ultrasound there should be difference between a basic and in advanced level. Basic abdominal ultrasound should be performed to rule out intraperitoneal fluid in case of shock (for instance FAST protocol). More advanced abdominal ultrasound requires more training and should be approached in the same manner as advanced cardiac ultrasound.

There are more reports on combined critical care ultrasound. [19,26,40,42,44-46]

The combination of cardiac POCUS with focused pleural, lung and abdominal ultrasound could enlarge the possibility to get a prompt diagnosis and to guide primary treatment. There is some proof that such a multimodal ultrasound approach is helpful. [4,7,8,40,47-51]

Venous compression is an element of the BLUE protocol to rule out distal thrombosis in order to look for pulmonary embolism in the dyspneic patient. [36,46] This last element of vascular POCUS is in our view optional or part of advanced training.

Although critical care ultrasound is gaining more popularity there is still discussion about the need to have every critical care physician trained in ultrasound.[14,52, 53]
If we agree on the idea that critical care ultrasound is a valuable tool for the critical care physician than it would be rational to include different aspects of ultrasound (cardiac, lung, vascular and abdominal).
Critical Care physicians than should be able to perform:

- basic cardiac POCUS
- basic lung POCUS
- basic abdominal POCUS
- basic vascular POCUS especially to guide the insertion of central lines (internal jugular vein).

There are many other applications for POCUS but these applications are more specific (for instance estimation of intracranial pressure in neuro traumatology) and are in our view beyond general POCUS.[1] Apart from basic POCUS suitable for every intensivist more advanced skills could be acquired along the specific needs for a specific situation or department.
Concerning cardiac POCUS, we propose to use no more than 2 different levels (basic and advanced). We agree that there should be training facilities and certifications to be regulated on a national and international level. We propose that TEE is reserved for the advanced level as is recommended in most papers.[11,19,29]

Basic cardiac POCUS

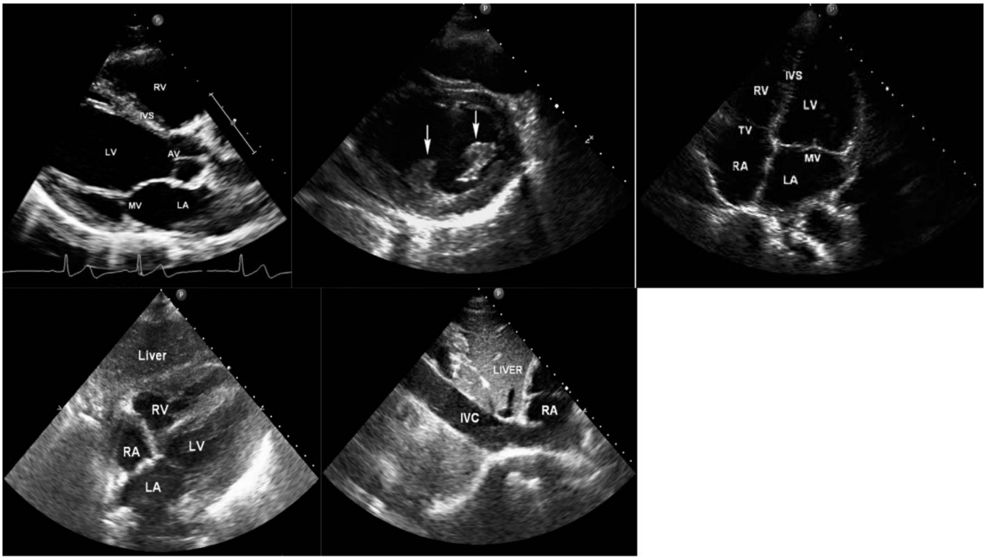
Basic cardiac POCUS consists of 5 standard TTE views (PLAX, PSAX, apical 4 chamber, subcostal 4 chamber and subcostal IVC) as is shown in Fig. 1.
With basic cardiac POCUS 4 questions regarding the hemodynamic status can be answered. Is the left ventricle dilated and what is the function (good, bad, moderate), is the right ventricle dilated and what is the function (good, bad, moderate), is there pericardial fluid (yes, no, sings of tamponade) and does the IVC show fluid overload or underfilling (in spontaneously breathing patients) or is the IVC indicative for fluid responsiveness (in patients on mechanical ventilation)?
In most recommendations basic cardiac POCUS uses only 2-D and M-mode techniques. The use of Doppler and the use of specific cardiac measurements are reserved for advanced cardiac POCUS. [54]

Training in basic cardiac POCUS

Literature regarding the issue of training in basic cardiac POCUS is available.[20-22,24,25,55] Kanji et al.[27] reviewed the literature on curriculum development and evaluation of critical care ultrasound. They conclude that there is a need and interest to train critical care learners in ultrasound but that it is hard to provide firm conclusions on this topic due to heterogeneity of the published curricula. It seems however possible to train basic cardiac ultrasound in a time efficient manner. Basic curricula in which cardiac function was assessed as a binary or qualitative outcome appeared to demand less time in training and to be better reproducible. Also web-based

pre-course training could be of value but the cornerstone in cardiac ultrasound training is hands on training sessions with a minimum of 5 h. There is also discussion on the topic of the required number of cardiac ultrasound studies for participants to make (probably around 30), whether cardiac ultrasound skills can be learned only on healthy volunteers and whether recommendations can be made on the topic of maintenance of cardiac ultrasound skills.
We would like to endorse the recommendations done by Kanji et al. for training in basic cardiac POCUS because there seems to be an optimum between result (in terms of quality in cardiac ultrasound skills) versus time and costs (in terms of time and efforts needed to reach a certain level of competence.

Fig. 1: RV = right ventricle, LV = left ventricle, AV =aortic valve, MV = mitral valve, TV = tricuspid valve, RA = right atrium; La= left atrium, IVS = interventricular septum, IVC = inferior vena cava, arrows indicate papillary muscles.



Advanced cardiac POCUS
There is discussion about maintenance of competence and how the transition from basic through some sort of intermediate level to the advanced level should be accomplished. Most experts state that this intermediate level is hard to describe and even harder in terms of certification.[29] Training in advanced cardiac POCUS has been addressed in the 2014 expert paper.[56] Advanced cardiac POCUS includes a comprehensive TTE examination (including dynamic parameters, Doppler measurements, tissue Doppler, examination of valvular pathology and

many more) and TEE. The required skills are also listed in the 2014 expert paper.[56]

Training in advanced cardiac CCUS

Advanced cardiac CCUS requires an extensive learning program. [56] The European Society of Intensive Care Medicine offers to qualified candidates a training program leading to certification in advanced cardiac CCUS (European Diploma in EchoCardiography, EDEC http://www.esicm.org/education/european-diploma).

Basic lung POCUS

In basic lung POCUS the focus is on ruling out important and life-threatening pulmonary syndromes. A protocol which is often used is the BLUE protocol with a well-defined decision tree, (Fig. 2) first described by Lichtenstein using 2-D ultrasound and M-Mode (Fig. 3). [36] There are arguments to use basic lung POCUS for ultrasound guided pleural drainage, but this is of course difficult to train in healthy volunteers.[34]

Data on training in basic lung ultrasound suggest that it can be learned within relatively short time frame. For instance, the identification of pleura effusion could be trained after a 3 h focused program by residents who were novices in ultrasound. [57] Recently Pietersen et al. published a systematic review on literature in lung ultrasound training and they concluded that no clear guidelines for future education and certification in clinical lung ultrasound could be given. This conclusion was mainly due to the fact that the include studies were substantially heterogeneous and therefor impossible to compare. [58]

Advanced lung ultrasound

Advanced lung ultrasound is used with applications also outside of the intensive care. [59] There are various training programs for residents in pulmonary medicine and pulmonologists.

As far as we know there is no single international accepted curriculum, but most thoracic societies of the different countries have their own curricula for training in basic and advanced lung ultrasound. For instance, in the Netherlands a textbook on the use of ultrasound for pulmonologists will be published soon.

Basic abdominal POCUS. Basic abdominal POCUS focusses primarily on the presence of intraperitoneal fluid, kidney outflow obstruction and to guide ascites drainage. [34] Other authors suggest that intensivists should be able to make a complete abdominal ultrasound.[60]

Data on learning abdominal critical care ultrasound are even more scarce and most data stem from emergency physician training curricula. [61, 62] Abdominal ultrasound is complicated and it seems justifiable to organize training in abdominal ultrasound identical to cardiac POCUS (combination of hands on training for 3–4 h, live demonstration and simulator cases).[63]

Advanced abdominal POCUS. To our knowledge there are no data on training in advanced abdominal POCUS. Comparable to advanced cardiac POCUS it would be understandable that advanced abdominal POCUS requires training comparable to the learning efforts done by residents in radiology

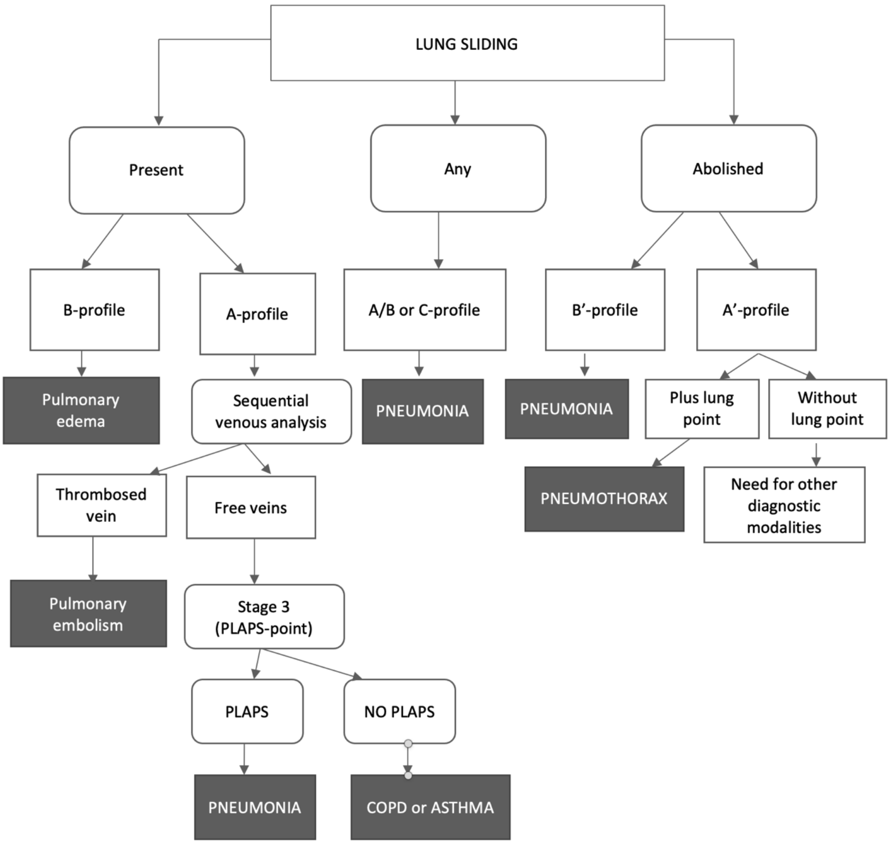


Fig. 2. Decision tree BLUE protocol (reproduced with permission of Professor Lichtenstein). (For interpretation of the references to color in figure legend, the reader is referred to the web version of this article.)

Table 1: ***Terminology and other aspects of cardiac critical care ultrasound***

	Terminology	Basic level	Training basic	Training advanced	Number of examinations basic	Number of examinations advanced
WINFOCUS 2008 (30)	Emergency echo Level 1 Level 2 Level 3	Standard views (PLAX, PSAX, A4CH,S4CH AND SIVC) No TEE	Not specified	Level 1 not specified Level 2 comparable to cardiologist Level 3 minimum level 2 education plus more	Not specified	Level 1 not specified Level 2 125 (50 TTE and 50 TEE minimum) Level 3 not specified)
ACCP/SRLF 2009 (19)	Critical Care Echocardiography (CCE) Basic Advanced	Standard views Basic Doppler for severe valve regurgitation TEE included	Not specified			
ESCIM round table 2011 (15)	Critical Care Echocardiography (CCE) Basic Advanced	Standard views TEE optional	10 h	40 h	30 TTE	150 TTE
JASE 2017 (11)	FOCUS Focused Cardiac Ultrasound	5 standard views No TEE	Not specified	Not specified	Not specified	Not specified
EACI 2014 (12)	FOCUS Focused Cardiac Ultrasound	Not specified	Not specified	Not specified	Not specified	Not specified
CCM 2016 (29)	Bedside Cardiac Ultrasound	Standard views	12 h	Not specified	Not specified	Not specified
EACI 2018 (31)	FOCUS Focused Cardiac Ultrasound	No TEE Standard views Lung ultrasound	Practical training followed by post course ultrasound examinations. Hours needed depending on local situation	Not specified	Not specified	Not specified

Parasternal long axis (PLAX), parasterbak short axis (PSAX) apical 4 Chamber view (A4CH), subcostal 4 chamber view (S4CH) and subcostal inferior vena cave (SIVC)

Table 2: ***Recommendations on different components of POCUS***

	Basic		Advanced	
POCUS Cardiac	Methods Trans Thoracic 5 standard views 4 questions to be answered Left ventricle size and function Pericardial fluid/tamponade Over or underfilling	Suggested training requirements Combination of web-based pre-course and hands-on training (minimum of 5 h) Can be locally trained using experienced local staff or other basic course Irg/eurpean-diploma-in-echocardiography-edec-apply-now/	Methods Compresnesive trans thoracic examination using at least Dynamic parameters Doppler techniques Valvular pathology Trans esophageal echocardiography (TEE)	Suggested training requirements Extensive program Training programs on national or international basis for instance European Society of Intensive Care Medicine https://www.esicm
Minimum of 3 h hands-on	No specific POCUS training	Part of training program in pulmonology Can be locally trained using experienced local staff or other basic course		

Abdomen	No firm recommendations, possible focus on Presence of intraperitoneal fluid Kidney outflow obstruction Guiding ascites drainage	Comparable to training in basic cardiac POCUS	No specific POCUS training	Recommendations from other specialties for instance American College of Emergency Physicians can be used https://www.acep.org/globalassets/uploads/uploaded-files/acep/- membership/sections-of-membership/ultra/- ultrasound-policy-2016--complete_updatedlinks_2018.pdf
Vascular	Training in guiding insertion of central lines using ultransound Diagnosis of deep venous thrombosis	Central line insertion is usually trained on the job Could be part of an integral basic POCUS training	No specific POCUS training	No recommendations

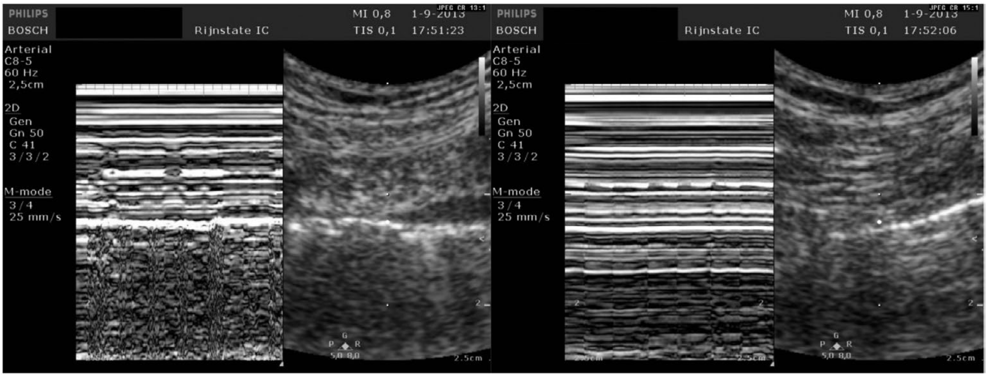


Fig. 3: Basic lung POCUS, the use of M-mode seashore sign (left) and barcode sign (right).

Basic vascular POCUS

Vascular ultrasound is also mandatory in many countries during the insertion of central lines (vascular access), especially in the internal jugular vein.[34,64,65] After central line placement ultrasound could be used to check for proper position and occurrence of complications. [34,66,67]

Because the insertion of central lines is a frequently per- formed technique in the intensive care, we assume that the use of ultrasound during insertion can be seen as a basic skill for every critical care physician. Being hard to train in healthy volunteers, the use of ultrasound for vascular access shall be in most clinics trained on the floor,[68] the use of phantoms may improve training skills.[69]

Vascular access can be part of a basic POCUS training program.[63] The use of ultrasound to rule out venous thrombosis is also considered to be a part of basic vascular ultrasound.[34,36,70]

Advanced vascular POCUS. There are no data on critical care advanced vascular POCUS, but advanced vascular POCUS could consist out of ultrasound of arterial (aortic, carotic or peripheral) and venous disease including the use of color-duplex techniques.

In Table 2 we summarize the different recommendations for each component.

5. How to implement POCUS in your local hospital?

At the moment not all intensivists are experienced in POCUS [52] but this number is increasing. There will be differences between hospitals in the amount of POCUS trained staff. Some intensive care departments are staffed by POCUS trained intensivists, in other departments some intensivists are trained and in some intensive care departments there are no trained intensivists. As described earlier there are also differences between countries in the degree of POCUS training of intensivists.
It is impossible to give recommendations suitable for every local situation in how to obtain POCUS skills. What seems to be indispensable is the ambition to start using POCUS and the willingness to train.
As most guidelines and reviews are put together by different societies of different backgrounds, we would advise the intensive care clinician wanting to implement POCUS to join hands with local departments, for instance cardiology, radiology and pulmonology (but also other departments could be included) to implement POCUS in the best way. Together aspects of quality of ultrasound skills, storage of ultrasound examinations, back up if extra ultrasound skills are needed and so on could be locally discussed and settled.
In our hospital we used the following strategy:

- the ICU staff agreed on the importance of obtaining POCUS skills.
- the ICU staff participated in basic training programs.
- we set up a local POCUS plan with help from the departments of cardiology and radiology for training and quality purposes.
- we expand POCUS skills by starting training residents.
- POCUS is incorporated in daily practice.

6. Medical-legal issues

Being a worldwide development legal issues concerning the use of POCUS will differ from one country to another. What is probably universal is that the physician using POCUS should be properly trained, certified and able to prove that competencies are maintained.[71] Again there will be differences between countries in the way POCUS is already firmly established within a legal framework. In the Netherlands for instance the general law on health care states that a physician is only authorized if competent. We advise to discuss this issue with one's local legal department and to follow the advice from the national authorities.

7. Conclusion

As we have described in our paper there are many reviews and guidelines concerning POCUS. However, in daily practice clinicians prefer a rational and practical approach concerning POCUS. In this paper we have tried to define POCUS in a rational way and to propose an implementation strategy of POCUS that could be helpful for clinicians. With the use of at least the basic components of POCUS the intensivist will have an extra powerful instrument in the evaluation of an unstable patient. Of course, POCUS is work in progress and there will be many new developments which will need proper evaluation. Issues such as development of proper training programs, the need for sufficient numbers of certified trainers, consolidation of ultrasound skills, certification, legal and financial questions remain challenges. POCUS is developing from only cardiac and pulmonary ultrasound to full body implementation of ultrasound and is an important addition to our physical diagnosis. Questions about quality and training in all different applications will have to be addressed.

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Chapter 3: Instructions for the use of critical care ultrasound in Dutch daily practice: the Rijnstate ICU manual, ready for broad acceptance

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Basic cardiac ultrasound and lung ultrasound

Introduction

The use of ultrasonography in the diagnosis and treatment of critical illness has increased extensively. Critical Care Ultrasound (CCUS) has become an important tool for intensivists. CCUS is easily accessible and is a rapid diagnostic bedside tool that should be considered as an extension of the physical examination. The answers to many clinical questions can be found through a focused CCUS investigation. This manual has been developed to address the requirement of intensive care physicians to rapidly identify cardiovascular and respiratory problems by using basic cardiac ultrasound (BCU) and lung ultrasound (LUS) in order to apply appropriate therapy – especially in life threatening situations. We want to emphasize that BCU is not intended to replace transthoracic echocardiography (TTE) performed by cardiologists; as well as LUS, it is meant as a targeted examination to find answers to specific clinical questions. However, it is not feasible to have a cardiologist or radiologist available on call on a 24-hour basis to perform bedside ultrasound in the ICU.[1] Recently the term binary ultrasound was introduced by Bosch et al.[2] to emphasize that ultrasound should be used to answer clinical questions with a yes or a no. With proper training, intensive care physicians can achieve a high level of competence in all aspects of ultrasonography; the intensivist ultrasonographer has to be proficient to be qualified. Proficiency includes the knowledge of when to ask for expert advice.

According to the 2009 La Société de Réanimation de Langue Française (SRLF) / American College of Chest Physicians (ACCP) "Statement on Competence in Critical Care Ultrasonography" CCUS is divided into General Critical Care Ultrasonography (GCCUS) (pleural/lung, abdominal and vascular) and Critical Care Echocardiography (CCE) or cardiac ultrasound (CU) basic and advanced.[3] This manual will discuss "the Arnhem protocol" of BCU and LUS through stepwise instructions and illustrations supported by internet-based video demonstrations.

Daily practice in the Netherlands

One of the difficulties in Dutch daily practice is that physicians who want to become skilled in CCUS have limited access to training. Although local training programs have been developed, specific training programs designed for intensivists at national level are not yet widely available. The RACE (Rapid Assessment of Cardiac Echo) course,[4] currently organized by the Netherlands Society of Intensive Care, is the national basic ultrasound course. There are also other courses organized by various hospitals.

Training programs

Focused bedside ultrasonography by intensivists is feasible and can be performed safely and rapidly in order to guide the diagnosis and management of critically ill patients. However, false interpretation or application of data obtained by a poorly skilled ultrasonographer may have adverse consequences.[5] To avoid misuse, adequate training is essential.[1] Maintaining good levels of competence in staff is also a key element of the successful use of CCUS. Inappropriate use or misapplication of CCUS could potentially slow the acceptance of bedside ultrasound performed by intensivists.[1]

Training requirements

According to the 2009 European Society of Intensive Care Medicine (ESICM) annual meeting "Expert Round Table on Ultrasound in ICU", the following minimal requirements leading to competence in GCCUS and basic CCE/CU have been defined as follows.

For theoretical training: a minimum of 10 hours is required to be divided between lectures and didactic cases with image-based training, in which both internet-based learning and lecture format should be available to trainees in a blended fashion.

For practical training: there was no consensus regarding the required number of examinations to be performed by the trainee. However, a review of the literature suggests that 30 fully supervised transthoracic echocardiography studies is a reasonable training target for people to achieve competence in image acquisition. The trainee should maintain a logbook of his/her scanning activities including reports of ultrasound examinations performed and/or interpreted and co-signed by both trainee and supervisor.[6]

Future developments

At present we are at the beginning of the development of CCUS in the Netherlands. The challenge is to provide adequate training to every intensive care physician. This will enable them to perform BCU and LUS at point of care in order to guide the diagnosis and management of patients with cardiopulmonary failure.[7] In the near future, it will be possible to expand competence to all aspects of CCUS such as bedside diagnosis of deep venous thrombosis, identification of intra-abdominal fluid, or diagnosis of hydronephrosis. We recommend that the initial training of Dutch intensivists should focus on BCU and LUS.

Basic cardiac ultrasound

The aim of BCU is to provide answers to a limited number of clinical questions frequently encountered by intensive care physicians. BCU is a qualitative and targeted tool that can be repeated in order to evaluate specific therapeutic interventions, such as, whether to choose between fluids or diuretics, vasodilators or vasopressors. Because specificity is favored over sensitivity, well-defined results will lead to changes in patient regimen, whereas indeterminate results will require consultation with a more experienced echocardiographer.[3] Competence in BCU requires intensive care physicians to integrate echocardiographic results into management strategy after cognitive training. The goals of training are as follows.

Goals

1. Through BCU, an intensive care physician is able to identify normal cardiac images together with their adjacent structures and accessory anatomy.
2. Through BCU, an intensive care physician is able to recognize and apply the five standard basic cardiac ultrasound views (PLAX, PSAX, A4C, SC, SC-IVC).
3. Through BCU, an intensive care physician is able to identify and interpret aberrant phenomena, especially hemodynamic disturbance (LV-dysfunction, RV-dysfunction, tamponade and intravascular volume status). The results of the examination are translated into daily clinical practice in order to apply focused therapy.

Type of transducer

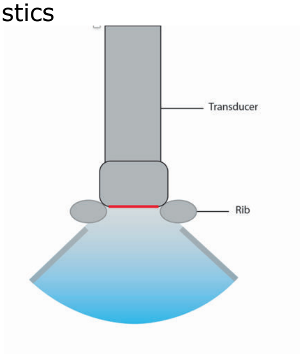
A BCU examination is performed with a phased array transducer (1.5 - 4 MHz) (figures 1, 2) that has a small footprint to fit between the ribs, thus making it best suited for cardiac imaging. Because of low frequency, it has good penetration but poor axial resolution. In terms of electronic steering, it has a better lateral resolution than the curvilinear probe.[4]

Positioning and preparation

1. The patient is placed in the left lateral position, if possible, with the left arm abducted (figure 3).
2. The patient's details are entered into the machine.
3. The ECG is connected to the ultrasonography machine.

Fig. 1: Phased-array transducer.

Fig. 2.Schematic phased-array characteristics



Standard views [4]

1. **Parasternal Long Axis (PLAX) view**
   - Probe position: normally, 2nd to 4th intercostal space, left of the sternum (figure 3).
   - Pointer direction: at around 11 o'clock (figure 3).
   - View: longitudinal section of the heart (figure 4).
   - Optional: link to internet-based video demonstration of PLAX. [8]

2. **Parasternal Short Axis (PSAX) view**
   - From the PLAX position to PSAX (figure 5): rotate the transducer 90° clockwise.
   - Tilt the transducer superiorly and inferiorly to obtain the three levels of the left ventricle (LV):

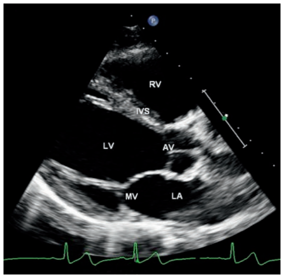
1. Basal: mitral valve (figure 6)
2. Mid: papillary muscles (figure 7)
3. Apical (figure 8)
   - Tilt the transducer superiorly and angle medially to obtain the aortic valve level (*figure 9*).
   - Optional: link to internet-based video demonstration of PSAX.[9]

Apical 4 Chamber (A4C)

- The transducer is placed directly on the area where the apical pulse is palpable (figure 10). This position is usually located at the 5th intercostal space and in the mid-axilla area.
  - The pointer is directed towards the 3 o'clock position (posteriorly).

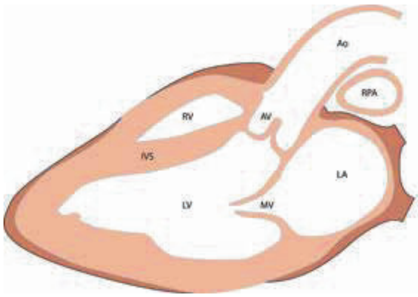
Fig. 3: PLAX positioning: the patient is placed in the left lateral position, if possible, with the left arm abducted. Probe position: 2nd to 4th intercostal space, left of the sternum. Pointer direction: at about 11 o'clock.

Fig. 4 A: PLAX view



RV: right ventricle. IVS: interventricular septum. LV: left ventricle. LA: left atrium. MV: mitral valve. AV: aortic valve

Fig.4 b: PLAX schematic view



RV: right ventricle. IVS: interventricular septum. LV: left ventricle. LA: left atrium. MV: mitral valve. AV: aortic valve. Ao: aorta. RPA right pulmonary artery

- The transducer is tilted superiorly.
- The A4C view can be obtained (figure 11).

The apical 5 chamber (A5C) and apical 2 chamber (A2C) views and their accessory measurements, determination of stroke volume and detailed analysis of segmental function, respectively, will be covered in the advanced ultrasound course. However, recognizing these views in BCU can contribute to the process of understanding the potential obtained views in the A4C position.

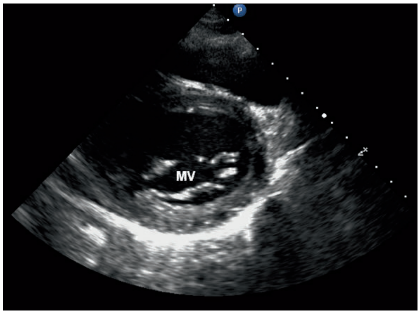
- Optional: the transducer is tilted anteriorly from the A4C view; the A5C view can be obtained (figure 12).
- Optional: to switch from the A4C view to the A2C view (figures 13, 14) rotate the transducer approximately 60° counterclockwise.

The pointer is at approximately 12 o' clock (superiorly).

- Optional: link to internet-based video demonstration of apical view (A4C, optional: A5C and A2C). [10]

Fig. 5: PSAX positioning: rotate the transducer 90° clockwise

Fig. 6: PSAX view, basal level. MV: Mitral valve



3. Subcostal (SC) view

- The transducer is placed in the subxiphoïd position along the midline of the patient and tilted slightly anteriorly.
- The transducer is pointed at the left mid-clavicular region or left shoulder (figures 15, 16).
- The pointer is at approximately 3 o' clock.

Fig. 7A: PSAX view mid-level. Arrows: papillary muscles

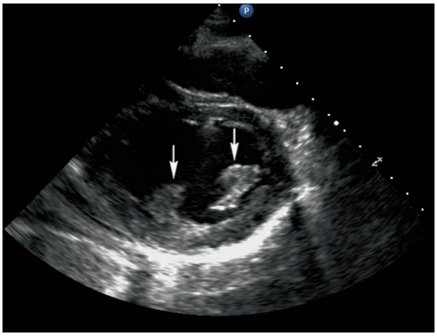
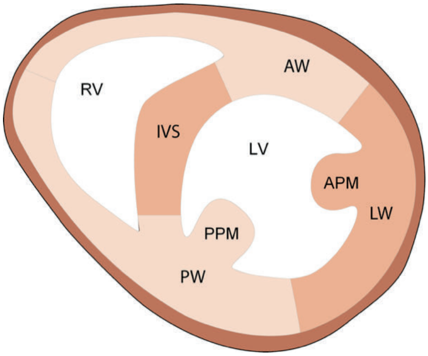
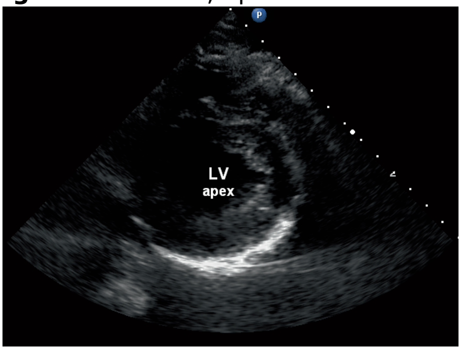


Fig. 7 B: Schematic PSAX view.



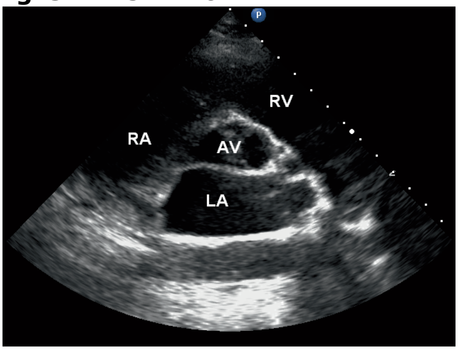
LV: left ventricle. RV: right ventricle. IVS: interventricular septum. AW: LV anterior wall. PW: LV posterior wall. LW: LV lateral wall. PPM: posterior papillary muscle. APM: anterior papillary muscle.

Fig. 8: PSAX view, apical level.



LV: left ventricle

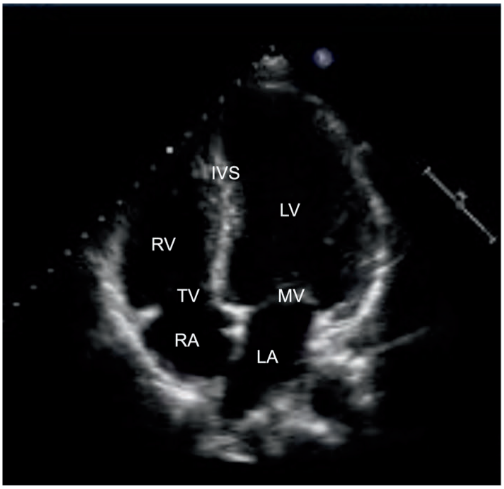
Fig .9 A: PSAX view



RA: right atrium. AV: aortic valve. LA: left atrium. RV: right ventricle.

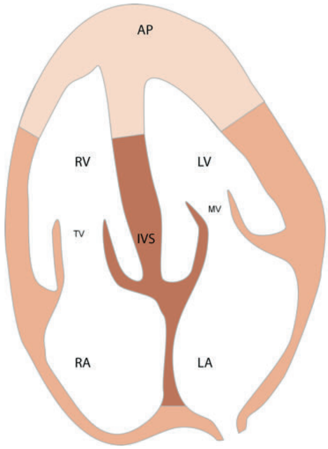
Fig. 10: To obtain the A4C view: the transducer is placed directly on the area where the apical pulse is palpable.

Fig. 11 A: A4C view



RV: right ventricle. LV: left ventricle. TV: tricuspid valve. MV: mitral valve. RA: right atrium. LA: left atrium. IVS: interventricular septum

Fig. 11 B: Schematic A4C view



RV: right ventricle. LV: left ventricle. TV: tricuspid valve. MV: mitral valve. RA: right atrium. LA: left atrium. IVS: interventricular septum. AP: apex.

Fig. 12: A5C view

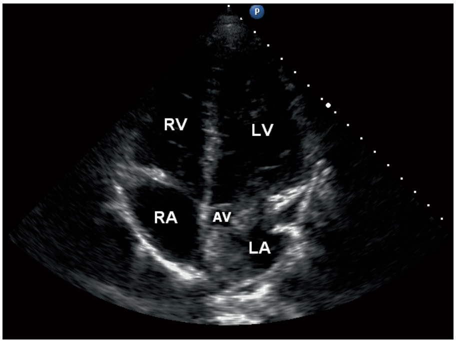
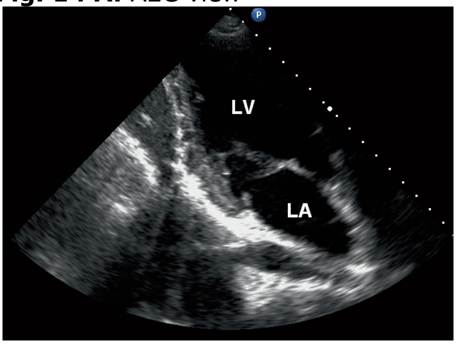


Fig. 13: A2C view: to switch from A4C to A2C view: rotate the transducer 60° counterclockwise. The pointer is at approximately 12 o'clock.

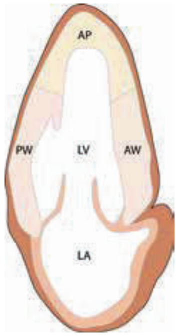
RV: right ventricle. LV: left ventricle. RA: right atrium. LA: left atrium. AV: aortic valve

Fig. 14 A: A2C view



LV: left ventricle. LA: left atrium

Fig. 14 B: Schematic A2C view



LV: left ventricle. LA: left atrium. AW: anterior wall. AP: apical wall. PW: posterior wall.

Fig. 15: SC view: the transducer is pointed at the left mid-clavicular region or left shoulder. The pointer is at approximately 3 o'clock.

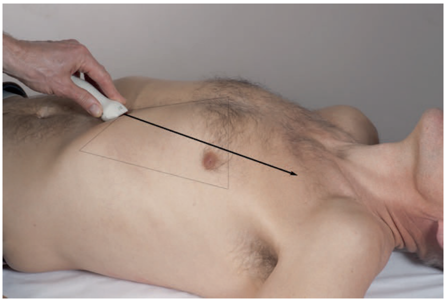
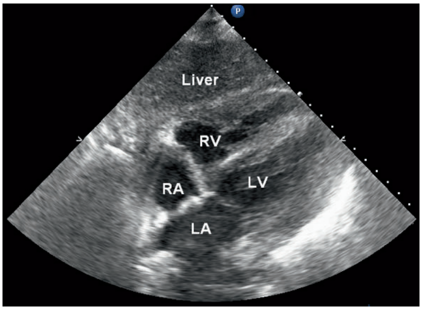


Fig. 16: SC view



RV: right ventricle. RA: right atrium. LV: left ventricle. LA: left atrium.

This view is often the best quality view in a critically ill patient. It provides a good view for the assessment of cardiac function in order to rapidly identify imminently life-threatening causes of shock (e.g. pericardial tamponade, acute cor pulmonale, profound hypovolemia with LV end systolic effacement, or thrombus in transit).
- Optional: link to internet-based video demonstration of subcostal view. [11]

4. Subcostal Inferior Vena Cava (SC-IVC) view

From the SC position the transducer is angled towards the patient's right side and is subsequently rotated counterclockwise until the transducer marker is at the 12 o'clock position. This results in a long axis view of the IVC, as it passes through the liver and terminates at the IVC-right atrium junction (figures 17, 18).
- Optional: link to internet-based video demonstration of SC-IVC view. [12]

Left heart assessment

In the acute clinical setting, an assessment of LV function is a key part of the BCU examination. The high prevalence of coronary artery disease and associated ischemia often affects LV contractility, acute or chronically. This can result in compensatory LV dilatation and regional wall motion abnormality.[4]

Basic questions about LV function

- What is the global LV function?
- Presence of dilatation? Answer: yes/no/not sure.

Right heart assessment

Right heart failure should always be considered as a possible cause for hemodynamic failure.

- It can be a source of primary pathology.
- It can reflect circulatory changes as a result of LV pathology.
- It can provide information concerning major respiratory pathophysiology.[4]

The subcostal (SC) view is often most suitable, especially where obese, mechanically ventilated patients or patients with chronic pulmonary disease are concerned.[4]

In right heart assessment, the size and contractibility of the RV are examined. Tricuspid Annular Plane Systolic Excursion (TAPSE) measurement can assess RV contractility without the need for sophisticated machines or Doppler studies. TAPSE reflects the longitudinal motion of the tricuspid annulus and correlates with RV systolic function. It is measured in the A4C view by placing an M-mode cursor along the lateral tricuspid annulus and is defined as the peak-to-peak distance of the total excursion during systole (figure 19). A greater distance travelled implies greater RV systolic function. The normal reference limit is a TAPSE of > 17 mm.[13]

Basic questions about RV function

- What is the global RV function?
- Presence of dilatation? Answer: yes/no/not sure.

Pericardial effusion [4]

Normally 5-10 ml of fluid is present in the pericardial space. Various pathophysiologic processes can cause either slow or rapid accumulation of fluid in the pericardial space.

- The pericardium can be a source of primary pathology (e.g., infection, inflammation) gradually resulting in pericardial effusion.
- Acute accumulation of pericardial fluid or blood in the pericardial space can cause cardiac tamponade resulting in hemodynamic failure.

The PLAX and subcostal views are often most suitable in this condition.

Pericardial effusion can be seen as an echo-free space. In the case of an echo-free space, it is important to rule out the presence of a fat pad and pleural effusion. Fat pads can be seen in obese patients and are, in contrast to pericardial effusion, not completely echo-free. Furthermore, a fat pad moves in concert with heart motion and is only present anteriorly, not posteriorly. Pleural effusion can be seen as an echo-free space posterior to the descending aorta.4

Pericardial effusion is anterior to the descending aorta, while pleural effusion is posterior to the descending aorta (figure 20)

Severity of pericardial effusion (table 1): the largest epi- and pericardial separation (echo-free space) is measured at end-diastole

Fig 17: SC-IVC view: the transducer is rotated approximately 90°. Point posteriorly. Pointer upward

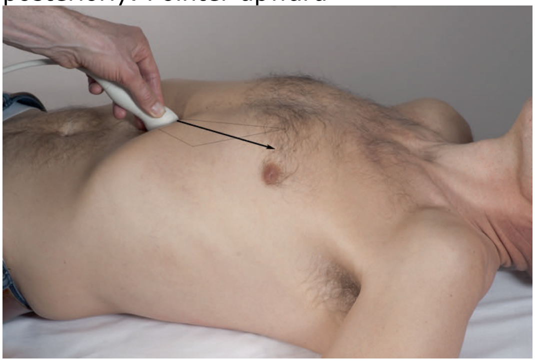
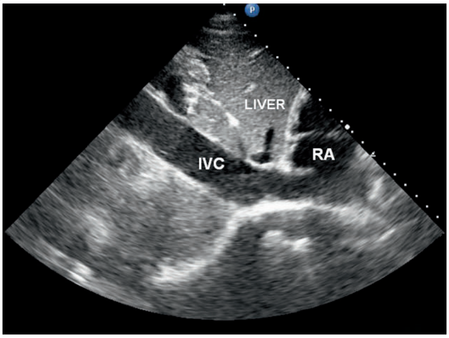


Fig. 18: SC-IVC view.

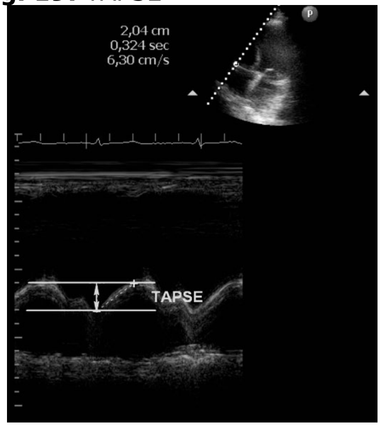


Basic questions about pericardial effusion:

- Is pericardial fluid present? Answer: yes/no/not sure
- If yes: significant quantity (> 20 mm)? Answer: yes/no

Note 1: Tamponade is considered a clinical diagnosis. Ultrasound is an important aid to making the diagnosis of tamponade.

Fig. 19: TAPSE

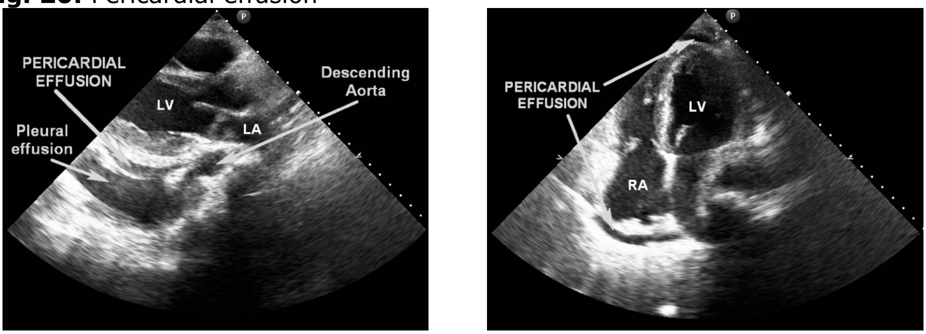


Note 2: The diagnosis of pericardial effusion/tamponade in post-cardiothoracic surgery patients can be more difficult than in non-operated patients. This may require expert level assessment with transesophageal echocardiography

Volume status

Maintaining adequate circulation in patients is one of the main tasks of intensivists, especially in cases of shock.
However, assessing intravascular volume remains one of the most challenging jobs in intensive care medicine.[4]
The methods that are currently available, such as respiratory IVC diameter variation (ΔIVC) and right atrial pressure correlation, have their limitations as interpretation is often influenced by the existence of comorbidity and mechanical ventilation.[4]

Fig. 20: Pericardial effusion



A. in PLAX view. LA: left atrium. B. in A4C view. RA: right atrium. LV: left ventricle.

Recently Muller et al. emphasized that ΔIVC, being a dynamic preload index, cannot reliably predict fluid responsiveness in patients with acute

circulatory failure (ACF) who are breathing spontaneously.[14] In contrast to findings reported in mechanically ventilated septic patients, dynamic parameters have been shown to be an ineffective fluid responsiveness predictor in patients breathing spontaneously. [15]
In patients with spontaneous ventilation, respiratory variations are highly variable from one cycle to another in any given patient and between different patients. As a result, the influence of the breathing pattern on ΔIVC is also variable. In addition, ΔIVC may be influenced by the magnitude of respiratory movements, especially in cases of dyspnea in patients with circulatory failure and/or shock.[15] In summary, ΔIVC should be interpreted with caution in patients breathing spontaneously with ACF. In general it can be stated that high ΔIVC values (> 40%) are usually associated with fluid responsiveness, while low values (< 40%) cannot exclude fluid responsiveness.[14]

Table 1: [4]

Severity	Characteristics
Minimal/physiological	End-systolic separation of epicardium and pericardium posteriorly
Small	Echo-free space in both anterior and posterior space Echo-free space Appears throughout the cardiac cycle Echo-free space: < 10 mm
Moderate	Echo-free space: 10-22 mm Surrounds the entire heart
Large	Echo-free space:> 20 mm Swinging heart motion

More studies are needed to further evaluate ultrasound and fluid responsiveness.
In the case of mechanical ventilation, predicting fluid responsiveness is also difficult.
In the future it would be conceivable to incorporate an assessment of intravascular volume and fluid responsiveness as a substantial subject in an advanced ICU ultrasound course. In BCU, fluid responsiveness and/or assessing volume status might be the most difficult part. However, having said this, it is also possible for less experienced doctors to assess volume status and fluid responsiveness on both ends of the volume spectrum: massive overload versus extreme fluid depletion.

Inferior Vena Cava (IVC)[4]

The IVC diameter and its changes are measured during respiration in patients who are breathing spontaneously. The most suitable probe position is the subcostal view. The patient is in the supine position.
IVC is significantly affected by the patient's position, being largest in the right lateral position, intermediate in the supine and smallest in the left lateral position.

2-D

- The transducer is tilted and pointed to obtain the largest IVC diameter.
- The 2-D images are frozen at both end-expiration and end-inspiration.
- The IVC diameter is measured at a distance of 2 cm (point of maximal collapse) from the IVC-RA junction.

M-mode (time-motion)

- Tilt and point the transducer to obtain the largest IVC diameter.
- Place the cursor perpendicular to the IVC at a distance of 2 cm (point of maximal collapse) from the veno-atrial junction.
- Start M-mode and ask the patient to "sniff" (the sniff maneuver) (figures 21, 22).

Fig. 21: Normal IVC response to sniff maneuver

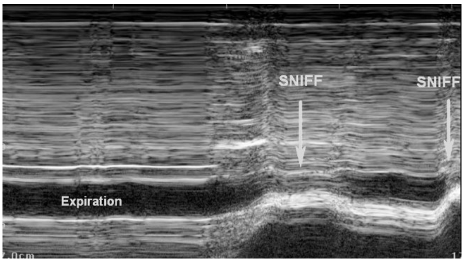
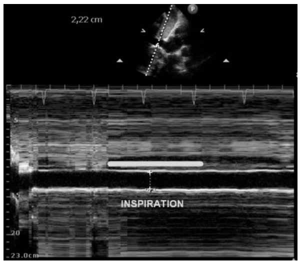
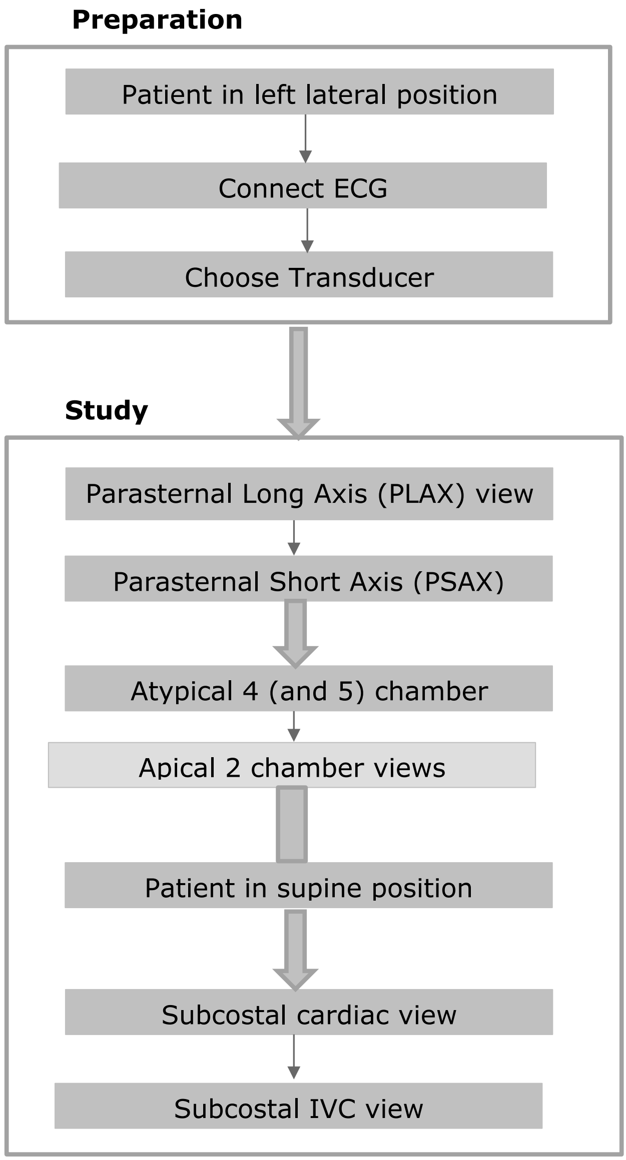


Fig. 22: Non-collapsing and dilated IVC in a spontaneously breathing patient



Summary basic cardiac ultrasound

Flowchart 1 [4]



Template report BCU

1. **LV function characteristics?**
   - Size (diastole): small/normal/dilated (through ‘eyeballing’).
   - Contractility: normal/decreased/hyper-dynamic.
2. **RV function characteristics?**

In general terms the RV must be smaller than the LV. When the RV size is similar to or larger than the LV size it indicates the presence of underlying disease. Additional quantitative ultrasound by a cardiologist is recommended.

- Size: small/normal/dilated.
- Contractility: normal/decreased/hyper-dynamic.
- TAPSE: ≤ 17 mm: abnormal, indicates reduced RV systolic function13, > 17 mm: normal RV function. 13

3. Tamponade?

Signs of tamponade:

- Right atrium: early systolic collapse.
- Right ventricle: early diastolic collapse.
- IVC diameter and collapsibility (in mechanical ventilation)
    - dilated and/or fixed: True Tamponade;
    - non-dilated and collapsible: fluid depletion resulting in low diastolic pressure.
    - Intravascular volume status?

Be careful with the interpretation of the assessment of volume status and/or fluid responsiveness in spontaneously breathing patients. In the absence of accurate universal ultrasonographic methods, we suggest using ∆IVC.

In spontaneously breathing patients:

∆IVC: (Dmax – Dmin/Dmax) x 100. Where D = IVC diameter.[4, 14]

Cut-off values:

∆IVC > 40% is usually associated with fluid responsiveness, while∆IVC < 40% cannot exclude fluid responsiveness.[14]

Lung ultrasound (LUS)

The major advantage of pleural- and lung ultrasound is its immediate bedside availability. Several recent publications demonstrate that ultrasound is more reliable than bedside chest radiography, and that it is similar in performance characteristics to computed tomography (CT) scan for critical care applications. [16-20] LUS is a non-invasive and straightforward method that allows the frontline clinician to identify important findings such as pneumothorax, normal aeration pattern, interstitial abnormality, consolidation, and pleural effusion. At a more advanced level, it allows regional assessment of lung recruitment and close monitoring of treatments and maneuvers aimed at improving lung aeration. Bouhemad et al. correlated bedside LUS with pressure-volume curves for the assessment of PEEP-induced lung recruitment.[21]

Learning LUS is straightforward. Competence requires the intensive care physician to integrate ultrasonographic results into management strategy after cognitive training and requires the following goals.

Goals

1. Through LUS, an intensive care physician is able to identify normal

images of pleura and adjacent structures/ phenomena (parietal and visceral pleura, bat sign, A-lines, B-lines, lung sliding).
2. Through LUS, an intensive care physician is able to recognize aberrant images/phenomena (absent lung sliding, lung point, lung pulse, pleural effusion, PLAPS).
3. Through LUS, an intensive care physician is able to interpret aberrant images/phenomena and translate them into daily clinical practice (e.g. absence of ventilation, pleural effusion).

Type of transducer

The LUS examination is performed with a Linear transducer (5-12 MHz) (figures 23, 24). This transducer has a large footprint. Because of high frequency it has good axial resolution for structures closer to the body surface. It has poor penetration. As an alternative, the cardiac transducer may be used if deeper thoracic structures are to be imaged, or if the patient has a thick chest wall (due to obesity, oedema, heavy musculature). Use of the lower frequency transducer improves penetration but at the expense of reduced resolution.

LUS: Schematic anatomy of patient's right side (figure 25)

Positioning and preparation
1. The patient is placed in the supine position, if possible.
2. The patient's details are entered into the machine.

Fig .23: Linear-array transducer

Fig. 24: Schematic linear array characteristics

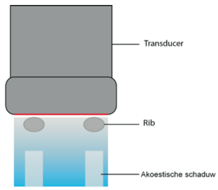


Fig. 25: Patient's right side in LUS: schematic anatomy. Note: the patient's left side in LUS represents a similar schematic anatomy, only instead of the liver the spleen can be identified.

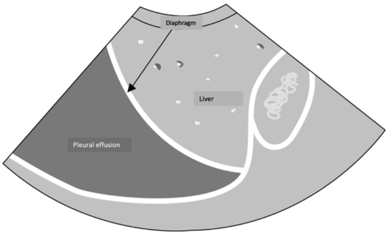
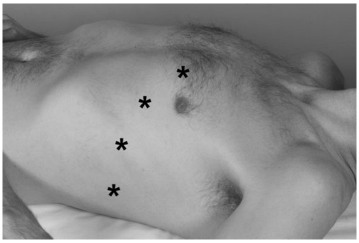


Fig. 26: The transducer is moved towards the lateral thorax, checking for lung sliding at different locations (asterisks).



Probe position: on both sides of the thorax (figure 26).

- Third to fourth intercostal space between parasternal and midclavicular line.
- The transducer is moved transversely on two ribs from medial to lateral.

To obtain a structured examination, both sides of the thorax are divided into three zones (figure 27) as follows: 1) anterior,2) subaxillary, 3) dorsal. In all of these zones two scans are performed, upper and lower half. The examination can be completed in a few minutes. [16-19, 21]

The normal ultrasound image

First, it is important to make a reference image in order to recognize the structures. The transducer is placed perpendicular to the ribs so that two ribs are represented. The echographic shadow of both ribs produces the characteristic image called bat sign (figure 28). Approximately 0.5 cm deep to the periosteal line, a white line is visible. This represents the pleural interface (figures 28, 29).1[6]

Bat sign (figures 28, 30)

Subsequently, the next normal structures can be perceived:

- **A-lines**

A-lines arise as artifacts from reflections of the pleural line in reference to the skin and are at the same distance from one another (figure 31). [17]

- **B-lines**

B-lines or comet tails arise from the pleural line (figure 32). B-lines have seven characteristics: a) comet-like, b) arise from the pleural line, c) hyperechoic, d) well-defined, e) spreading to the lower edge of the screen, without fading, f) synchronous with lung sliding, g) are generated by elements with a high acoustic impedance gradient from the surrounding structures; such as fluid and air.17 More than three B-lines in one intercostal space is abnormal and indicates the presence of an alveolar or interstitial process.

- **Lung sliding**

The movement of visceral pleura in reference to parietal pleura produces the image called lung sliding (figure 33). This physiologic and dynamic sign can be checked in a few seconds; it is identified as respirophasic movement of the pleural line during respiration. [18] It is an indirect sign indicating the presence of the visceral pleura that is in apposition to the parietal pleura.[18] The presence of lung sliding indicates that there is no pneumothorax at the site of the examination.
The Seashore sign refers to the image of lung sliding by using M-mode scanning: the outer motionless part of the chest wall generates horizontal lines, 'the waves', and the deep motion artifacts below the pleural line generate 'the sandy pattern' (figure 34). [16, 17, 20]
Optional: link to internet-based video demonstration of Lung Sliding (shimmering line) and Seashore sign. [22]

Aberrant images

Pathology

Pneumothorax results in loss of lung sliding, as the visceral and parietal pleural surfaces are not in apposition. However, there are other causes for loss of lung sliding such as:

- atelectasis
- main-stem intubation
- ARDS
- pleural adhesions
- pulmonary contusion

Pneumothorax (PNX)

Through LUS, the diagnosis of pneumothorax is quickly excluded by the identification of lung sliding. The anterior thoracic areas should be scanned first in the supine patient, as the pneumothorax space will be anterior in location. Absent lung sliding is the basic and initial step for the diagnosis,16 and strongly suggests pneumothorax (figure 35). However, the clinician must consider other causes for the absence of lung sliding, so that clinical correlation is always required. Absent lung sliding is associated with a characteristic M-mode pattern called Barcode sign (figure 36).

- Optional: link to internet-based video demonstration of pneumothorax.[23]
- Optional: link to video with absent lung sliding in pneumothorax. [25]

Fig. 27A/27B: Ultrasound areas. Zone 1: investigation of the anterior chest wall. Zone 2: lateral wall. Zone 3: posterolateral chest wall. Each zone is divided into upper and lower halves, resulting in six areas of investigation.

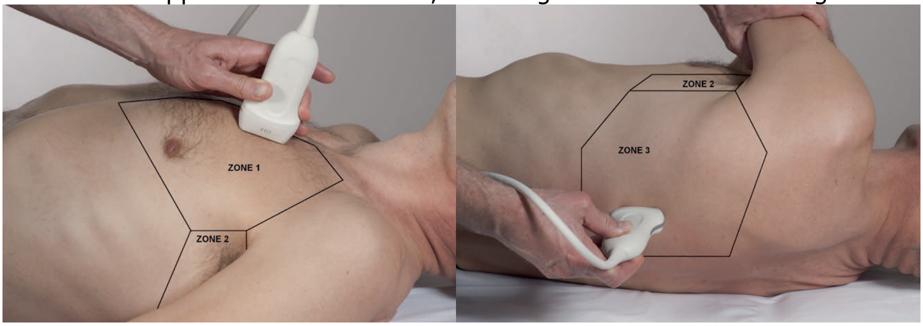


Fig. 28: Normal LUS image with characteristic bat sign.

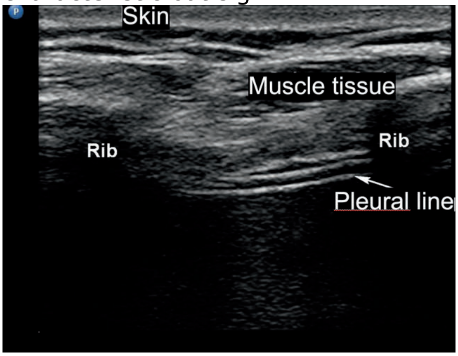


Fig. 29: Schematic image of normal LUS.

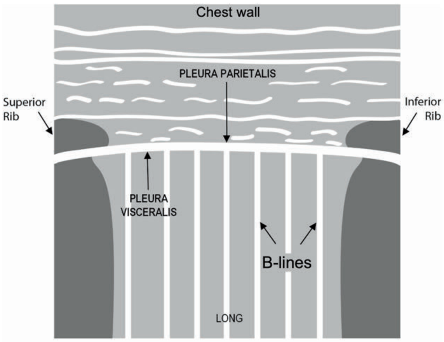


Fig. 30: Bat sign: rib's shadow (asterisks)

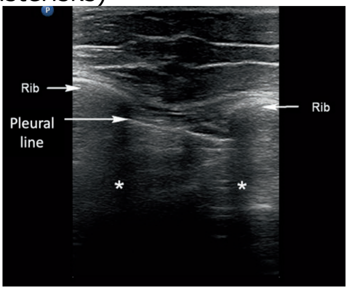


Fig. 31: A-lines

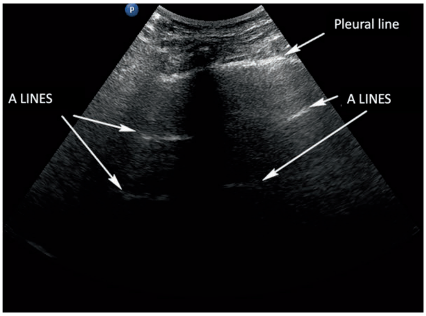


Fig. 32: B-lines (asterisks) arising from the pleural line

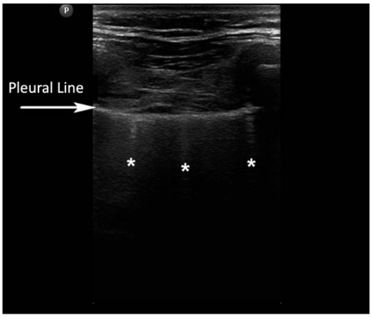


Fig. 33: Lung sliding: horizontal movement or shimmering of the pleural line. Rib's shadow (asterisks).

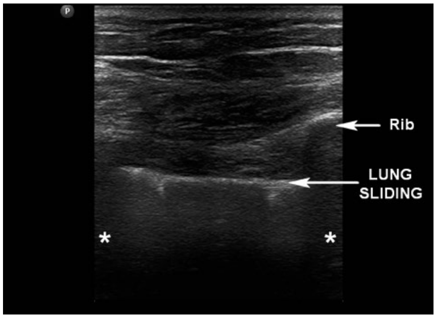


Fig. 34: Seashore sign in M-mode scanning: excludes pneumothorax

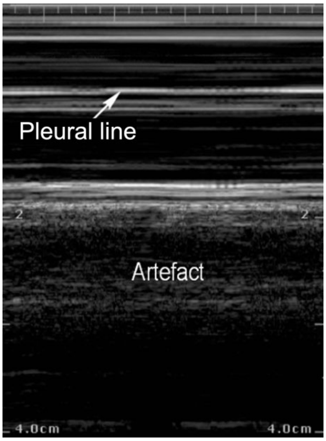
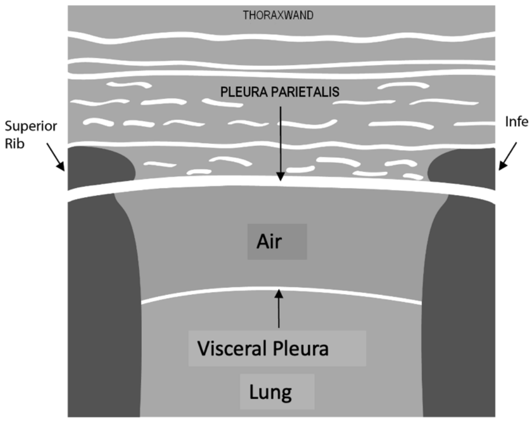


Fig. 35: Schematic image of PNX



Other definitions

- Lung point: the point where the tip of the collapsed lung adheres again to the parietal pleura. The lung point allows confirmation of PNX with 100% specificity.[18] Although some pneumothoraces are total, i.e. the lung is completely collapsed, most are partial with some remaining apposition of the visceral and parietal pleura at some point in the lateral or posterior thorax. The lung point is found where there is respirophasic movement of the partially collapsed lung in and out of the pneumothorax space.
- Lung pulse: a vertical movement of the pleural line synchronous to the cardiac rhythm. Occasionally it can be detected in the absence of lung sliding. It is caused by the transmission of the heartbeat through

a consolidated motionless lung or during apnea. Visualization of lung pulse rules out PNX.[18]

The following diagram describes the steps after finding absent lung sliding (flowchart 2)[18]

Pleural effusion

Pleural effusion is a disorder containing exclusively fluid and no air.16 Pleural fluid, unless loculated, assumes a dependent position in the thorax in the supine patient. Pleural fluid has characteristic findings on ultrasonography:

- Typical anatomic boundaries: this requires definitive identification of the chest wall, the surface of the lung, and the diaphragm.

LUS does not only detect effusion, it can also provide information on its nature. Theoretically, a transudate is hypoechoic, while an exsudate is hyperechoic with mobile particles or septa.[16]

- Hypoechoic or hyperechoic space: this requires definitive identification of either a relatively hypoechoic space or hyperechoic space that is the pleural effusion which is surrounded by the typical anatomic boundaries.
- Dynamic changes: this requires definitive identification of dynamic changes that are characteristic of a pleural effusion such as diaphragmatic movement, movement of atelectatic lung, and movement of echogenic material within the effusion.

Identification of the diaphragm is a key element for safe performance of thoracentesis using ultrasonographic guidance. This requires the examiner to positively identify the diaphragm and subdiaphragmatic organs (spleen or liver, on the left and right respectively), in order to avoid inadvertent subdiaphragmatic device insertion when performing thoracentesis. During respiration it is possible for consolidated or atelectatic lung tissue to move into the image plane.

Various quantities of pleural effusion (figure 37):

- Posterolateral alveolar and/or pleural syndrome (PLAPS): pleural effusion visible as a black shadow just beyond the pleura, often accompanied with atelectasis; visible as a lung part with a higher density (figure 38).[17]
- Optional: link to internet-based video demonstration of ultrasound detection of pleural fluid. [24]

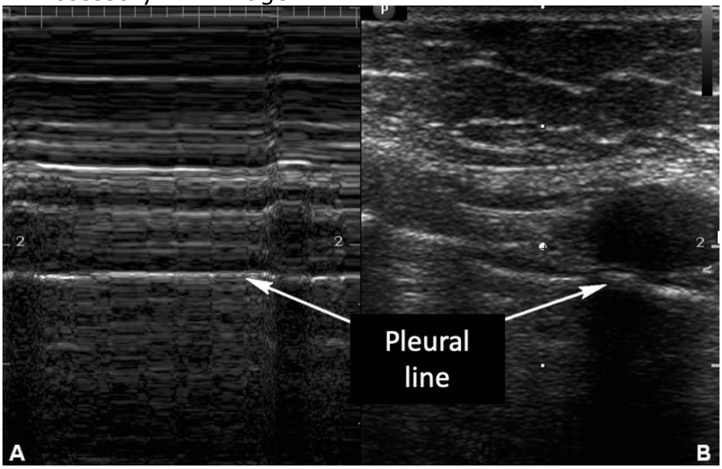
Consequences of LUS examination

- In case of CPR: acute drainage at the side of suspected PNX.
- In cases of dyspnea but clinically stable patients: bedside chest radiograph, CT-scan.

Summary lung ultrasound

Ultrasound of pleura and lungs is a technique that can be learned easily and can be applied instantly and at the bedside. In patients with acute dyspnea a potential lethal condition like pneumothorax can be excluded quickly. Moreover, other diagnoses can be made by ultrasound (flowchart 3).

Fig. 36 A: Barcode sign in PNX at M-mode: no motion of chest wall under lung.
Fig. 36 B: Accessory 2-D image



Flow chart 2. [18]

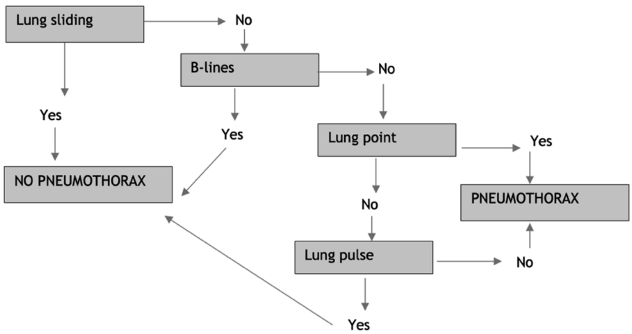


Fig. 37 A: Small quantity of pleural effusion.

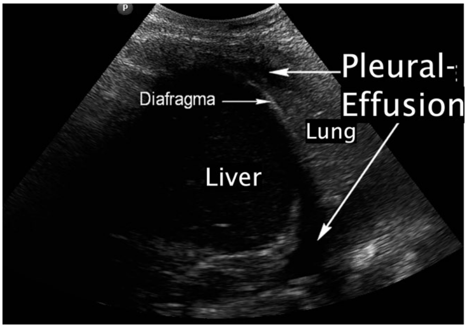


Fig. 37 B: Large quantity of pleural effusion.

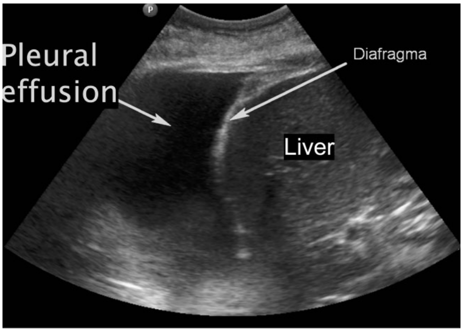


Fig. 37 C Loculated pleural effusion.

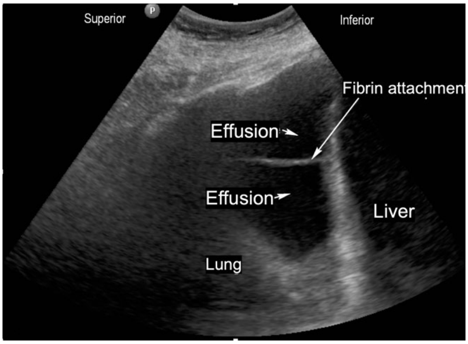
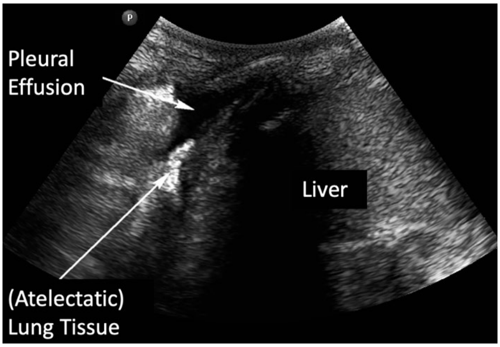
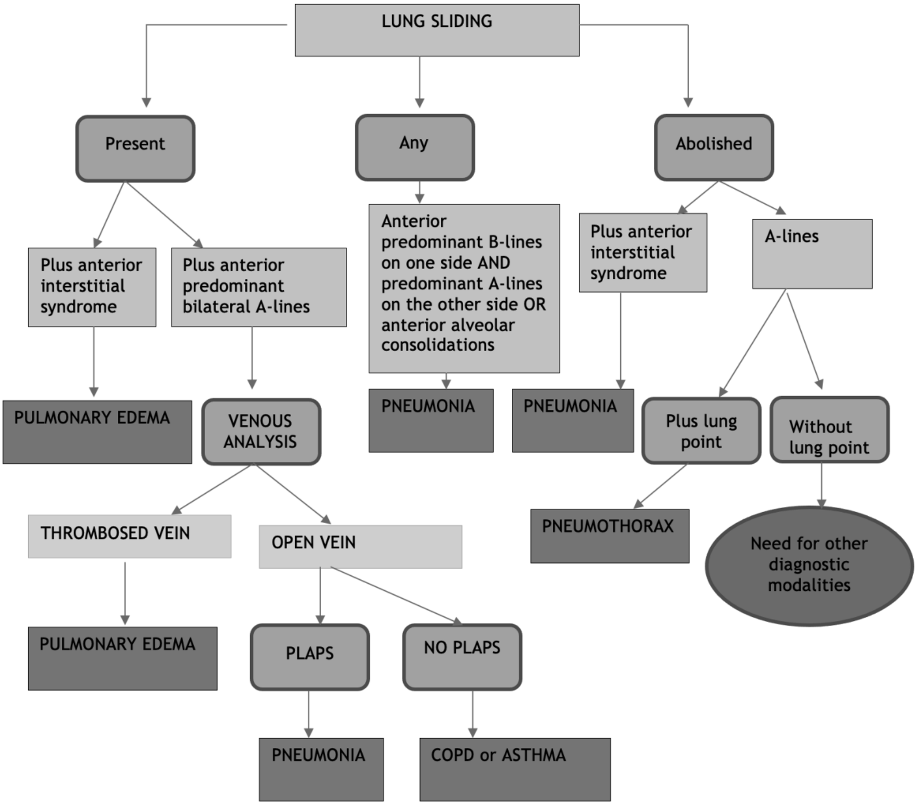


Fig. 38: Posterolateral alveolar and/or pleural syndrome (PLAPS).



Flowchart 3. Utilizing LUS to guide diagnosis of severe (acute) dyspnea according to the BLUE protocol of Lichtenstein et al.20 (with the minor adjustment of translating the profile characters into possible obtainable ultrasound patterns).



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Chapter 4: The implementation of POCUS and POCUS training for residents: the Rijnstate approach

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Abstract

Point-of-care ultrasound (POCUS) is gaining interest in intensive care medicine and good reviews and guidelines on POCUS are available. Unfortunately, how to implement POCUS and practical examples how to train staff and junior doctors is not well described in literature. We discuss the process of POCUS implementation, and a POCUS training program for residents prior to their intensive care rotation in a Dutch teaching hospital intensive care unit. The described four-day basic POCUS course consists of short tutorials and ample time for hands-on practice. Theoretical tests are taken shortly before on the last day of the course, and after three months to assess learning retention. Practical tests are taken on the last day of the course and after three months. We stress the importance of POCUS for intensive care and hope that our experiences will help colleagues who also want to go forward with POCUS.

Highlights

A stepwise implementation strategy for POCUS is presented
Implementation of POCUS requires training of staff, defining components of basic and advanced POCUS, and training of junior staff
Support by radiology and cardiology departments can be of significant value in the acquisition of POCUS knowledge
A course curriculum for residents in internal medicine is presented
POCUS beginners should know their own limitations and ask for help without hesitation

Key words

Implementation, intensive care, point-of-care ultrasound, training program

Introduction

Today, point-of-care ultrasound (POCUS) is considered an important tool for intensivists. [1] Reviews and guidelines on POCUS are published but there is still debate surrounding it , including definitions, content, and training requirements,[2-8] but POCUS is still considered an indispensable tool for every intensivist.[8, 9] Although recognized as an important skill by national societies, POCUS is trained differently in various countries.[10] In the Netherlands, the Dutch Society for Intensive Care (NVIC) provides a basic course (two days on heart and lungs) and a consolidation course in which 40 supervised heart/lung ultrasound exams are included.

In addition to intensivists, the Dutch Society of Internal Medicine recently decided that residents in internal medicine should also be trained in POCUS; a national training program is under construction with some aspects already published.[11]

While literature provides professionals with theoretical guidelines on how to use POCUS, there is far less literature discussing the practical issues of implementing and training in POCUS. The Rijnstate Hospital Department of Intensive Care has used POCUS since 2009 and in 2017, implemented a training program for residents in internal medicine prior to their intensive care rotation. In this narrative review, we share our experiences with the process of implementing POCUS and how we designed our resident POCUS training program on the basis of current literature. We have received questions from colleagues from other hospitals on these issues and hope that by publishing our experiences, both successes and weakness, we can inform and help other educators who want to develop their own local educational POCUS program.

1. Implementing POCUS

This section is divided into three elements: the start, equipment, and collaboration.

1.a. The start

With the increase in publications on the use of POCUS in intensive care, the intensivists of the Rijnstate Hospital Intensive Care Department decided in 2009 that they also wanted to use this technique. Within a week of this decision, the process of POCUS training and implementation was initiated, and training in the basics of cardiac and lung POCUS were provided by an Australian team of POCUS experts (Marek Nalos et al, Nepean Hospital, Australia), a week prior to an international ICU congress. This training-on-the-job approach led to a leap in knowledge and ability to perform basic cardiac and lung ultrasounds by all members of the intensive care staff. Three out of 10 intensive care staff members added skills for abdominal ultrasound by attending a basic abdominal ultrasound in Dusseldorf Germany (Matthias Hofer; http:// medidak.de/semester/sono) and during

daily practice, all staff members and residents were trained in using ultrasound during insertion of central venous catheters. As of the writing of this manuscript, the entire intensive care staff is trained in at least basic cardiac and lung POCUS. Two of the staff members are more experienced and participate in national training programs for POCUS for the Dutch Intensive Care and Internal Medicine Societies In our experience, the simultaneous training of the entire staff helped boost POCUS use in our department and we would recommend this approach.
Success: Every intensivist in our intensive care department is trained in basic lung and cardiac POCUS. All procedures, such as the insertion of central lines are guided by the real-time use of ultrasound.
We published our view on POCUS content,[12, 13] and have integrated POCUS into our daily practice. Today, ultrasound is part of daily care at the Rijnstate Intensive Care Department. In almost all patients, thoracic ultrasound is performed during or shortly after admission and if indicated, also abdominal ultrasound (for example, of the kidneys in cases of urosepsis). Ultrasound is also performed in cases of clinical deterioration. POCUS exam results can be described in our electronic health record (figures 1, 2, 3, and 4, in Dutch).
We are involved in scientific ultrasound research projects, both self-instigated [14, 15] and in collaboration with other institutes,[16] and are currently investigating the use of POCUS for our emergency team; other projects are in preparation.

Fig. 1: *Cardiac POCUS*

○ Indicatie	
○ Uitvoerder	
○ Supervisor	
○ Type echo	• Cor ○ Abdomen ○ Long ○ Vaten
○ Rechter ventrikel	○ Ja o Nee
○ Functie	○ Slecht o Goed o Matig
○ Toelichting	
○ Pericardvocht	○ Ja o Nee
○ VCI	
○ Conclusie	
○ Beelden opgeslagen	○ Ja o Nee

Weakness: The acquisition and retention of POCUS skills took almost a decade and still, not every intensivist in our department has the same POCUS skills. Reasons for the time needed: some have more interest in POCUS than others and POCUS skills must be learned without a pause in daily routine and night shifts. The development of these skills on our ward

is not very different from what the literature reports. Although POCUS is seen as an important tool, it is not used on every patient, [17] and there are intensive care colleagues who state that an intensivist can still be a good intensivist in the absence of POCUS skills.[18]
How can we speed up this process? First, by training internal medicine residents, the use of POCUS in the intensive care department will be stimulated. Forty-four percent of Dutch intensivists have internal medicine as their primary specialism (data from NVIC, personal correspondence), meaning that in the near future, these intensivists will already be trained in basic POCUS. A basic ultrasound course is also advised to residents in anesthesiology but is not obligatory. (https://www. anesthesiologie.nl/uploads/files/Opleiding_ LOP2o I 9 NVA. pdf); 40% of Dutch intensivists have anesthesiology as their primary specialism (data from NVIC, personal, correspondence). At this moment, there is no national obligatory ultrasound training program for intensive care fellows (https://nvic.nl/sites/nvic.nl/files/opleidingseisen%20IC%202006%20%28gewijzigde%20 versie%2oper%201-3-2016%29.pdf), although most fellows will come across POCUS during their fellowship and will be trained on the job. We speculate that in the near future, the Dutch board for intensive care training (GIC) will present formal ultrasound training requirements for fellows which will speed up POCUS implementation in the Netherlands.

Fig. 2: ***Lung POCUS***		
○ Indicatie		
○ Uitvoerder		
○ Supervisor		
○ Type echo	○ Cor ○ Abdomen •. Long ○ Vaten	
○ Links lungsliding aanwezig	○ Ja	o Nee
○ Rechts lungslidig aanwezig	○ Ja	o Nee
○ M-mode sea shore sign	○ Ja	o Nee
○ B-lines	○ Ja	o Nee
○ Conclusie		
○ Beelden opgeslagen	○ Ja	o Nee

POCUS: point-of-care ultrasound; VCI: vena cava inferior

In the meantime, current intensive care staff should be motivated to enroll in at least a basic POCUS course. The NVIC basic course is always fully hooked, but there are other (inter)national courses (www.deus.nl, https:// www.esicm.org/education/courses-2/lives-mc-basic-course-echocardiography/). Publications like our paper can help generate awareness of POCUS and can stimulate colleagues to start a POCUS implementation process on their own intensive care departments.

Fig. 3: *Abdominal POCUS*	
○ Indicatie	
○ Uitvoerder	
○ Supervisor	
○ Type echo	○ Cor • Abdomen ○ Long ○ Vaten
○ Verslag echografie	
○ Beelden opgeslagen	○ Ja o Nee

Fig. 4: *Vascular POCUS*	
○ Indicatie	
○ Uitvoerder	
○ Supervisor	
○ Type echo	○ Cor ○ Abdomen ○ Long • Vaten
○ Verslag echografie	
○ Beelden opgeslagen	○ Ja o Nee

It is a challenge to train all intensivists, fellows, and residents in POCUS, and unfortunately, there are too few available educators to train the large number of physicians. Although guidelines exist on the requirements for the POCUS learner on how to achieve competence, there are less-clear guidelines for the requirements of POCUS-educating staff. POCUS trainers can be physicians from different disciplines, preferably certified in echocardiography, but should at least have significant experience in critical care ultrasound.[6] In our situation, we combine the knowledge of experienced intensivists (without formal advanced certification) with the knowledge of cardiology and radiology colleagues, who are co-authors of this paper.

Some larger intensive care departments may have one or more cardiologists on staff. According to most guidelines, a fully trained cardiologist can be seen as an advanced ultrasound user, thereby capable of educating others in basic cardiac ultrasound. For intensive care departments without a cardiologist, close cooperation with the local cardiology department is advised. [19] An alternative way of ensuring advanced skills is to have one or more intensive care staff members follow an advanced cardiac ultrasound course, for example, the European Diploma in advanced critical Echocardiology (EDEC, https://www.esicm.org/education/edec-2/), but this requires a significant time investment. To our knowledge, there is no advanced abdominal ultrasound course for intensivists, meaning that for expert help, local radiology departments should be available.

Table 1. ***Components of POCUS training***

Image generation	
General introduction	The student will learn the basics of ultrasound (knobology, pitfalls, etc.) The student will learn to perform ultrasound exams using established protocols The student will learn basic ultrasound; no color Doppler The student will learn when ultrasound can be of added value and when more expertise is warranted
Cardiac POCUS	Basic image generation: PLAX, PSAX, A4C, se, SC-IVC
Lung POCUS	Determine the presence or absence of lung sliding Recognize A & B lines Recognize pleural Fluid
Abdominal POCUS	Recognition of normal anatomy (liver, gallbladder, kidneys, spleen, pancreas, large vessels and movement of the bowels Recognition of normal anatomy in the pelvic region (bladder, prostate, uterus, adnex Recognition of intra-abdominal fluid The e-FASTexam (focused assessment by sonography in trauma)
Vascular POCUS including neck	Recognition of large vessels Correct use of ultrasound in performing vascular cannulation Normal anatomy of neck

A4C - apical 4 chamber view: PLAX - parasternal long axis: POCUS - point-of-care ultrasound; PSAX - parasternal short axis; SC - subcostal view; SC-IVC- subcostal inferior vena cava

1.b. Equipment

In our opinion, every intensive care department should have their own ultrasound equipment. Today, even the handheld machines are capable of producing adequate images and the development of portable ultrasound systems has contributed to the increased use of POCUS,[20] but one should be aware of their shortcomings. [21] In this article, we will not discuss the various options; we chose to obtain two high-end ultrasound machines (Philips Affinity) for optimal image quality. In particular, in the beginning when trying to acquire reasonable ultrasound images, it is wise to use an ultrasound machine with optimal image resolution. A hand-held ultrasound device (Philips Lumify) is attached to our emergency trolley and can be used during medica] emergency calls in the hospital.

In addition to data storage on the ultrasound machine itself, we encourage the use of digital image storage facilities to be able to re-assess ultrasound examination for quality or educational purposes.

Success: Both our two intensive care wards have their own high-end ultrasound machines and are connected by WIFI to a digital storage facility.

Weakness: We became highly dependent on our ultrasound machines and, in the beginning, had some technical challenges that were resolved together with the Department of Technical Engineering. We advise having a spare machine available in case of break-down or maintenance.

1.c. Collaboration

From the start, we involved the radiology and cardiology departments in our plans. We have previously reported on POCUS as an important tool for intensive care and that this development was embraced by not only international intensive care societies but also by cardiology societies as well. [3-5, 22, 23] We asked the departments of radiology and cardiology to assist us in our ambitions by helping us train our staff, and later our residents, and to share their ultrasound experience and skills. Their involvement enables them to actively contribute to our training program, and by training together, we emphasize the difficulty of ultrasound and the need to be critical towards the acquired ultrasound skills.[24] In many cases, the radiology or cardiology departments currently receive much more precise clinical questions from the Intensive Care Department because the POCUS examination is performed upfront. In addition, POCUS is likely to become more widespread and thus, we have an opportunity to shape an effective training program; this view is shared [3, 4] by scientific cardiology ultrasound societies. The storage of POCUS examinations is encouraged in order to be able to evaluate POCUS examinations afterwards.

During the start of POCUS training, we also collaborated with the pulmonology department, even though they too, were beginners at ultrasound. We still do ultrasound projects together, and recently the Departments of Pulmonology, Radiology, and Intensive Care published a handbook for pulmonary ultrasound (Springer Healthcare Benelux ISBN /

ISSN 9789492467225,]uly 22, 2019, Echografie van de thorax, Corien Veenstra, Michiel Blans et al).
Success: We were fortunate that our cardiology and radiology colleagues were willing to help. Since we were able to discuss our plans in advance, we could take advantage of their advice and consider justified concerns. We were aware of the absolute prerequisite that we had to implement ultrasound in a safe and responsible way. After many years of (inter)national experience with POCUS in the Intensive Care Department, we hope that, in the Netherlands , the controversy on this topic will disappear and we encourage intensive colleagues to discuss POCUS with their cardiology and radiology colleagues. We acknowledge the differences between a POCUS study performed by one of our intensivists, compared with a fully comprehensive 'normal' ultrasound study completed by our cardiology or radiology departments, and we have discussed this with both departments prior to developing our program. POCUS is aimed at detecting a limited number of acute clinical problems and its results are immediately useful. This method of using ultrasound is different from the comprehensive ultrasound studies done by cardiologists, radiologists, or their ultrasound technicians. Usually, the latter ultrasound studies are not aimed at a specific clinical situation but are more often done by examining the heart or all abdominal organs using a fixed framework, with the results given afterwards. Major intensive care and ultrasound scientific organizations state that POCUS can be performed by intensivists, but that it is important that the intensivist using POCUS knows his or her own limitations in ultrasound skills and asks for help if needed, [3, 6, 20, 25] POCUS and 'normal' ultrasound can therefore be seen as complementary; POCUS is not a replacement of a 'normal' ultrasound or other radiology modalities.
Weakness: On an individual level, there are still some colleagues in our hospital who are less enthusiastic about the intensive care department performing their own ultrasound exams; so far, this not resulted in serious conflicts. To date, no ultrasound-related incidents in direct patient care in our VIM database (hospital system for medical errors) have been registered.

2. Training residents

The Dutch Society for Internal Medicine has recently stated that POCUS is an obligatory element in the curriculum for internists (Landelijk opleidingsplan 2019). By designing a POCUS training program for intensive care residents, we combined both our own ambition to have staff and residents trained and the obligation to have Dutch residents in internal medicine trained in POCUS. Our aim is to have residents trained in POCUS before they start their intensive care rotation. Residents in internal medicine or its subspecialties in Rijnstate rotate through intensive care in their second year of residency and this rotation lasts 4-6 months. There are also residents in the Rijnstate Intensive Care Department who are not in training

but do the same work as residents in training; on average, residents not in training stay in the department for one year. Residents not in training also participate in the POCUS course and are encouraged to use POCUS regularly.
In the Rijnstate Hospital, the POCUS course is scheduled three times per year with the possibility to train 10 candidates each time. We started our course in 2017 and until now, have trained 64 residents, all courses are fully booked.
We decided that not only internists in training can be candidates for the course, and also ask residents who have an obligatory intensive care rotation (such as cardiology and pulmonology residents) to participate. This means that a far larger number of residents need to be trained. In Rijnstate, each year, five physicians start their internal medicine training program but the number of residents from other specialties is about five times higher.
Key issues of POCUS curricula are becoming more clear but evidence about the precise content and duration of a training program is limited. [26, 27] In our view, only POCUS of the heart and lungs is insufficient as intensivists and internists are also confronted with acute abdominal pathology. 28, 29 We decided to combine basic thoracic and abdominal POCUS, and our view on the components of basic POCUS was recently published.[13]

3. Training program

The Rijnstate POCUS course for residents consists of three key areas,[8] which will be described hereafter: a. image generation, b. image interpretation, and c. clinical integration.

3. a. Image generation
After a general lecture on the theoretical background of ultrasound and possible pitfalls, the course participant is trained in acquiring the pre-defined appropriate images (table 1).
Short tutorials on every component of POCUS are followed by hands-on sessions under supervision in which the candidates use each other as mannequins. The morning sessions are under supervision of the radiology department and during morning hours, abdominal ultrasound is the main topic. The afternoon sessions are under responsibility of the intensive care and cardiology departments and during afternoon hours, the focus is thoracic ultrasound (heart and lungs).
During the hands-on sessions, the number of candidates per ultrasound machine should be limited. In our experience, the optimal number of candidates per ultrasound machine and tutor is 3:1. The tutors should be experienced and qualified ultrasound experts.
The Rijnstate basic POCUS course consists of four days (Monday, Tuesday, Thursday, and Friday). Residents often have other educational obligations on Wednesdays, so we have no fixed program on that day. We divided the several POCUS items over four days in a way we found appropriate for every

POCUS item in terms of importance and or learning difficulty on the basis of available literature. Learning basic lung ultrasound is the quickest; [30] learning cardiac and abdominal POCUS requires more time, but all elements of basic POCUS can be trained in a limited period of time.[27, 31,32] In table 2, the time and number of test questions per POCUS item is shown. A two-day multi-organ POCUS training was efficient for intensive care fellows, [33] others advise one day per application, [34] but one-day courses are also described. [35] Our four-day course gives ample time to soundly train POCUS and from a practical point, it means that residents have to be taken off rotation for one week.

Table 2. ***Components of POCUS training and testing***

Component of POCUS	Hours (%)	No questions (%)
General introduction	2 (6,25)	3 (6)
Cardiac POCUS	14 (43,75)	22 (44)
Lung POCUS	2 (6,25)	3 (6)
Abdominal POCUS	12 (37,5)	19 (38)
Vascular POCUS incl. neck	2 (6,25)	3 (6)
Total	32 (100)	50 (100)

3.b. Image interpretation

During the course, the use of young healthy mannequins attributes to the element of image generation but the changes of finding pathology (image interpretation) are very low. Therefore, course participants learn to recognize normal ultrasound images and are instructed to be alert when images in patients are different from the normal images. During the introduction talks for each component, examples of ultrasound abnormalities are shown, and the characteristics of ultrasound pathology discussed (table 3).

In the coming years, we foresee a bigger role for simulation education for ultrasound training as already has been described in literature,[36] although simulation-only education is probably insufficient and hands-on training remains important.[37] In the Rijnstate course, we use the Sonosim which is a computer-based platform in which ultrasound studies with real pathological situations are installed. Attached to the computer is an ultrasound probe with movement detection. By moving the ultrasound probe, different views are simulated. Candidates are therefore confronted with real ultrasound pathology. The candidates are stimulated to use the Sononsim during quiet hours. On the last day of the course, the candidates (in pairs) have to assess five Sonosim scenarios: cholethiasis, severe right and left ventricle dysfunction, e-FAST protocol showing a pneumothorax on the right side, massive pulmonary embolism, and right kidney hydronephrosis. In the near future, we will explore whether we can optimize the use of ultrasound simulation.

For the insertion of central lines, we use a vascular mannequin (Blue Phantom) on which the technique of ultrasound-guided catheterization of the internal jugular vein can be practiced. In our department, residents are trained to insert central venous catheters into the internal jugular vein with ultrasound guidance, as endorsed in literature. [38] This technique is part of the Rijnstate course but is rehearsed at the beginning of the intensive care rotation.

Table 3. ***Image interpretation***

Image interpretation	
Cardiac POCUS	Left ventricle is enlarged yes/no Left ventricle function: normal, moderately diminished, severely diminished Right ventricle is enlarged yes/no Right ventricle function assessed by TAPSE Pericardial fluid present yes/no, signs of tamponade yes/no Width of IVC, variation during respiration in cms
Lung POCUS	Signs of pneumothorax PLAPS yes/no
Abdominal POCUS	Kidney size in cms left and right, signs of obstruction Major liver and gallbladder abnormalities Spleen size and aspect Abdominal aorta aneurysm Bladder abnormalities Abdominal free fluid and were to look for it
Vascular POCUS	Femoral and popliteal thrombosis

PLAPS - posterolateral alveolar and/or pleural syndrome; POCUS - point-of-care ultrasound; TAPSE - tricuspid annular plane systolic excursion; IVC - inferior vena cava

3.c. Clinical integration

Clinical integration of ultrasound findings is, in our view, the most difficult part. There are reports that physicians do not adequately maintain ultrasound competency after a basic course, [39] and it is challenging to obtain specific recommendations from literature on maintenance of competency.[19] The NVIC has designed a 'consolidation course', which includes, in addition to a two-day refresher of basic skills, the evaluation of 40 ultrasound examinations performed by the candidates within a period of nine months. These 40 thoracic ultrasound examinations are to be described according to the intracavitary ultrasound protocol (www.nvic.nl/ consolidatiecursus).

In the near future, ultrasound portfolios for residents will be in place in our hospital, in which 40 ultrasound examinations (thoracic and abdominal) will be reviewed during a one-year period after the course.
There is discussion on the exact number of ultrasound exams needed to reach acceptable competency,[31] and for residents in internal medicine, an exact number will be replaced soon by the concept of entrustable professional activities (EPAs). [11]
Every Thursday afternoon at 3:00 p.m., there is an ultrasound round on the intensive care and general wards. Patients with interesting ultrasound findings are asked to participate and are examined by ultrasound by attending residents and one ultrasound supervisor.
By designing a basic POCUS course in combination with a one-year portfolio, the possibility to store exams digitally, weekly ultrasound rounds, and easy access to ultrasound supervision, we try to optimize the acquisition and retention of ultrasound skills. We fully endorse and emphasize the need to warn our residents that in the wrong hands, POCUS can be dangerous, and that it is essential to know one's limits and to call for expert help if needed.[3,4,24]
Residents stay in Rijnstate for a maximum of one to three years, and after this period, they continue their training elsewhere. It will be up to them to maintain their POCUS skills and hopefully they will join a department with a positive POCUS attitude and program. The NVIC notices that just a small percentage of candidates from the basic course joins the consolidation course (data from NVIC, personal correspondence), meaning that most colleagues either stop performing POCUS after the basic course or continue with a personalized form of POCUS education (possibly 'learning on the job' without formal training).

3.d. Testing

The candidates are tested in theoretical and practical knowledge.
An online theoretical multiple-choice test consisting of easy and more difficult questions with proportional percentage of questions for each component of POCUS (table 1) was developed. This test is taken shortly before the course to assess basic knowledge and candidate preparation, on the last day of the course to assess possible acquisition of knowledge, and after three months to assess whether the trained skills are retained by the candidates (learning retention). The questions and order of answers are changed digitally to prevent possible foreknowledge. A practical exam is taken on the last afternoon of the course. The candidates are asked to show appropriate images of two lung, four heart, and four abdominal views in 10 minutes. They are evaluated in terms of speed, imaging quality, and ergonomics (table 4). This practical test is also rehearsed after three months to assess whether practical skills are retained. For intensive care fellows, a two-day multi-organ ultrasound course was found to improve ultrasound proficiency after three months.[33] In a recent study on medical students, there was a difference in decay of motor and cognitive skills for pleural and cardiac images,[40] meaning that we have to be aware that

learning and retaining POCUS skills might be different for each component. We are planning to evaluate the results for our resident training program in 2020: Does our course improve ultrasound knowledge and skills, are knowledge and skills retained after three months, and is there a difference between retention of motor and cognitive skills?

Table 4. ***Checklist POCUS imaging process***

	Speed (min:sec)	Image quality (good/moderate/ bad)	Ergonomics adequate/inadequate
Assessor (initials) FB MB			
Candidate:			
Date:			
Lung: Blue 1 right			
Lung: Plaps right			
Heart: PLAX			
Heart : PSAX (2 levels): Aortic valve Papillary muscle			
Heart: A4C			
Heart: IVC			
Abdomen: Aorta Transversal sagittal			
Abdomen: Kidney right side Kidney length			
Abdomen: Spleen Spleen length			
Total score:			

A4C - apical 4 chamber: Blue 1 - upper blue point: PLAPS - posterolateral alveolar and/or pleural syndrome; PLAX - parasternal long axis; POCUS - point-of-care ultrasound; PSAX - parasternal short axis; IVC - vena cava inferior; min - minutes; sec – seconds

Final remarks

Although there is lack of hard evidence that ultrasound saves lives, [41] we do strongly believe that POCUS is a very important new development in intensive care and emergency medicine. We are convinced that using it 'as the new stethoscope' leads to safer, better, and cheaper patient care. There is ample circumstantial evidence indicating that the use of POCUS leads to more accurate diagnosis [42-52] has therapeutic implications,[42, 46, 48, 49, 51-53] leads to lesser use of other medical resources, [48, 49, 51, 54, 55] and probably leads to lower mortality. [53, 56]
Furthermore, the use of POCUS may reduce uncertainty in the diagnostic process.[49] From our experiences in our own clinical day-to-day work, we have encountered many situations in which the use of POCUS resulted in significant diagnostic and therapeutic alterations. Recently, we admitted a 45-year-old woman who suffered from a severe carbon monoxide (CO) intoxication. After several hours, her hemodynamic status deteriorated. POCUS not only showed a severe CO-related cardiomyopathy, but also showed a 20- week-old pregnancy, sadly without heart activity. We are sure that like us, colleagues who embrace POCUS will pass or have passed that point of no return when not using POCUS is just unimaginable.
In this paper, we describe our stepwise approach to implementing the integral use of POCUS and we also describe how a POCUS training program for residents could be designed. Of course, these topics are dynamic and require regular evaluation, improvements, and adjustments. By sharing our implementation and training experiences, we want to contribute to the spread of POCUS and be of help to colleagues who wish to implement POCUS into their intensive care departments.

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Chapter 5: Evaluation of a 4-day ultrasound course for residents in internal medicine in the Netherlands.

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Submitted

Abstract

Background

Point-of-care ultrasound (POCUS) is of increasing interest to internal medicine (IM) physicians, but its implementation is not yet complete. Residents are motivated to acquire sonographic skills but more literature on POCUS training is needed. We evaluated the effectiveness of a POCUS course for IM residents.

We conducted a prospective observational cohort study and included participants of the Rijnstate multi organ POCUS course. The course consisted of four days (short tutorials and ample hands-on training). A theoretical test was taken prior to the course and both theoretical and practical tests were taken on the last day and three months after course completion.

Results

48 residents were included in two years. The percentage of correct answers were 54.5% 66.3%, and 63%, respectively. This indicated an increase in and some retention of knowledge. After three months the practical testing was performed faster which indicated practical skills retention. Most candidates moderately used POCUS after the course (1-4 times per week).

Conclusion

A four-day POCUS course for IM residents results in good basic understanding of ultrasound and application of practical skills. These results are retained after completion of the course with best results for practice.

Keywords

Point-of-Care Ultrasound
Internal medicine
Training
Retention

Introduction.

In acute medicine the clinical use of ultrasound has gained momentum. It offers the advantage of instant clinical information and absence of patient transportation to a radiology suite. [1] This application of ultrasound at the bedside is known as Point-of-care ultrasound (POCUS). Critical care and emergency physicians already use POCUS and increasingly, it has been recognized that POCUS could be useful to internal medicine too. [2] However, implementation of POCUS in this discipline is far from complete. [3] Meanwhile there is a growing demand by residents for POCUS training. [4-7] and ultrasound curricula for internal medicine residents have been developed.[8,9]
In the Netherlands, the Dutch society of internal medicine (NIV) has decided positive on POCUS training for residents. A program proposal has been published which incorporates ultrasound skills in the existing assessment tool of entrustable professional activities (EPA's). [10] Literature on effective POCUS training for critical care and emergency medicine exists. [4]
To our knowledge scientific literature on POCUS training for internal medicine residents is scarce and more literature on the implementation and validation of POCUS courses is needed. In this paper we describe a four-day course in POCUS for residents in internal medicine in the Netherlands. We evaluate the effectiveness of our training program by examination of theoretical ultrasound knowledge (cognitive skills) and practical skills after course completion and three months follow up. Furthermore, we explore for differences between retention of motor and cognitive skills in time.

Material and methods

This prospective, observational cohort study was conducted in a large teaching (750 beds) hospital in the Netherlands (Rijnstate hospital, Arnhem, the Netherlands). Study participants were residents from the Rijnstate hospital without prior ultrasound training (1-3 Post Graduate Year (PGY)).

Ultrasound supervisors

The ultrasound supervisors were all experienced sonographers from the departments of radiology, cardiology, internal medicine, and intensive care medicine.

Ethics

In accordance with relevant guidelines and regulations, the Rijnstate Hospital institutional board of directors approved this study. As no patients but hospital employees are involved, this study is subjected to Dutch Law (general data protection regulation; GDPR), therefore all participating candidates were informed about this study in advance and could choose to opt out. All participants agreed to participate in this study.

Course curriculum

The ultrasound course consisted of four days in one week (Monday, Tuesday, Thursday, and Friday). Our training goals corresponded broadly with the proposed NIV program. The course content had been published and distributed to the participating candidates in advance. [5] Some relevant POCUS articles [11,12] and web based POCUS learning tools (https://www.usa.philips.com/healthcare/education-resources/education-training/ultrasound-education-critical-care-emergency-medicine?npagination=1) were shared two weeks in advance for preparation purposes.

In short: during four days basic POCUS of heart, lungs, abdomen, and vascular system were taught. We estimated the necessary time to train each component resulting in a majority of time reserved for cardiac and abdominal scanning protocols and less time for the lung and vascular scanning protocols. The course content is described in table 1 including the duration per item.

POCUS: Point-of-care ultrasound, PLAX: parasternal long axis, PSAX: parasternal short axis, A4C: apical four chamber, SC: subcostal, SC-IVC: subcostal inferior vena cava, e-FAST: extended focused assessment by sonography in trauma. Each course item began with a short tutorial (10-15 minutes) followed by supervised hands-on training during which the candidates used each other as mannequins and practiced to acquire ultrasound images of interpretable quality. A ratio of three candidates to one ultrasound machine and one supervisor were scheduled. In total approximately twenty-six hours were spent on hands-on training and four hours on theory during the course.

Testing:

The examination of the candidates was described extensively in the paper published previously. [5] In short: cognitive testing was done using online theoretical multiple-choice test. This exam was taken shortly before (within one week before start) on the last day of the course and after three months. Results were stored in survey monkey®. The question distribution included basic knowledge on ultrasound and the POCUS scanning protocols studied during the course. Item were assessed by a mix of relatively simple and advanced questions. The former demanded simple anatomical recognition while the latter also required clinical interpretation of POCUS recordings. To avoid recall bias the test questions and multiple-choice answers were randomly reordered at each of the test moments.

The test questions have been peer-reviewed by two of the course directors (FB and MB). A practical test to assess motor skills was taken by one supervisor and one candidate on the last course day and again after three months. We have designed an assessment tool (appendix A) which scores cumulative time, image quality, and ergonomics. This practical test had to be completed within ten minutes which enabled the investigators to examine all participants (table 2). To standardize scoring all candidates during the first course were evaluated by all three supervisors.

Simulation
During the course time was spent on simulation training [5] for different course items. Ultrasound simulation offers the possibility to confront candidates with ultrasound pathology. In this course a computer-based platform was used in which ultrasound studies showing real pathological situations are installed (Sonosim). On the final day of the course pairs of subjects were asked to assess five Sonosim scenarios (cholelithiasis, severely impaired right and left ventricular function, e-FAST showing a pneumothorax on the right side, massive pulmonary embolism, and right kidney hydronephrosis). The results were also noted for evaluation.

Longitudinal effects, learning retention.
After three months candidates were reassessed on their motor and cognitive skills and asked about their frequency of use of POCUS after completion of the four days ultrasound course.

Statistical analysis
A marginal model was used to compare the results of the theoretical test and speed of the practical tests at the different time points. Estimated marginal means (EMM), standard error (SE), and Bonferroni corrected p-values were reported. The VAS satisfaction score was reported as mean with 95% confidence interval. All analyses are made using SPSS version 25

Results

Between November 2018 and November 2020 six POCUS courses were held. 48 residents participated in the course. They were in training for internal medicine (N = 36), emergency medicine (N = 2), anesthesiology (N = 5), surgery (N = 4), and pediatrics (N=1), respectively (total N = 48). Only two residents had significant prior ultrasound experience (they reported to use ultrasound pre-course on a regular basis but had not received prior official training). No candidate refused to participate in the study.
All 48 participants completed the post-test evaluation. 47 participants completed both pre- and post-test. Thirty candidates finished pre- post- and 3-months tests. The 18 participants who were lost to follow up had moved to another hospital for the continuation of their residency and could therefore not attend.
Systematic registration of the practical tests began later (after the first two courses) and therefore 39 candidates attended the post test. Nine candidates failed to attend the 3-months practical test due to the same reasons as noted at the theoretical tests.
In figure 1 the flowchart of candidate participation is shown.

The results of the theoretical tests are shown in table 3.
The percentage of correct answers at the different time points are presented and tested between pre- and post-test, pre- and 3-months.

The cumulative amount of time of the practical tests are presented in table 4
All participants were capable of displaying interpretable ultrasound views and had sufficient scanning ergonomics after course completion and 3-months follow up.

Table 1. ***Course content (including duration per item)***

	Component	Hours (%)
General introduction	The student will learn the basics of ultrasound (knobology, pitfalls, etc.).	2 (7.1)
	The student will learn to perform ultrasound exams using established protocols. The student will learn basic ultrasound, no color Doppler. The student will learn when ultrasound can be of added value and when more expertise is warranted.	
Cardiac POCUS	Basic views: PLAX, PSAX, A4C, SC, SC-IVC, recognition of normal anatomy.	12 (42.9)
Lung POCUS	Determination of presence or absence of lung sliding. Recognition of A & B lines, recognition of pleural fluid.	2 (7.1)
Abdominal POCUS	Recognition of normal anatomy (liver, gallbladder, kidneys, spleen, pancreas, large vessels and movement of the bowels). Recognition of normal anatomy in the pelvic region (bladder, prostate, uterus, adnex). Recognition of intra-abdominal fluid/ the e-FAST exam.	10 (35.7)
Vascular POCUS incl neck	**Recognition of large vessels.** **Correct use of ultrasound in performing vascular cannulation.** **Recognition of normal anatomy of neck.**	2 (7.1)

Table 2: ***Checklist POCUS imaging process***

	Speed (min:sec)	Image quality (good/moderate/bad)	Ergonomics Adequate/inadequate
Assessor FB/MB/BK			
Candidate:			
Date:			
Lung: Blue 1 right			
Lung: Plaps right			
Cardiac: PLAX			
Cardiac: PSAX Aortic valve Papillary muscle			
Cardiac: A4C			
Cardiac: SC-IVC			
Abdomen: Aorta Transversal/sagittal			
Abdomen: Kidney Right side/length			
Abdomen: Spleen/length			
Total score:			

FB: Frank Bosch, MB: Michael Blans, BK : Bram Kok, Blue 1 (upper blue point), Plaps (PLAPS: posterolateral alveolar and/or pleural syndrome), PLAX (parasternal long axis), PSAX (parasternal short axis), A4C (apical 4 chamber), SC-IVC (subcostal inferior vena cava), min (minutes), sec (seconds).

Table 3: ***Theoretical testing***

Theoretical testing	Pre-test EMM (SE)	Post-test EMM (SE)	3-Months EMM (SE)	P Value Post vs pre	P Value 3 months vs pre	P Value 3 months vs post
% correct answers	**54.4 (1.3)**	**66.3 (0.9)**	**62.7 (1.4)**	**<0.001**	**<0.001**	0.06

(EMM: estimated marginal means, SE: standard error)

Fig.1 a: Theoretical test

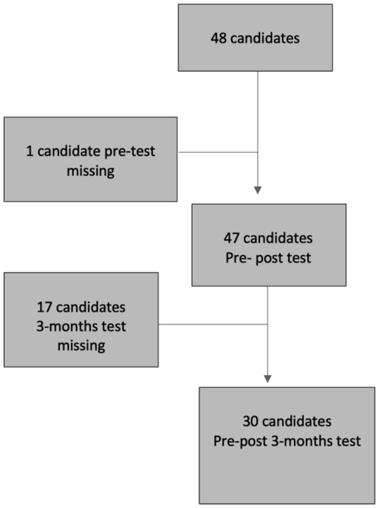

Fig. 1 b: Practical test

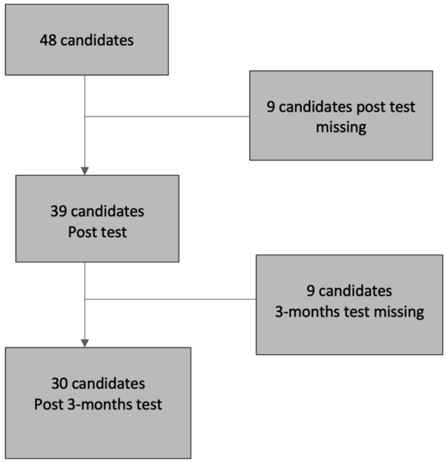

Table 4: ***Cumulative time of practical testing***			
Practical testing	Post-test EMM (SE)	3 months EMM (SE)	P-value
Lung (min: sec)	**1:18 (0:06)**	**0:54 (0:06)**	0.002
Cardiac (min:sec)	4:18 (0:18)	3:12 (0:12)	0.002
Abdomen (min:sec)	3:54 (0:12)	3:30 (0:12)	0.14

(EMM: estimated marginal means, SE: standard error)

All participants were grouped in pairs and completed five ultrasound simulation cases at the last course day. The rate of correct diagnosis was 100%. We also evaluated if the candidates continued to use ultrasound in the three months after the course. Thirty candidates shared their ultrasound use. The large majority uses POCUS 1-4 times per week (N= 24), four reported not to use it and only one reported to use POCUS >5 times per week. We could not find a correlation between frequency of POCUS use and test results after three months (neither theoretical nor practical testing).

We evaluated candidate satisfaction the last course. Candidates were very positive about the content of the course with an average score of 8.6 (7.6-9.1), visual analogue score 0-10.

Discussion

A four-day ultrasound multi organ POCUS course with short tutorials and about 26 hours of hands-on training enables residents without significant prior ultrasound experience to successfully master basic knowledge and skills. The multi organ POCUS approach enables physicians to integrate scanning into the physical examination and thus truly make it applicable in day-to-day care. Retention of these skills is substantial after three months. In our study the theoretical test results realistically reflect a subject's capability to integrate ultrasound into clinical practice. The multiple-choice questions cover the entire course curriculum and have been thoroughly peer reviewed in advance. The questions are presented in random order, and each subject is given a unique sequence of the questions to avoid possible forgery. Over time we measured a small decline in test results during three months follow up but results were still better than at the start of the course. We do expect a further decline in abstract knowledge such as ultrasound physics and a retention of knowledge that is more readily used.

The practical test results show an increment in speed over time. The examination is composed of three scanning protocols often used in daily practice; therefore it is possible that a faster exam with interpretable views reflects improvement of skills. The majority of the course participants report using ultrasound albeit not every day. Another explanation can be the fact that the practical examination is kept unchanged which might have resulted in performing a repetitive task and thus efficiency.

Our hands-on training is practiced on healthy mannequins rather than patients. This has the advantage of obtaining good image quality from the beginning and focusing on recognizing normal anatomy. The disadvantage of not practicing on patients is the often experienced difficulty in scanning them. In our opinion, training novices to recognize normal anatomy will provide them with confidence to start scanning in patient care. It should be emphasized that a large number of scanning of patients is necessary to obtain sufficient skills. Possibly, a combination of practicing on healthy mannequins and patients would be ideal.

Our results are in line with other published articles on the subject of resident POCUS training. [6, 7, 13-16] However, due to large variation in course programs it remains a challenge to fully compare results. The courses vary in duration (hours versus multiple days), candidates (residents from different specialties, medical students, attendings or combinations), content (mono-organ versus multiple organ POCUS), testing (theoretical, practical or both), follow up in time (none versus months), location worldwide [8] and kind of hospital (academic or community-based). [17]

Jones et all evaluated theoretical and practical skills in 21 EM residents with ample prior ultrasound experience (20 - > 150 non cardiac ultrasound exams performed) who were trained in basic cardiac ultrasound in a five-hour didactic and one-hour practical course. [6] Both theoretical and practical skills went up (pre-course versus post course), but no follow up data are

available. Clay et al studied the effectiveness of a one-day workshop for internal medicine residents with two additional one-hour training sessions in the following six months. [7] One third of the participants had prior ultrasound experience, the course content comprised basic cardiac, lung, vascular, and abdominal ultrasound. 24 of 33 IM residents completed the six-months test. Theoretical test results improved from 61% to 85% (pre – and post – course) and declined somewhat to 79% after six months indicating knowledge retention. No practical skills nor actual use of ultrasound after completion of the course were evaluated. Yamada et al compared residents and physicians without prior ultrasound experience who were trained during a one-day course on cardiac, lung, vascular, and abdominal ultrasound imaging skills and interpretation at the semi-annual meeting of the Japanese Society of Hospital General Medicine. 14 The participants were tested before and after the course. Interestingly both groups showed an equal improvement in knowledge and skills which was also found in our study. No longer follow up was done in this study. Yamamoto et al studied 31 medical and surgery residents who were taught on focused echocardiography during a two-hour course. A decay in knowledge and practical skills was observed one month after the course and knowledge continued to decrease after three months. [13]
Anstey et al describe a different approach. They discuss a longitudinal ultrasound training program which covers multiple years of residency. The program starts off with a limited number of ultrasound items and expands to a total body ultrasound program in two to three years. After completion of this extensive training program testing reveals substantial gains in knowledge and confidence and in frequent use of cardiac and lung POCUS. [15] Due to the different set up the results of this study cannot be compared to ours.
Boniface et al also describe a longitudinal design, during six months residents received monthly training sessions. [16] In this period consecutive POCUS topics were trained. After six months theoretical testing showed an increase in knowledge but not all candidates were able to attend all monthly sessions or attended the hands-on skill session with decremental influence on the six months score.
LoPresti et al defined requirements for POCUS training in internal medicine residency and our course meets almost all elements needed. [18] For residents to maintain POCUS proficient after course completion it is important to have access to ultrasound equipment during clinical work, to acquire scans for supervision purposes, and to have trained internal medicine supervisors who are experts in sonography. Their availability is still scarce, which is a problem acknowledged worldwide. [3, 19, 20]
In summary, one day courses in point of care ultrasound show similar results for both residents and attending physicians but follow up data on retention of knowledge and practical skills are either lacking or disappointing. A longitudinal ultrasound training program could be a viable alternative, but the downside of this approach is the loss to follow up of

participants. Also, novices in ultrasound might feel a lack of confidence after just one day of training and experience resistance in using ultrasound.
The strength of our study is the evaluation on multiple elements of an ultrasound training program: feasibility of a multi organ POCUS program for residents, assessment of ultrasound knowledge and skills and testing for their retention after three months and reporting on frequency of use of POCUS after course completion. One of the factors that lead to our positive results might be the fact that our course consists of four consecutive days of intense POCUS training. However, there are no data on the influence of POCUS course duration

Limitations

We present a small single center study which limits generalizability and also as discussed before in the field of POCUS training there is no uniformity. We have applied the same POCUS training strategy in consecutive courses and the increment in knowledge and skills are found in participants in each course. Ideally our findings need to be validated by external application and evaluation of our training program. A significant number of candidates were lost to follow up: theoretical test 18 (37.5%) and practical test nine (23%). Although these numbers might be expected in follow up studies of residents it could mean that a self-selecting group of ultrasound interested candidates completed all tests thereby influencing the results.
Not all POCUS trained residents will feel the need to make POCUS part of their daily routine. Some residents subspecialize in fields with less affinity for POCUS, others with interest for acute internal medicine or hospital medicine will be more eager to use POCUS.
Another limitation is the fact that our follow up is only three months. We know that to maintain proficient in point of care ultrasound one must use it often. Reports on decay of POCUS skills after longer time exist.[21] We also see a small decline in theoretical knowledge but retained practical skills after three months. Due to small sample size, we could not find a correlation between three months testing and the reported number of POCUS exams done per week. Again, a trained skill might decline in time when not maintained and three months might be a too short period to evaluate this element properly. [21]
We designed our course for residents in internal medicine, but we allow residents from other specialties to participate. We decided to include the results of all participants and the majority of candidates are indeed internal medicine residents but there might be some differences between residents.
We encourage other professionals to start with the implementation of an ultrasound course for residents in internal medicine as is endorsed by others too, [22, 23] but also to have staff members who are experts in POCUS [19] to ensure that this valuable tool can be used optimally. It might be difficult to implement our strategy in general, but it could very well serve as a useful example.
At the end the results of our course evaluation show that cognitive and practical skills were adequately trained in four days, but an important

question is whether these skills will lead to adequate clinical use of POCUS, our study does not provide data on that topic. We know from literature that in case of focused/basic cardiac ultrasound short training programs will result in competency for most learners. [24] We conducted a study on the use of cardiac and lung POCUS during Medical Emergency Team (MET) calls in which we showed that diagnostic accuracy improved significantly when POCUS was used by residents during MET deployment. (accepted Ultrasound Journal). Completing our four days POCUS course was a prerequisite for study participation. So, we assume that by completing our course a strong basis for the adequate use of POCUS is provided but we acknowledge that besides completing our course regular (supervised) use of POCUS is warranted

Conclusions

A point of care ultrasound course for residents internal medicine of four days results in good basic understanding of ultrasound and application of practical skills. These results are retained after completion of the course with best results for practice. Challenges for maintaining ultrasound skills over time remain.

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Ethics approval and consent to participate
The Rijnstate Hospital institutional board of directors approved this study. As no patients but hospital employees are involved, this study is subjected to Dutch Labor Law, therefore all participating candidates were informed about this study in advance and could choose to opt out. All participants agreed to participate in this study.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Chapter 6: Ultrasound in acute internal medicine; time to set a European standard

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Abstract

Nowadays point-of-care ultrasound (POCUS) is considered indispensable for critical care and emergency physi-cians. POCUS is a noninvasive tool, can be done at the bedside, leads to instant diagnostic information and is safe in terms of radiation. POCUS could also be very suitable for internists in the field of acute internal medicine. There are differences between European internists in the use of POCUS from no use at all to more outlined educational programs. In literature there are examples of comprehensive POCUS guidelines which could serve as an example for the European Federation of Internal Medicine (EFIM). In this review some aspects of POCUS are highlighted, and the authors encourage EFIM to set European standards for this important development.

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Keywords:
Point-of-care ultrasound, Acute internal medicine, Standards, EFIM

The internist, and especially those dealing with acute illness, must be trained to recognize and manage a broad range of diseases and, with the aging population, many patients with chronic and multiple disorders. In this review we show that the use of ultrasound in acute internal medicine leads to better, faster and safer patient care.
Traditionally the internist first talks to the patient to get a history and then does a general physical exam in order to make an initial diagnosis and start therapy and /or order extra tests. When necessary this approach must be modified for acutely ill patients by using the same ABCDE method originally developed for trauma patients, so that "what kills first is treated first" and further harm is prevented.[1] A focused ultrasound exam of the patient can be of great use in this primary process.
Filly postulated in 1988 that ultrasound could be the stethoscope of the future. [2] Nowadays ultrasound devices are becoming smaller, and there are handheld pocket sized machines that provide images of highly acceptable quality, making them ideal for instant bedside use; sensors are also available that can be plugged into a smartphone or tablet, thus making the availability, convenience and portability of this new technology close to that of the traditional stethoscope.
In recent years there has been growing interest in the use of point- of-care ultrasound (POCUS) [3] in the primary assessment of patients. In general POCUS is a bedside ultrasound examination targeted at the clinical problem leading to instant diagnostic information. Other advantages of ultrasound are that it can be done at the bedside, is noninvasive and yields no harm to the patients in terms of radiation risks. POCUS is already recognized in the fields of critical care and emergency medicine,[4-6] and it has been suggested that it should be mandatory for the initial management of critically ill patients.[7-9] Apart from the use of ultrasound in the process of diagnosis or primary resuscitation, ultrasound can also be used to guide certain procedures such as the insertion of a centra! venous catheter, drainage of pleural or abdominal fluid etc., thereby improving patient safety. [10-13]
Although ultrasound will not be the answer to everything for internists, it is a very suitable tool for the acute setting to speed up the diagnostic and therapeutic process. Ultrasound skills need to be properly taught, as misdiagnoses due to improper or unqualified use may hurt the patient in terms of treatment and/or outcome. [14] A complicating factor is that there are significant differences in the use ultrasound between the various European countries and possibly also within different countries; a good example is its use in the field of musculoskeletal ultrasound. [15]
Currently literature on specific ultrasound training programs for internists is limited. [16-18]
Recently the American College of Emergency Physicians (ACEP) published a revised policy statement on ultrasound guidelines (www.ACEP.org) Ultrasound guidelines: Emergency, Point-of- care, and Clinical Ultrasound Guidelines in Medicine. In this extensive paper many aspects of ultrasound

in the acute setting are discussed. Emergency ultrasound is classified into different functional categories, most of which are also applicable to the field of acute internal medicine. This revised policy statement (first edition in 1990, latest edition 2016) contains very usable comments on ultrasound definitions, protocols, training, credentialing, quality management and value/ reimbursement. The ACEP ultrasound guidelines can be used as an example for the EFIM to set European guidelines on bedside ultrasound performed by internists. In some individual European countries (Italy being a prime example) there exists a nationwide ultrasound program for internists. [19]
Point-of-care-ultrasonography (POCUS) can be divided into basic and more advanced levels of competence. [20-25] Kanji et al. [26] concluded that it is possible to train ultrasound naïve doctors in basic cardiac ultrasound in a time efficient manner. Basic curricula in which cardiac function was assessed as a binary or qualitative outcome appeared to demand less time in training and were more reproducible. Although web-based pre-courses are valuable, a minimum of 5 h of "hands-on" training is essential. The number of cardiac ultrasound studies participants should be required to make is probably around 30, and there is debate on whether skills can be learned by only using healthy volunteers and on the topic of maintenance of cardiac ultrasound skills.
(POCUS) is not restricted toa specific group of doctors or organs and its protocols can be individually designed or made for a specific department depending on specific circumstances. No consensus in literature exists on the exact definition of POCUS. However, the concept is to focus on ruling in or out a diagnosis that must not be miss in the acute setting. This approach implies that more comprehensive exams may need to be done later when the patient is in a more stable situation. For instance, a focused cardiac ultrasound may be performed to rule out severe left or right sided heart failure or tamponade. The POCUS protocols will ask the operator binary or otherwise simple questions like "is the left ventricle is dilated? yes or no", "is the overall left ventricle function is normal, mildly depressed or severely depressed?" etc. A full cardiology ultrasound by a fully trained echo-cardiographer can always be done later if required.
The desire by residents in internal medicine to be trained in it is also growing [18] and ultrasound training programs are now becoming available for medica! students and internal medicine physicians, etc. [27, 28] Competencies have been published for POCUS other than cardiac ultrasound, such as abdominal or lung ultrasound,[24] thus ensuring that basic ultrasound skills can be efficiently propagated.
Since internal medicine covers the total body it seems logical that internists should be trained in multi-organ ultrasonography. [29-31]
Unfortunately evidence-based literature on the positive effects of POCUS is limited, [32] as it is hard to design a study protocol in which the effect of POCUS can be properly evaluated in a randomized way. There are, however, papers on the positive influences of ultrasound on the process of diagnosis,

[33-35] patient management [36, 37] the need for other imaging studies [38-40] and on outcome. [39, 41] Although most recommendations from cardiac ultrasound societies stress the need for adequate training, certification, maintenance of ultrasound skills and the need to ask for expert help if needed, [22, 25] there are few reports on any negative effects of POCUS. When compared to other diagnostic modalities, for instance in pulmonary or abdominal diseases, bedside ultrasound can be very accurate [42, 43] and is at least comparable to standard imaging. One of the main advantages of POCUS is that the patient does not need to be transported to another facility, which saves time, money and discomfort.

Although there is no concrete proof that ultrasound is advantageous in the acute setting the circumstantial evidence is strong. The increasing amount of scientific papers on POCUS shows that bedside ultrasound is an irreversible development, and that basic skills can be learned in a time efficient manner. In the acute setting POCUS leads to more rapid and accurate diagnoses, has a positive effect on patient safety (invasive procedures), leads to earlier treatment and has a low cost-benefit ratio (even in remote or less wealthy surroundings it will be easier to purchase an ultrasound device compared to a CT scanner).

EFIM states that Internal medicine forms one of the mono-specialty sections of The European Union of Medica! Specialties (UEMS) which are responsible for harmonizing the curriculum of internal medicine, both in terms of the period required for training, and now includes, with increasing emphasis, the curriculum for continuing professional development (CPD) of practicing doctors. It is therefore imperative that an important development such as POCUS for internists will be sub-ject of general accepted European standards.

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Chapter 7: A point-of-care thoracic ultrasound protocol for hospital medical emergency teams (METUS) improves diagnostic accuracy

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Abstract

Background: Point-of-care ultrasound (POCUS) has proven itself in many clinical situations. Few data on the use of POCUS during Medical Emergency Team (MET) calls exist. In this study, we hypothesized that the use of POCUS would increase the number of correct diagnoses made by the MET and increase MET's certainty.
Methods: Single-center prospective observational study on adult patients in need for MET assistance. Patients were included in blocks (weeks). During even weeks, the MET physician performed a clinical assessment and registered an initial diagnosis. Subsequently, the POCUS protocol was performed, and a second diagnosis was registered (US+).
During uneven weeks, no POCUS was performed (US−). A blinded expert reviewed the charts for a final diagnosis.
The number of correct diagnoses was compared to the final diagnosis between both groups. Physician's certainty, mortality and possible differences in first treatment were also evaluated.
Results: We included 100 patients: 52 in the US + and 48 in the US− group. There were significantly more correct diagnoses in the US+ group compared to the US− group: 78 vs 51% ($P = 0.006$). Certainty improved significantly with POCUS ($P < 0.001$). No differences in 28-day mortality and first treatment were found.
Conclusions: The use of thoracic POCUS during MET calls leads to better diagnosis and increases certainty.
Trial registration. ClinicalTrials.gov. Registered 12 July 2017, NCT03214809:
https://www.clinicaltrials.gov/ct2/show/NCT03214809?term=metus&cntry=NL&draw=2&rank=1

Background

Medical Emergency Teams (METs) are called to the bedside when patients on hospital wards deteriorate.[1, 2] METs use various algorithms to assess the patient's condition, most frequently the ABCDE method. The MET physician will use a combination of history, physical examination, and point-of-care laboratory tests to assess the patient. The addition of point-of-care ultrasound (POCUS) could potentially improve diagnostic accuracy. [3] METs are associated with a reduction in patient mortality, [4] but few data exist on differences in operation procedures by METs. The role of POCUS for instance during MET calls has not been investigated extensively yet, even though its role in the emergency room (ER) and intensive care unit (ICU) is well established. [5-13] Recently, Zieleskiewicz et al. published the first prospective observational study on the effect of the use of a multi-organ POCUS protocol during MET calls.[14] In this study, the use of a multi-organ POCUS protocol improved diagnostic accuracy of the MET significantly. We also designed a prospective trial hypothesizing that multi-organ POCUS would increase MET diagnostic ability and postulated that the use of POCUS would also increase the diagnostic certainty of the MET physician. Influence on certainty by the use of POCUS has been found in a study on ER patients [5] and improving certainty might also be important to attending MET physicians. Because most MET calls are requested for respiratory and or hemodynamic deterioration,[15], we designed a POCUS protocol consisting of cardiac and lung (thoracic) ultrasound.

Methods

Study design and setting

Design

This is a prospective observational study examining the use of thoracic POCUS in adult patients on the general ward treated by the MET. The Modified Early Warning Score (MEWS) was used to assess the need for MET assistance (figure of MEWS score in Additional file 1).
The study (METUS NL61884.091.17) was approved by the local ethical committee and conducted in a Dutch 750 bed teaching hospital (Rijnstate Hospital, Arnhem) from January 18, 2019 until February 1, 2020. The study was registered at ClinicalTrials.gov. (NCT03214809).

Characteristics of participants

All patients 18 years and older in all regular hospital wards in need of a MET call were included.

Exclusion criteria were:

- Pregnancy
- Acute illness requiring direct lifesaving intervention (e.g., intubation, cardiopulmonary resuscitation).

- Glasgow Coma Score < 9 or a decline of the Glasgow Coma Score ≥ 2 as the primary reason for MET attendance.

Patients’ consent was obtained directly after the MET call; in case of an incapacitated patient, the next of kin was contacted. Deferred consent was also permitted.

MET team staffing

The ICU of Rijnstate Hospital runs a MET since 1996. The MET is staffed by 2 intensive care nurses and 1 ICU resident physician. Board certified intensivists are available within 15 min. The ICU of Rijnstate Hospital uses POCUS since 2009. ICU residents are trained in basic POCUS shortly before ICU rotation. The training program consists of 4 training days in basic cardiac, lung and abdominal ultrasound, POCUS is part of daily care. [16]

POCUS protocol

Our cardiac POCUS protocol consists of 5 straightforward questions combined with a simple qualitative interpretation. Standard transthoracic windows using only 2D-ultrasound were used. [17]

The following questions were answered:

1. Is the left ventricle dilated? —yes/no/don’t know.
   Is the left ventricle function hyperdynamic/normal/ moderately decreased/severely decreased/don’t know?
2. Is the right ventricle dilated? —yes/no/don’t know
3. Is the right ventricle function normal/abnormal/ don’t know?
4. Is pericardial effusion present? —yes/no/don’t know
5. Is pericardial tamponade present? —yes/no/don’t know

From the subcostal view the inferior vena cava (IVC) was identified. The IVC was measured and categorized:

- Collapsed: < 1.5 cm.
- Normal: 1.5–2.5 cm.
- Dilated: > 2.5 cm.
- Not visualized.

Lung ultrasound was used according to the BLUEprotocol by Lichtenstein [18] with the following diagnostic profiles:

- A-profile: normal lung.
- A/A′-profile (one sided): suspect pneumothorax, atelectasis, pleurodesis, pneumonectomy.
- B-profile: (both sides) suspect pulmonary edema, acute respiratory distress syndrome (ARDS).
- A/B-profile (one sided B-lines): suspect pneumonia.
- C-profile (consolidation): suspect pneumonia, atelectasis, or compression.

The MET physicians started with cardiac POCUS in case of primary hemodynamic problems and with the BLUE protocol of the lungs in case of primary pulmonary problems.

We used a handheld ultrasound device (Philips Lumify® S4-1) connected to an Android tablet attached to the MET cart. The LumifyR S4-1 is a phased array transducer with software for cardiac and lung ultrasound exams.

Data collection

Eligible patients were included consecutively: in even weeks the POCUS protocol was used (US+), in odd weeks standard care without the use of POCUS (US−) was deployed.

After the initial assessment, a diagnosis was registered by the MET physician.

In the US+ weeks, a second diagnosis was registered after subsequent use of the POCUS protocol. The attending MET physician could decide to use POCUS in the US- weeks after an initial diagnosis was made. This deviation of protocol was registered and, in these cases, also a second diagnosis (after the use of POCUS) was noted.

All diagnoses were recorded in a case research form (CRF).

An experienced intensive care consultant and member of the hospital mortality committee (independent expert) conducted a full chart review (electronical medical record, HIX®) on all enrolled patients to determine a definite diagnosis 2 weeks after inclusion. The independent expert was unaware of the ultrasound findings (recorded in a separate CRF), the initial diagnosis made by the attending MET physician, and he had no other role in the study. After evaluation by the independent expert, the MET diagnosis was rated as completely correct or completely incorrect. In case of multiple definite diagnosis made by the independent expert (for instance, acute heart failure and COPD), the MET diagnosis could also be rated partially correct if not all elements of the definite diagnosis were recorded in the CRF.

Diagnostic certainty was scored on a visual analogue scale of 0 (no clue) to 10 (absolute certain). The 10-point VAS scale was used because all other clinical scoring in our hospital is done with the 10 points VAS score (for instance pain). Other scales like the 5-point Likert scale would be novel for our physicians to use thereby possibly clouding the results. Ten-point VAS scores have been used in other studies before in certainty assessment.[19] In the US+ weeks the MET physician rated certainty before and after the use of POCUS. In the US− weeks certainty was scored without the use of POCUS and in case of protocol deviation also after the use of POCUS.

We also registered the reason the MET was called, base- line demographics (age, gender, previous medical history, weight and height), clinical and laboratory parameters (heart rate, blood pressure, temperature, serum lactate and white blood cell count) and 28-day mortality.

The MET physicians were asked to rate the quality of the POCUS studies (good, moderate, bad) and were encouraged to capture the POCUS studies for review. Two investigators (FHB and MJB) checked the stored studies.

Outcome measures

The primary outcome measure was the percentage of correct diagnoses made by the MET physician in the US+ and US− weeks. The second diagnosis after the use of POCUS in the US+ weeks and the initial diagnosis

in the US− weeks without the use of POCUS were compared to the final diagnosis made by the independent expert.
Secondary outcome measures were a change in diagnosis after the use of POCUS in the US+ group and (after protocol deviation) in the US− group, percentage of correct diagnosis in the US− group after the use of POCUS, the change in diagnostic certainty before and after the use of POCUS and 28-day mortality. The MET physician also noted first treatment (intravenous fluids, diuretics, vasopressors/inotropes, anti-coagulants, anti-arrhythmic drugs, vasodilators, morphine/sedatives, intubation, or non-invasive ventilation, O2 supply, or other treatments and the need for supervisor attendance).

Statistical analysis

Descriptive statistics are presented as mean with standard deviation for normally distributed continuous data, median and inter-quartile range (IQR) for skewed continuous variables and as numbers and percentages for dichotomous and categorical variables. Differences between groups (US+ group and US− group) were tested using the Pearson Chi-square test, Fisher exact and Students' T test. In case of not normally distributed variables, differences between groups were tested using the Mann–Whitney U test. Changes within groups were tested using the Wilcoxon signed rank test and the McNemar–Bowker test. Statistical analysis was done using SPSS® software (version 25). Sample size was estimated to detect an increase in the number of correct diagnoses of 30% ($\alpha = 0.05$ and $\beta = 0.20$). Based on Jones et al.[13] we estimated that a total of 76 patients should be enrolled (38 patients per group). Because few data exist on the use of POCUS during MET calls, we decided to include 100 patients in total.

Results

We included a total of 100 patients, 52 patients in the US+ group and 48 patients in the US− group. In 5 patients the independent expert could not determine a reliable definite diagnosis (2 in the US+ and 3 in the US− group). These patients were excluded from the comparison of initial/second diagnosis with the definite diagnosis but were included in other analysis. In total, there were 310 MET calls during the study period.
Flowchart of study enrollment and exclusion reasons are in listed in Fig. 1.
Patients' characteristics are described in Table 1.

Primary outcome

Percentage of correct diagnosis US+ versus US− group

In the US+ group 39 (78%) of the diagnoses after the use of POCUS was completely correct versus 23 (51.1%) of the diagnosis without the use of POCUS in the US− group (Pearson Chi Square Test: P = 0.006) (Table 2.)

Secondary outcomes

Change in diagnosis

In the US+ group, the initial diagnosis improved to partly correct in 3 (6%) and to completely correct in 10 (20%) of the patients (McNemar–Bowker test P = 0.004). In 3 (6%) patients an incorrect diagnosis was not improved with the use of POCUS and in 3 (6%) patients the diagnosis after ultrasound worsened from completely correct to partially correct. In no case the diagnosis changed from completely correct before to completely incorrect after the use of POCUS (Table 3).

Percentage of correct diagnosis in the US- group after the use of POCUS

In 12 (25%) patients in the US- group there was a protocol deviation. In 11 of these patients, a final diagnosis could be established. POCUS increased the agreement with the final diagnosis from 27.3% to 63.6%, but this difference was not statistically significant, due to the small sample size. The actual diagnoses before and after POCUS are listed in Table 4.

Certainty

Diagnostic certainty before the use of POCUS was the same in the US + and US− groups. In both groups the median certainty was 8 with comparable ranges.

Certainty improved in the US+ group after the use of POCUS (Wilcoxon signed rank test P < 0.001) (Fig. 2).

This was also found in the 12 patients from the US- group in which ultrasound was used (Fig. 2) Wilcoxon signed rank test P = 0.001. In the minority of cases, the use of POCUS did not increase certainty.

Mortality

28-Day mortality rates were not statistically different: US+ weeks 14 (26.9%) and the US− weeks 13 (27.1%).

Initial treatment and need for immediate supervisor attendance

No statistically significant differences were found between the US+ and US− groups in first treatment (intravenous fluids, diuretics, vasopressors/inotropes, anti-coagulants, anti-arrhythmic drugs, vasodilators, morphine/sedatives, intubation or non-invasive ventilation, O2 supply, or other treatments) nor in the number of times supervisor attendance was needed.

The MET physicians rated the quality of ultrasound exams as good in 25 (39%), moderate 27 (42%) and poor in 12 (19%). One in five studies were evaluated by two experts (FHB and MJB), in one case the quality was adjusted from good to moderate, in all other cases the experts agreed on the rating of POCUS study quality done by the MET physician.

Fig. 1: flowchart of patient enrollment

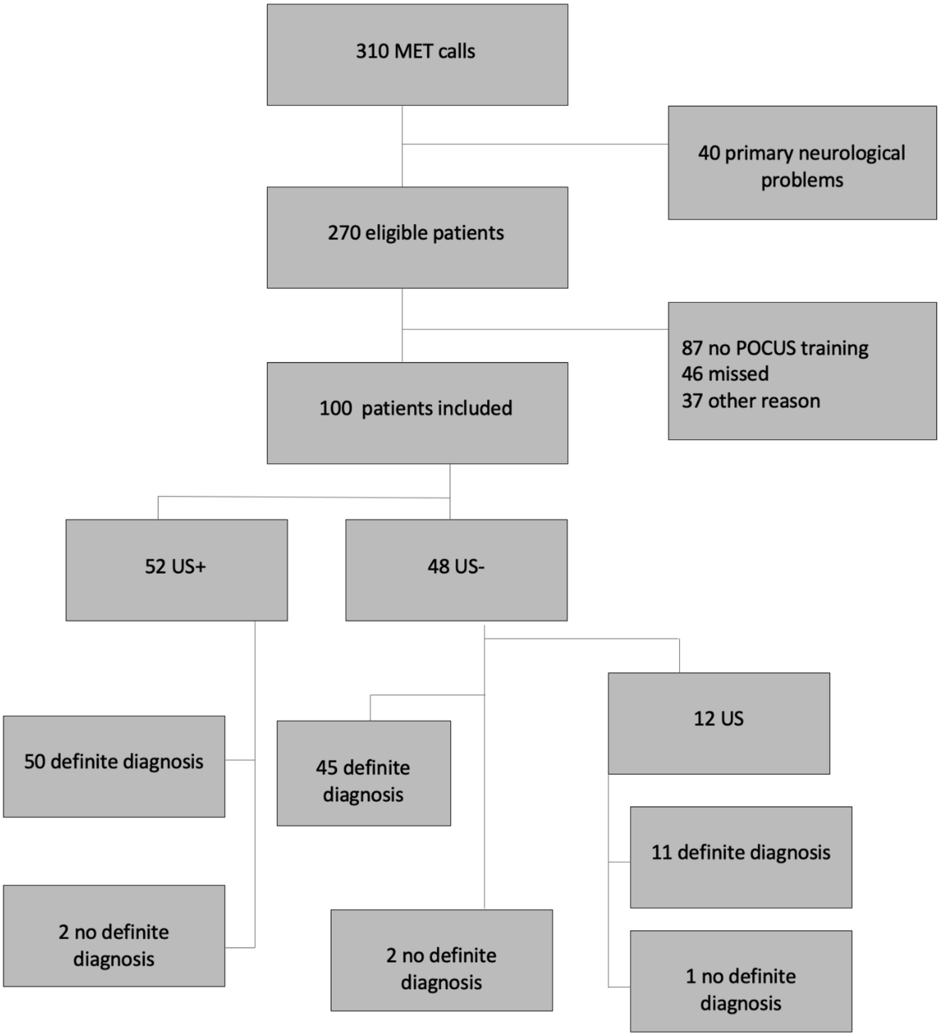

Table 1: *Baseline characteristics*					
	Even week		**Uneven week**		*P* value
	N=52		**N=48**		
	Mean (SD)	**N (%)**	**Mean (SD**	**N (%)**	
Age (years)	72.2 (15)		69.7 (12.1)		0.354
Gender, male		28 (53.8)		27 (56.3)	0.803
BMI [a] (kg/m^2)	26.5 (5.9)		28.2 (5.8)		0.175
Systolic BP (mmHg)	134 (36.5)		127 (42.9)		0.408
Diastolic BP (mmHg)	78 (22.0)		76 (26.2)		0.544
Heart rate (bpm)	110 (33.4)		111 (32.9)		0.870
Temperature (°C)	37.5 (1.6)		37.5 (1.2)		0.859
WBC [b] ($x10^9/L$)	10.4 (5.2)		11.5 (7.6)		0.491
Plasma lactate (mmol/L	3.1 (2.6)		3.3 (2.6)		0.731
Reason for call					
Annaphylaxis		0 (0.0)		1 (2.1)	0.296
Gastro-intestinal bleeding		2 (3.8)		0 (0.0)	0.175
Hypotension		16 (30.6)		18 (37.5)	0.469
Respiratory insufficiency		34 (65.4)		27 (56.2)	0.349
Tachycardia		0 (0.0)		2 (4.2)	0.137
Pre-existing condition					
Heart failure		14 (26.9)		5 (10.4)	0.037 *
Myocardial infarction		12 (23.1)		4 (8.3)	0.045 *
Peripheral vascular		9 (17.3)		5 (10.4)	0.323
COPD [c]		14 (26.9)		13 (27.1)	0.982
Renal insufficiency		16 (30.8)		7 (14.6)	0.056
Dialysis		1 (1.9)		1 (2.1)	0.943
Diabetes mellitus		8 (15.4)		8 (16.7)	0.860
Metastatic malignancy		4 (7.8)		7 (14.6)	0.281
Immunological insufficiency		1 (1.9)		1 (4.2)	0.503
Gastro-intestinal bleeding		2 (3.8)		0 (0.0)	0.175
Hematological malignancy		0 (0.0)		2 (4.2)	0.137

* $P<0.05$; a BMI body mass index; b WBC white blood cells; c COPD chronic obstructive pulmonary disease

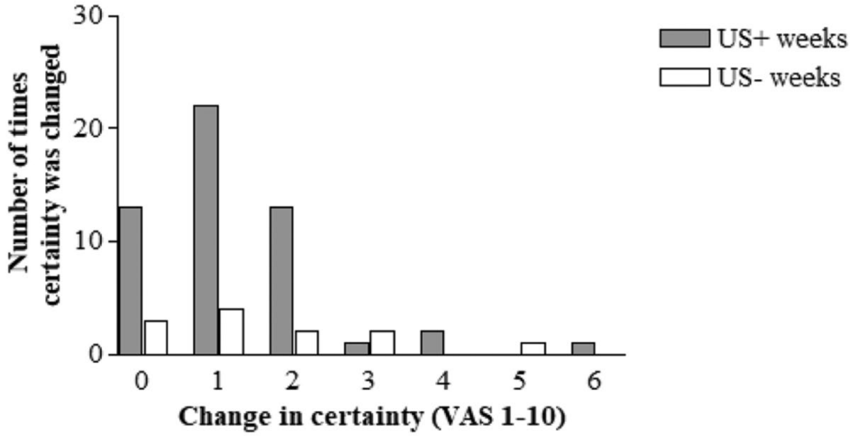

Fig. 2 Difference in certainty before and after US in US− weeks after the use of POCUS

Table 2: *Initial diagnosis versus final diagnosis US+ and US -*			
Initial diagnosis compared to final diagnosis	US+ weeks Number (%)	US− weeks Number (%)	Total Number (%)
Completely correct	39 (78.0)	23 (51.1)	62 (65.3)
Partly correct	8 (16.0)	9 (20.0)	17 (17.9)
Completely incorrect	3 (6.0)	13 (28.9)	16 (16.8)
Total	50 (100)	45 (100)	95 (100)

Table 3: *Initial versus diagnosis after POCUS in the US+ group*				
Initial diagnosis before POCUS				
	Completely correct Number (%)	Partly correct Number (%)	Completely incorrect Number (%)	Total Number (%)
Diagnosis after POCUS				
Completely correct	26 (52)	3 (6.0)	10 (20.0)	39 (78.0)
Partially correct	1 (2.0)	7 (14.0)	0 (0.0)	8 (16.0)
Completely incorrect	0 (0.0)	0 (0.0)	3 (6.0)	3 (6.0)
Total	26 (53.1)	10 (20.0)	13 (26.0)	50 (100)

Table 4: ***List of diagnoses before and after ultrasound in the US+ and US- group***	
US+ Diagnosis before ultrasound (completely incorrect)	Diagnosis after ultrasound (completely correct)
No diagnosis	Hypoventilation
No diagnosis	Respiratory problems due to abdominal disease
No diagnosis	Acute heart failure
Pneumonia	Acute heart failure + pneumonia
Acute heart failure	Pneumonia + septic shock
Acute pulmonary embolism	Hypoventilation
Acute heart failure	Underfilling
Acute exacerbation COPD	Pulmonary Fibrosis
Acute heart failure	Pneumonia
Acute exacerbation COPD	Acute heart failure
Diagnosis before ultrasound (partially correct)	Diagnosis after ultrasound (completely correct)
Pneumonia + atelectasis	Atelectasis
Acute exacerbation COPD	Acute heart failure + exacerbation COPD
Retention bladder	Septic shock + retention bladder
US − Diagnosis before ultrasound (completely incorrect)	Diagnosis after ultrasound (completely correct)
Pneumonia + exacerbation ILD	Acute heart failure
Tension pneumothorax	Hemothorax
Tension pneumothorax	Atelectasis
Diagnosis before ultrasound (partially correct)	Diagnosis after ultrasound (completely correct)
Septic shock	ARDS

COPD chronic obstructive pulmonary disease, ILD interstitial lung disease, ARDS acute respiratory distress syndrome

Quality of POCUS exams

The MET physicians rated the quality of ultrasound exams as good in 25 (39%), moderate 27 (42%) and poor in 12 (19%). One in fve studies were evaluated by two experts (FHB and MJB), in one case the quality was adjusted from good to moderate, in all other cases the experts agreed on the rating of POCUS study quality done by the MET physician.

Discussion

In this single-center prospective observational study the use of a thoracic POCUS protocol improved the number of correct diagnoses significantly. We also found that the number of correct diagnoses increased in the US+ group after the use of POCUS and that POCUS increased MET physician's certainty significantly. We did not find differences in mortality, first MET treatments or supervisor attendance.

There are multiple studies evaluating the use of POCUS in the ICU and ER department, until now only two studies focused on the use of POCUS during MET calls. Zieleskiewicz et al. published a paper [14] in which they evaluated the effect on diagnostic adequacy of thoracic POCUS during MET calls. As in our study, they found a significant increase in the number of correct diagnosis when POCUS was used (80% versus 94%). Furthermore, the time to first treatment was significantly lower in the POCUS group and there was an association with outcome parameters such as mortality, but the latter was not confirmed in the propensity score. Although this study has many similarities with ours, there are also some important differences. Both studies are single centered and prospective observational studies. The inclusion criteria are comparable as is the inclusion rate over time and the number of inclusions out of the total MET calls (34% Zieleskiewicz et al. versus 32% Blans et al.). In both studies, the protocol consisted of cardiac and lung POCUS, Zieleskiewicz et al. also used vascular POCUS to rule out lower extremity thrombosis, but the latter was used infrequently. Both studies found that the use of POCUS during MET calls improved the number of correct diagnoses made by the MET physician (primary endpoint). In both studies, chart review was used to establish a definite diagnosis, but there are some differences in the exact way in which this process was carried out. In contrast to the Zieleskiewicz et al. study, we used the term "partly" correct diagnosis if not all elements of the definite diagnosis made by the external expert were scored by the MET physician. If we add the partly correct to the completely correct numbers, our results would increasingly be comparable to the Zieleskiewicz results (US+ group 94% correct and US− group 69% correct).

Another important methodological difference with our study is the fact that Zieleskiewicz et al. used two MET teams, one which used POCUS and one did not. The two MET's alternated every other day. Both MET deployments (POCUS and not using POCUS) were considered standard therapy and therefore no consent was deemed necessary. We, however, choose to use the same MET but asked to use POCUS only during even weeks and discouraged the use of POCUS during odd weeks. Because Zieleskiewicz et al. used two separate METs, theoretically the difference in the number of correct diagnoses was not only the result of the use of POCUS, but also due to differences between the achievements of the two separate teams although a large number of seniors and juniors randomly composed each

MET. In our study, the MET physician was the same during both weeks (US+ and US−).
Furthermore, it is unclear in the Zielskiewicz et al. study who exactly performed the POCUS protocol, their METs are staffed by junior and senior physicians (with minimally a level 2 in thoracic ultrasound). We also found a significant impact on diagnostic accuracy, but in our study, POCUS was done by residents only, this aspect is worth emphasizing; POCUS can be of an extra value to the less experienced physician during MET calls. We found that without POCUS the number of correct diagnoses was relatively low (51.1%). Although this has been found before in studies in which POCUS was done by more experienced staff, [11, 20], we think that this low percentage can also be partially explained by the fact that in our study less experienced physicians (residents) included the patients.
Several studies show that training programs for residents in multi-organ POCUS have satisfactory results in terms of acquiring adequate ultrasound skills and increasing diagnostic abilities. [21-28]. Our study sup- ports the evidence that residents may obtain clinically relevant POCUS skills in a relatively short period of time, including making the right diagnosis during a MET call.
Our findings are of interest for other hospitals in which the MET is also staffed by residents; POCUS training will improve their diagnostic ability and certainty also during acute situations like MET deployments. Also important to stress is the fact that the use of the POCUS protocol never resulted in a change towards a completely incorrect diagnosis.
Because we asked the MET physician to note to a diagnosis before the use of POCUS and one after the use of POCUS, we could measure more precisely the effect of the use of POCUS, and this was significant in the US+ group and also positive though not significant due to small numbers in the US− group. This also supports the fact that POCUS was the reason for more diagnostic accuracy.
The other study on the use of ultrasound by MET's was published by Sen et al. [29] In this small study of 50 patients on the effect on diagnosis of a combined lung and lower extremity vascular POCUS protocol was evaluated. They showed that lung POCUS was feasible, but due to the small number of patients there was no statistically significant effect on the number of correct diagnoses. They therefore concluded that the use of lung ultrasound was non-inferior to MET clinical assessment. It could well be that by the addition of cardiac POCUS and the inclusion of more patients Zieleskiewicz et al. and we were able to prove a beneficial effect of POCUS on diagnosis during MET calls.
We also evaluated the effect of POCUS on physician's certainty. We showed that in the US+ and US− groups baseline certainty was quite high (eight on a 10-point VAS scale), but certainty increased significantly in the US+ group after the use of POCUS indicating that POCUS did not only improve certainty because certainty levels were low to begin with. There is one other study on the impact of POCUS on diagnostic certainty. [5] Shokoohi et al. looked at

118 ER patients and found that the use of a multi-organ POCUS protocol lowered uncertainty for a diagnosis. We are aware of the relatively small increase in certainty that was found in our study, but this finding could be psychologically important for residents during stressful clinical encounters such as MET calls. Junior physicians are less certain in the diagnostic process compared to more experienced colleagues. [30]

We could not find differences in other outcome parameters (28-day mortality, initial treatment or supervisor attendance) possibly due to the small number of included patients. It will be difficult to design a study on the use of POCUS during MET calls large enough to detect differences in outcome parameters such as mortality. Preferably, a multicenter trial could help in including large enough numbers of patients. On the other hand, one could argue that the existing evidence is sufficient to support the incorporation of POCUS in MET protocols.

Our study has several limitations. This study was conducted in a single center and focused on ward patients with respiratory and or hemodynamic deterioration. Therefore, the presented results may not necessarily apply to other clinical settings. There were some differences in baseline characteristics between the US+ and US− groups. Significantly more patients in the US+ group had a history of myocardial infarction and heart failure. We have no reason to believe that these baseline differences had a significant impact on the study results. Our study design is prone to selection bias, but also has several advantages as discussed above. We decided to exclude the MET physicians without sufficient POCUS training from the trial. This resulted in a substantial number of non-included patients (87).

Our POCUS protocol consisted out of a combination of 5 basic cardiac questions and for the lung the BLUE protocol was used which is consistent with current international POCUS practice. No further prespecified POCUS flow chart was used which makes our findings perhaps difficult to validate by others.

The diagnoses of the MET physicians were compared to the final diagnosis made by one blinded experienced intensive care consultant 2 weeks afterwards (independent expert) on the basis of a thorough chart review. This method remains challenging although often used in POCUS studies. [12, 13] In our study, only one independent expert reviewed the charts and was blinded to the ultrasound findings and diagnosis made by the attending MET physician. He had absolutely no other role in the study and because he is a member of the hospital mortality committee, he is experienced in extracting official diagnoses from chart review.

Conclusion

We found that the use of a thoracic (cardiac and lung) POCUS protocol during MET calls due to respiratory and or hemodynamic deterioration has significant positive impact on establishing the correct diagnosis and a small but significant impact on MET physician's diagnostic certainty.

Supplementary Information

Modified Early Warning Score							
Score	3	2	1	0	1	2	3
O2-supply				Room air	≤ 5l/min	≥5 l/min	
SpO2%	≤ 91	92-93	94-95	≥ 96			
Resp. rate	≤ 8		9-11	12-20		21-24	≥ 25
Heart rate	≤ 40		41-50	51-90	91-110	111-130	≥ 131
BP (syst)	≤ 90	91-100	101-110	111-219			≥ 220
Consiousness				A		Delirum	V/P/U
Temperature (Celsius)	≤ 35.0		35.1-36.0	31.1-38.0	38.1*39.0	≥ 39.1	

MEWS 0, 1, or 2:	Check vitals 1 x 8 hours, if repeatedly 0, 1, or 2 check 1x per 24 hours
MEWS 3, 4, 5 or agitated	Check vitals 1 x 4 hours discuss with another nurse or department physician
MEWS ≥ 6	Check vitals every hour contact department physician directly Call for MET assistance if needed

If MEWS increases by ≥ 3 points within 8 hours: contact department physician directly call for MET assistance if needed

A= alert V = verbal p = pain U=unresponsive

THINK OF SEPSIS
consider lactate?
Culture and antibiotics

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Chapter 8: The use of ultrasound during and after central venous catheter insertion versus conventional chest X-ray after insertion of a central venous catheter

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Abstract

Background: After insertion of a central venous catheter (CVC) a conventional chest X-ray (CXR) is usually taken to check for complications and correct position. Ultrasound might be equally effective as CXR and is less time consuming. We studied the use of ultrasound versus CXR after insertion of a CVC in general ward patients.
Methods: General ward patients in need of a CVC were included. CVCs were inserted under direct ultrasound guidance. After insertion, ultrasound was performed and compared with CXR to check for complications and position. The waiting time for CXR was noted.
Results: In total, 53 patients were included. In 52/53 patients ultrasound was feasible. The results of ultrasound and CXR only differed in 3 of 53 patients. The sensitivity of ultrasound in detecting the correct CVC position was 98% (89.4-100%). No complications were detected (ultrasound or CXR). The median waiting time for CXR was 24.5 minutes.
Conclusions: Our study shows that an integral use of ultrasound during and after CVC insertion is effective in establishing that the CVC is correctly positioned and for identifying post-procedural complications in patients from the general ward when compared with CXR.

Keywords

Central venous catheter, (lung) ultrasound, chest X-ray, echocardiography, complications, general ward

Introduction

Patients on the general wards regularly need a central venous catheter (CVC) for the administration of intravenous feeds or medications, especially if a peripherally inserted central catheter is not feasible or for the purpose of hemodialysis.
Most CVCs, however, are introduced in the intensive care unit (ICU) or emergency department and it was estimated that in the UK 200,000 CVCs were inserted annually.[1] For introduction of a CVC for patients on the general ward in our hospital, the patient has to be transported to a specialized unit or room and that will be the case in most other hospitals. If patients from the general ward are in need of a CVC, the use of ultrasound during and after insertion could be of great value. Using ultrasound during insertion will help in getting the CVC into the correct vessel, and because ultrasound can also be done immediately after insertion there will be no need to do a chest X-ray (CXR). This strategy might also be safe and time efficient for the general ward patients in need of a CVC.
It has been shown that the use of ultrasound during the insertion of a CVC in the internal jugular vein results in fewer complications and fewer attempts are necessary for correct placement compared with the landmark technique. [2] Many guidelines and expert opinions prescribe the use of ultrasound guidance during insertion of a CVC into the internal jugular and subclavian vein. [1, 3-5]
By using the Seldinger technique, a guide wire is introduced after puncture of the vessel under direct ultrasound guidance. Afterwards, the position of the wire is checked by ultrasound, further reducing the problem of misplacement. [6] After introduction of a CVC, the position is checked by CXR, acknowledging that a pneumothorax or malposition may be missed through this investigation. Furthermore, there is little consensus on what the best position is on a chest radiograph; [7] there are conflicting reports on the use of ultrasound for this question. [8, 9] Ultrasound has advantages compared with CXR. [10, 11] It has been shown to be superior to CXR in the identification of an anterior pneumothorax and can be performed immediately after the procedure, while waiting for a CXR takes time and is associated with discomfort and the need of radiation exposure for the patient. Furthermore, the immediate appearance of microbubbles in the right atrium after injection of agitated saline through the CVC proves unequivocally the intravascular position of the CVC.
We performed a proof-of-concept prospective study in which we compared ultrasound versus CXR in general ward patients receiving a CVC in the internal jugular or subclavian vein for the detection of post-insertion complications and to confirm the correct position of the CVC. Ultrasound was used as guidance during insertion. We also studied the time interval between the procedure itself and the results of the CXR.

Material and methods

We conducted this study in a large teaching hospital in the Netherlands. General ward patients in need of a CVC were included. We excluded patients < 18 years and pregnant women. The study protocol was approved by the Local Ethics Committee and consent was obtained directly. Sex, age, body mass index, approach used for CVC placement, reason for CVC placement (antibiotics, total parental nutrition, lack of other venous access, combination of reasons) and the time (minutes) needed to obtain the result of a bedside CXR were noted.
Complications during insertion were noted separately (e.g., bleeding or rhythm disturbance).
All CVCs were placed under direct ultrasound guidance by experienced doctors (staff and residents). Due to logistic reasons general ward patients were transported to the ICU for insertion of the CVC during this study.
All CVCs were inserted using the Seldinger technique. After puncture of the vessel the position of the guide wire was checked by ultrasound in the long axis. In our departments triple lumen CVCs (Edwards Lifesciences) are used. For the left-sided CVCs a catheter of 20 cm is used, on the right side 15 cm. For dialysis purposes Medcomp catheters are used, also in two different lengths (20 and 15 cm).
After insertion, while waiting for the CXR, the following ultrasound examinations were performed by MB and FB, both experienced in the use of ultrasound:

- With the use of a linear-array ultrasound probe (CX50 Philips) the ipsilateral internal jugular vein was examined (in case of insertion in the subclavian vein) or the ipsilateral subclavian vein was examined (in case of insertion in the internal jugular vein).
- With the use of a linear-array ultrasound probe (CX50 Philips) the ipsilateral thorax was screened for pneumothorax. The linear transducer was used to examine several ipsilateral anterior intercostal spaces for the presence of lung sliding with its presence ruling out pneumothorax.
- B-mode cardiac ultrasound (CX50 Philips): subcostal view or apical view if subcostal view was impossible: direct visualization of the right atrium, right ventricle and inferior vena cava. Contrast-enriched ultrasound was performed using the standard technique (10 ml syringe containing 9 ml of saline solution and 1 ml of air, mixed with a stop clock to obtain a homogenous solution). Under view of the right atrium 5 ml was injected through the distal lumen of the central line. The pattern of microbubbles entering the right atrium was observed. Interpretation of the images was done according to the study by Cortellaro et al.8 (table 1). If needed, a further 5 ml was administered (maximum 10 ml). The saline/air mix was injected after checking the correct functioning of the CVC by sucking blood in each lumen and flushing the lumens with saline.

Incorrect CVC position was defined as:

- Tip in right atrium or right ventricle (cardiac misplacement);
- In homolateral or contralateral veins, or in the brachiocephalic vein (intravascular misplacement).

Position was defined as incorrect if there were no or few air bubbles, or a late appearance (> 2 seconds) of bubbles, seen from the superior vena cava entering the right atrium, or if there was turbulent flow in the right atrium or right ventricle.
The ultrasound examinations were done blinded from the CXR results. All CXRs were viewed by the attending radiologist who was not informed about the ultrasound results.
A true positive result was defined as the correct ultrasound placement confirmed by CXR and true negative placement as incorrect ultrasound confirmed by CXR. False positive was defined as correct placement by ultrasound not confirmed by CXR, and false negative placement as incorrect ultrasound placement not confirmed by CXR.

Calculation
Continuous data are presented as mean ± standard deviation (SD) or median and interquartile range (IQR) as appropriate. Categorical data are presented as frequencies and percentages. Using CXR as a reference standard, the sensitivity of ultrasound with a 95% confidence interval was calculated. Statistical analysis was performed using IBM SPSS Statistics (version 21).

Table 1. ***Interpretation of micro bubbling injection pattern***

Characteristics	Interpretation
No bubbles	Negative test: possible extravascular, extracardiac placement
Few bubbles or appearance > 2 seconds	Negative test: intravascular misplacement in neck veins or tip position too far from RA
Numerous bubbles with turbulent flow in the RA or direct visualization of catheter tip in right atrium	Negative test: intracardiac (RA) misplacement
Numerous bubbles with linear flow coming from SVC within 2 seconds	Positive test: correct tip positioning

RA = right atrium; SVC = superior vena cava.

Results

Between January 2015 and September 2015, 53 patients were included (table 2). In this study 25 (47%) patients were male, aged 64 (± 12.8), with a body mass index (BMI) of 26.7 (± 5.2).
Other characteristics such as the reason for CVC insertion, the approach used (jugular or subclavian), whether the CVC was inserted by staff, or a resident and the time needed for CVC insertion are also described in table 2.
In all but one patient ultrasound was feasible. In one patient no cardiac view could be obtained. In one patient ultrasound revealed a correct position but the CXR showed an aberrant location of the catheter. In this patient the attending radiologist advised an iodine contrast cavogram which showed an anatomical anomaly of the superior vena cava. Therefore, this CVC was correctly positioned in the superior vena cava. In one patient a catheter introduced in the internal jugular vein ended in the ipsilateral subclavian vein (also a large vessel). In this patient ultrasound showed a correct position, including normal pattern of microbubbles in the right atrium.
In one patient ultrasound showed a correct position but the radiologist concluded that the CVC was in the right atrium (table 3).
The sensitivity of the use of ultrasound in detecting that the CVC is correctly positioned (with CXR as a reference standard) was 98% (89.4-100%). The time needed for CVC placement was 17 ± 8.6 minutes (mean ± SD). The median time needed to wait for the result of the CXR was 24.5 minutes (IQR 18.1- 45.3). We omitted one patient who was included in the study when the digital radiology system was down for 44 hours due to severe technical failure.
In this study no post-procedural complications after CVC insertion were detected by either ultrasound and CXR.

Discussion

In this prospective observational study, we have shown that ultrasound is sufficient to exclude the existence of a pneumothorax and the absolute proof that the catheter is placed in a large vessel. For intensive care patients the use of ultrasound before and after CVC insertion has already been endorsed12 but ICU patients are not the only group of patients in need of a CVC. In this study we included general ward patients in need of a CVC. According to the current hospital protocol they were transported to the ICU for CVC insertion, but this study opens the alternative of safely inserting a CVC in another designated area using mobile ultrasound. After insertion using ultrasound a check for correct positioning and complications can be done on the spot. In this way the patient is spared the burden of uncomfortable transport, extra waiting and additional radiation.

Furthermore, we have shown that a possible complication of the insertion can be examined immediately with ultrasound, while this is not the case with CXR. No post-insertion complications were found with either of these techniques. After insertion, ultrasound was directly used to check for position and complications. Extra time was needed to wait for the result of the CXR (median 24.5 minutes); in one case the result of the CXR was delayed for almost two days due to a serious technical failure.

Table 2: ***Patient characteristics***

Patient characteristics	Number, % or SD
Sex (male/female) ‘%)	28/28 (47/53)
Age (years ± SD)	64 (12.8)
Body mass index (kg/cm2 ± SD)	26.7 (5.2)
Reason for CVC (N/%) Antibiotics Inotropes TPN Other	 12 (23%) 2 (4%) 25 (47%) 14 (26%)
Approach (N/%) Lift IJV Right IJV Left SCV Right SCV	 5 (9 %) 45 (85%) 2 (4%) 1 (2%)
Staff/resident (n/%) Staff Resident	 7 (13%) 46 (87%)
Time needed for CVC insertion (minutes mean ± SD)	17 (8.6)

SD: standard deviation; ICU: intensive care unit; CVC: central venous catheter; TPN: total parenteral nutrition; IJV: internal jugular vein, SCV: subclavian vein.

Table 3: ***Concordance between ultrasound and CXR for correct position***

	CXR correct position	CXR incorrect position	Total
US correct position	49	3	52
US incorrect position	1	0	1
Total			53

US: ultrasound; CXR: chest X-ray

In our study of 53 patients there were only three patients in whom discordance was found between ultrasound and CXR in determining the correct position of the CVC. In one patient the CXR proved to be wrong and in two patients ultrasound proved wrong (in one patient the radiologist found the CVC to be positioned in the right atrium which is a difficult call to make using bedside CXR). The position in the subclavian vein was of no clinical significance, since this is a large vessel, regularly used for access or for location of a peripherally inserted central catheter. The location in the right atrium was doubtful and probably also not significant. Comparing the two techniques, the sensitivity of the use of ultrasound in detecting whether the CVC was correctly positioned (with CXR as a reference standard) was 98% (90.1-100%).
There are more reports on the use of ultrasound after CVC insertion, but these studies focus on ICU patients. There are more differences, for instance in our study we combined different factors to optimize correct positioning. All CVCs were inserted under direct ultrasound guidance including the identification of the guide wire before the skin; subcutaneous tissue and vessel wall were dilated. With the use of two different lengths (20 cm for left-sided lines and 15 cm for right-sided lines) the chance of a position being too deep in the average Dutch adult patient is limited.[13, 14]
The use of different lengths is a different strategy compared with the study by Cortellaro et al.[8] In the Cortellaro study CVCs of 20 cm length were used on both sides. They reported a very low incidence of incorrect positioning in the right atrium. Due to the fact that ultrasound identified only half of the incorrectly positioned CVCs, the authors state that ultrasound cannot substitute CXR in detecting incorrect positioning after insertion. In our study all but one of the CVCs were positioned above the right atrium and in almost all cases this was correctly detected by both CXR and ultrasound investigation.
In another study [9] a good concordance between ultrasound and CXR was shown in detecting complications and correct position after CVC insertion. However, in this study ultrasound was not used as guidance during insertion. In this study also CVCs of 20 cm length were used on both sides and compared with our study, substantially more subclavian veins were used (77% versus 5.7% in our study). In this study, due to the relatively high incidence of complications and incorrect positions of CVCs, good concordance between ultrasound and CXR in detecting complications and incorrect positioning was shown. In our study the a priori chance of complications and an incorrect position was limited by using ultrasound guidance during insertion and by using different catheter lengths for a left- and right-sided approach.
There is discussion about the correct position of CVCs anyway. In a recent review by Frykholm et al. the topic of catheter position was also discussed. After a search of the literature, they concluded that there are no conclusive studies on optimal catheter tip position. Since less rigid catheter materials are used, the risk of cardiac tamponade associated with catheter tips in the

right atrium is very low. In the case of a central line for the purpose of dialysis the position of the catheter tip in the right atrium might even be better. [15]
So perhaps the exact depth is less important than, for instance, whether the line follows the contour of the vessel (and is not perpendicular to the vessel wall). [7] It is true that the angle of the CVC cannot be seen on ultrasound but in our study, there were no cases of a CVC position perpendicular to the vessel wall and there is no scientific evidence that such a position might be dangerous. Furthermore, the rapid appearance of the contrast material in the right atrium proves a good flow of fluids through the catheter.
In a prospective clinical study by Pikwer et al. [16] it was shown that when using CXR in 1619 patients there was a low incidence of detecting an incorrect CVC position. In only 0.37% the CVC position needed adjustment after insertion. They state that CXR should not be routinely used but only when the CVC insertion procedure was difficult. Another problem using CXR is that the CVC position may vary about 1 cm craniocaudally during breathing. [17]
In our study no complications were detected (0%). When introduced under direct ultrasound guidance, the incidence of complications after inserting a CVC in, for instance, the internal jugular vein is also reported to be very low. [2, 18] The sensitivity of lung ultrasound for the detection of pneumothorax is excellent when compared with CXR, which is known to be notorious for missing anterior pneumothorax. [10, 19]
Another argument in favor of the use of ultrasound is the fact that ultrasound is more time efficient. In our study, due to technical failure the hospital radiology system (PACS) was out of order for 44 hours. Disregarding this incident, a substantial amount of time was needed before a CXR result was obtained. The time saving aspect can be of clinical significance.
Our study has a number of limitations. First, a small number of patients were included. The problem is that due to the a priori very low incidence of complications and incorrect positioning of CVCs the required number of inclusions is infeasibly high.
Another criticism might be that in our study only doctors experienced in ultrasound were involved in performing the ultrasound examination after CVC insertion. Although with ample training point of care ultrasound can be taught [20] it is possible that in less experienced hands the results would be different. The recognition of laminar versus turbulent flow in the right atrium requires experience but can also be taught when the right ultrasound view can be obtained.
Our patients had an average BMI of 26.7 (± 5). We did not select patients by BMI but included all possible patients, so this set of patients represents the average Dutch patient in need of a CVC. The one patient in which no cardiac view could be obtained was a patient with a BMI of 28.7, who had undergone recent abdominal surgery. The low number of patients in which

no cardiac view could be obtained in our study is not different from reports in recent literature. [21] With modern ultrasound equipment adequate cardiac views can be obtained in the vast majority of patients.

Conclusion

Our proof-of-concept study shows that an integral use of ultrasound during and after CVC insertion is effective in establishing correct CVC positioning and post-procedural complications in patients from the general ward when compared with CXR. Our study demonstrates that CXR is only necessary if lung sliding cannot be demonstrated or if there is not a rapid (< 2 sec) appearance of microbubbles in the right atrium. To further investigate the occurrence of infrequently occurring complications, we suggest that a larger study should be performed.

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Chapter 9: The use of an external ultrasound fixator (Probefix) on intensive care patients: a feasibility study

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Abstract

Background: In critical care medicine, the use of transthoracic echo (TTE) is expanding. TTE can be used to measure dynamic parameters such as cardiac output (CO). An important asset of TTE is that it is a non-invasive technique. The Probefix is an external ultrasound holder strapped to the patient which makes it possible to measure CO using TTE in a fixed position possibly making the CO measurements more accurate compared to separate TTE CO measurements.
The feasibility of the use of the Probefix to measure CO before and after a passive leg raising test (PLR) was studied. Intensive care patients were included after detection of hypovolemia using Flotrac. Endpoints were the possibility to use Probefix. Also, CO measurements with and without the use of Probefix, before and after a PLR were compared to the CO measurements using Flotrac. Side effects in terms of skin alterations after the use of Probefix and patient’s comments on (dis)comfort were evaluated.
Results: Ten patients were included; in eight patients, sufficient recordings with the use of Probefix could be obtained. Using Bland–Altman plots, no difference was found in accuracy of measurements of CO with or without the use of Probefix before and after a PLR compared to Flotrac generated CO. There were only mild and temporary skin effects of the use of Probefix.
Conclusions: In this small feasibility study, the Probefix could be used in eight out of ten intensive care patients. The use of Probefix did not result in more or less accurate CO measurements compared to manually recorded TTE CO measurements. We suggest that larger studies on the use of Probefix in intensive care patients are needed.

Keywords:

Intensive care, Cardiac ultrasound, Cardiac output, Passive leg raising test, External

Background

The use of echocardiography by intensivists is rapidly growing. [1] Transthoracic echocardiography (TTE) is performed at the bedside, provides clinically relevant information and is safe in terms of radiation. TTE can be used to estimate dynamic parameters such as cardiac output (CO) but using TTE for these kinds of dynamic measurements is not without possible flaws.[2] To detect changes in CO using TTE, successive measurements of CO are needed. To get accurate results, the CO measurements should ideally be taken at exactly the same location.

The Probefix is a non-invasive external ultrasound holder (Figs. 1, 2 and 3) which is strapped on to the patient with the use of non-traumatic straps.

When properly attached to the patient, the Probefix offers the opportunity to measure dynamic TTE parameters such as CO at exactly the same position thereby possibly increasing measurement accuracy.

To this date, there are no data on the use of the Probe fix on adult intensive care patients. The Probefix has already been used in a study on adult outpatient cardiology patients [3] and another tailored holder for echocardiography was described in a study on 5 pediatric patients. [4] We designed a feasibility study to determine whether the Probefix can be used on adult intensive care patients for the purpose of measuring CO. CO with TTE with and without the Probefix was measured by using CO measurements made by the Flotrac as a reference. The Flotrac is a system that monitors CO by analyzing the systolic arterial pressure wave. The arterial catheter of the Flotrac system can be placed in the radial artery and has no need for pulmonary artery catheterization or other calibration.[5]

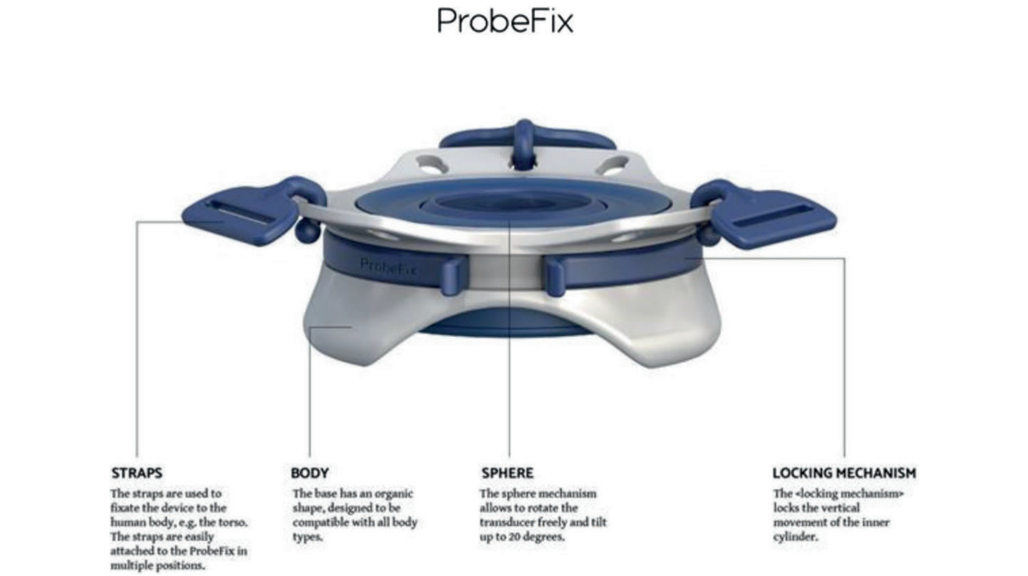


Fig. 1 Description of the Probefix

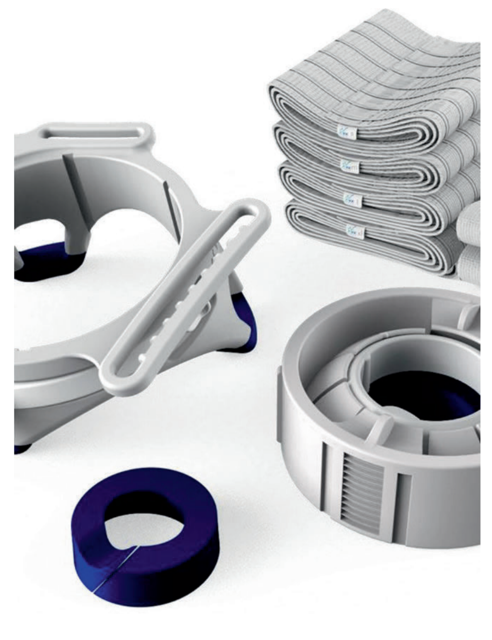


Fig 2: Components of the Probefix

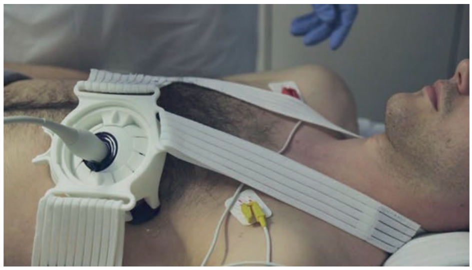


Fig. 3 Example of the fixation of the Probefix on a patient

Because there is variation between CO measurements between TTE and Flotrac, it will be difficult to assess the use of the Probefix during random CO measurements. It is more interesting to know whether possible changes in CO measurements will be the same after a therapeutic intervention such as a bolus of fluid.

Besides CO, the Flotrac system monitors stroke volume and calculates the stroke volume variation (SVV). SVV is the percentage variation of stroke volume measured during a 20-s interval. Monitoring SVV can be helpful in detecting hypovolemia. When stroke volume variation is above 10%, hypovolemia is present. [6] When hypovolemia is detected with the Flotrac, a passive leg raising test (PLR) can be performed. During PLR, 150–200 mL of blood returns from the lower extremity veins to the central circulation. [7] With PLR, a reversible volume challenge is provided. [8] This is in contrast to an infusion of fluid (Fig. 4).

Methods

In this prospective pilot feasibility study, the Flotrac system was used to detect possible hypovolemia (SVV > 10%) and Flotrac CO measurements were compared with the TTE CO measurements (with and without the use of the Probefix). CO was measured before and after a PLR test.

Primary endpoints

Percentage of patients in which the Probefix can be used. The correlation between the measurements done by Flotrac and TTE with and without Probefix.

Although no side effects are to be expected, we monitored the patients after the Probefix was removed for any skin damage. Possible skin damage was graded into three categories:

- No skin marks
- Mild skin marks (no treatment necessary)
- Severe skin marks (surgical or medical treatment necessary)

If awake, the patients were asked whether they felt the Probefix to be unpleasant on a scale of 0–10 (0 being: I did not feel anything and 10 being very unpleasant).

Inclusion criteria

Adult intensive care patients (≥ 18 years), with hypovolemia detected with Flotrac (SVV > 10%).

Exclusion criteria

Pregnancy, atrial fibrillation or other irregular heart rhythm, pulmonary edema, PLR not possible (e.g., neurological disease, spinal trauma, restricted limb movement, deep venous thrombosis, or any other reason as indicated by the attending intensivist) or age < 18 (years).

Measurements

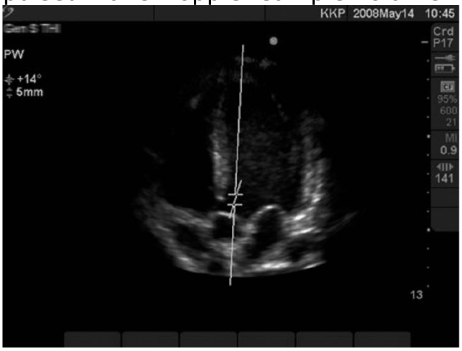
After detection of SVV of more than 10% by Flotrac, patients were eligible for inclusion and consent was asked. The TTE studies were done by 2 investigators (MB and FB) with Philips Affinity using the Phased Array probe; the patients were in supine position.

First in the parasternal long axis view (PLAX), the left ventricle outflow tract (LVOT) was measured in cm. Then, the following protocol was executed:

Measurements with Probefix

Step 1: The Probefix is attached to the patient.
Step 2: An apical 5 chamber view was obtained with a 2.5-MHz probe. A pulsed wave Doppler sample volume was measured just below the aortic valve (Fig. 2), sweep speed: 150 mm/s.
A velocity time integral (VTI) was calculated by tracing the envelope velocity. CO measurements were calculated by combining this result with the measurement of the opening of the aortic diameter, obtained in the PLAX.

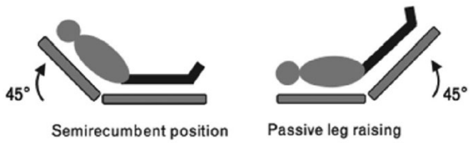
Fig. 4: Apical 5 chamber view with pulsed wave Doppler sample volume



Step 3: PLR test.
 Stage 1: raise the lower limbs of the patient to a 45° while the patient's trunk is lowered in supine position.
 Stage 2: after 1 min, measure the CO (Fig. 5).
Step 4: Steps 2–4 are repeated without the use of the Probefix.

Measurements without Probefix
Repeat step 2 and 3.

Fig. 5: The two positions in PLR



Statistical analysis
Primary study parameter(s)
1) Percentage of patients in which the Probefix can be used.
2) Scatter plots are constructed, and the limits of agreement are calculated.

Secondary study parameter(s)
Possible side effects of the Probefix.
Descriptive statistics are presented as mean with standard deviation for normally distributed continuous data.
The local ethic committee approved the study (NL62664.091.17); informed consent was obtained from all participants (or their next of kin) included in the study.

Results

From May 2018 to April 2019, ten patients (six female and four male patients) were included.
In table 1, patient characteristics are described.
In eight patients (80%), the Probefix could be used properly leading to interpretable measurements. In two patients, insufficient views with the Probefix were obtained and in these patients, there were sufficient views using the TTE probe manually; so, the problem was Probefix related and not TTE related.
One patient was breathing spontaneously, three patients were on controlled mechanical ventilation and six patients received pressure support. Mean peak inspiratory pressure was 13 cm H_2O (± 6.9), mean post expiratory end pressure 6 cm H_2O (± 5.1), mean tidal volume was 480 mL (± 110) and mean LVOT was 2.1 cm (± 0.23). When compared to the Flotrac measurements, there was no significant difference in correlation between TTE measurements with or without the use of the Probefix with the CO measurements done by Flotrac as a reference (Figs. 6, 7).
There were no serious skin lesions after the use of the Probefix. In four patients, there were minor skin marks that disappeared after some minutes. There was only one patient able to comment on the use of the Probefix and he reported only mild discomfort (2 on a scale of 10). In all patients, the time needed to process the protocol was within 15 min.

Table 1: *Patient characteristics*						
	Age	M/F	BMI	Diagnosis	Mode of ventilation	**Probefix feasible?**
Patient 1	70	M	23.1	Out of hospital cardiac arrest	Pressure Control	Yes
Patient 2	64	F	24	Out of hospital cardiac arrest	Pressure regulated volume control	Yes
Patient 3	69	F	23.4	Pneumonia	Pressure support	Yes
Patient 4	67	F	23	Chronic bronchitis	Pressure support	Yes
Patient 5	45	F	17.7	Pneumonia	Pressure support	Yes
Patient 6	59	M	19.4	Abdominal sepsis	Pressure support	Yes
Patient 7	68	F	24.2	Interstitial lung disease	Pressure support	Yes
Patient 8	61	M	24.5	Pneumonia	Pressure support	No
Patient 9	73	M	22.8	Pneumonia	Pressure control	Yes
Patient 10	63	F	25.4	Out of hospital cardiac arrest	Pressure support	No
Mean ± SD	**63.9 ± 7.9**		**23.5 ± 3.1**			

M male, F female, BMI body mass index, SD standard deviation

Fig. 6. Scatter plot transthoracic echo (TTE) cardiac output (CO) vs. Flotract with (green points) and without the use of Probefix (blue points)

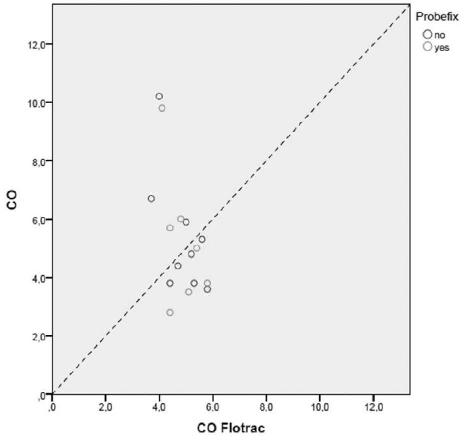
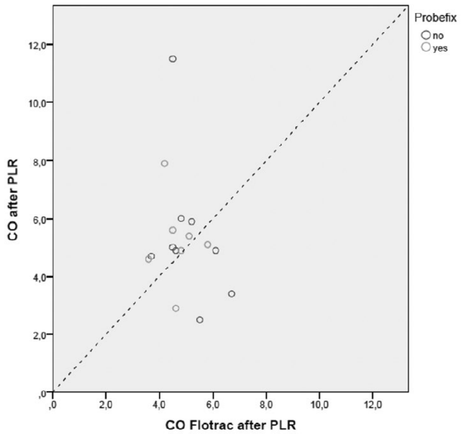


Fig. 7. Scatter plot transthoracic echo (TTE) cardiac output (CO) vs. Flotrac with (green points) and without the use of Probefix (blue points) after passive leg raising (PLR)



Discussion

We demonstrated in this small feasibility study that the Probefix could be used in eight of ten adult intensive care patients. All but one patient (patient 6) were medical patients. Male and female patients were included, and patients were both on controlled and support mechanical ventilation. When compared to CO measurements using Flotrac, there was no statistical difference between CO measurements by TTE with or without the Probefix. Our study is small and as far as we know the first on adult intensive care patient in which the use of Probefix is described. As mentioned before, there is already a small case study on pediatric intensive care patients but none on adult intensive care patients. [4]
The number of included patients was too small to be able to conclude whether the use of the Probefix will lead to more accurate CO measurements, but the opposite was also not found.
We know that measuring CO on intensive care patients using TTE is difficult in terms of comparison to other techniques such as thermodilution techniques [2] but it is feasible when done by intensivists. [9] In this study, only one heartbeat to measure CO using TTE was used which is fewer then normally performed but the aim of this study was primarily to assess the feasibility of the Probefix, not to establish the accuracy of the TTE CO measurements. By adding a PLR test to this study, we investigated also whether the Probefix could be used for dynamic measurements and using the PLR test, the possible side effects of volume loading were diminished.
In this study, TTE measurements were compared to the measurements done by Flotrac. We acknowledge the fact that there are doubts about the usefulness of pulse pressure analysis as a monitoring tool on the intensive care [10, 11] but we think that the Flotrac measurements could be used as controls to compare the TTE measurements with and without the use of the Probefix.
No skin injuries in the studied patients were found. Whether Probefix creates pressure sores with longer attachment periods needs to be investigated. Nine of ten patients could not comment on the (dis)comfort of the Probefix due to sedative medication so on this one comment only we cannot speculate on this aspect of the use of Probefix.
There are many interesting options for the use of Probefix; eventually, its use enables continuous non-invasive CO measurements.
For this development, we need software that can trans late the LVOT-VTI TTE images to real-time CO. By optimizing TTE for continuous CO monitoring, the use of more invasive techniques can be greatly diminished making this development of interest for almost every patient in the intensive care unit.

Conclusion

In this small feasibility study, it was shown that the Probefix can be used in eight out of ten adult intensive care patients for measuring CO also after a PLR test. More research is needed to further evaluate this new technique aiming at aspects such as accuracy, efficacy and costs.

Funding
The Probefix was made available by Usono. No grants or fee were paid.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
Ethical approval by the METC Nijmegen-Arnhem (NL62664.091.17). Consent was obtained from all patients or next of kin.

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Chapter 10: Summary, discussion and future perspectives

In this thesis we focused on several aspects of point-of-care ultrasound (POCUS). We explored the following three topics:
1. How should we define POCUS, what is the essential content, are different levels possible, is there a uniform nomenclature and what are the training requirements?
2. What are the necessary steps needed for implementation of POCUS in the ICU and how do we organize POCUS training?
3. Will POCUS result in improved patient care?

The results of our research are helpful for those seeking advice in training and implementing POCUS in their own ICU unit. In this thesis we also contributed to the research agenda on critical care ultrasound proposed by the European Society for Intensive Care Medicine including:

- Validation of standardized CCUS curriculum for residents and fellows
- Studies on new ultrasound technologies and approaches in the future
- Evaluation of replacement of standard chest X-ray by ultrasound

Chapter 2 is a narrative review [1] exploring the existing recommendations by major international scientific critical care and cardiology organizations on emergency care ultrasound. We show that recommendations were highly heterogeneous on issues such as nomenclature, content and training. We suggest the name point-of-care ultrasound or POCUS as it includes all possible ultrasound applications (heart, lung, abdomen, major blood vessels and others) and POCUS can be used by all professionals active in the field of acute medical care. We divide POCUS into a basic and an advanced level and make suggestions for the content of basic and advanced cardiac, lung, abdominal and vascular POCUS. We suggest training requirements for the different POCUS applications and state that the basic components of POCUS can be learned in a few days. Finally, suggestions for POCUS implementation are provided.

In **chapter 3** we describe a manual for basic cardiac and lung ultrasound in the Netherlands. [2] We describe in detail basic cardiac and lung ultrasound content and which clinical questions regarding cardiac function, pericardial effusion, volume status and major pulmonary conditions can be answered by using thoracic ultrasound. We provide stepwise instructions and illustrations supported by internet-based video demonstrations. The four basic cardiac ultrasound views and the subcostal inferior vena cava view are discussed. We elaborate on the main clinical questions: size and function of the left and right ventricle, the presence of pericardial fluid (including the ultrasound signs of tamponade) and the assessment of intravascular volume status. Also, the principles of lung ultrasound are explained, including a flowchart based on the BLUE protocol. [3]

In **chapter 4** we describe how we have implemented POCUS on our ICU and we publish the content of a self-designed POCUS course for residents.[4] By informing our readers of our implementation process (including successes and weaknesses) and our POCUS course design we hope that we have presented a useful example for other colleagues who want to implement and train POCUS themselves.
In the first section of this paper, we describe our POCUS implementation process starting with a simultaneous training of the entire ICU staff in basic cardiac and lung POCUS. We describe the necessary equipment predominantly the need for an ICU to have access to ICU dedicated ultrasound machinery and stipulate the necessary collaboration with other ultrasound experienced specialties. We sought collaboration with the departments of radiology and cardiology and received the necessary support and back-up. We acknowledge the difference between a targeted POCUS exam and comprehensive ultrasound studies done by radiologists and cardiologists. We conclude that it is possible to implement POCUS on the ICU if the aforementioned conditions (training, support and equipment) are met although it will take time and effort to have POCUS implemented on all Dutch ICU's.
In the second part of this paper we describe in detail how we designed a POCUS course for residents. We designed a four-day course with the following components: basic cardiac POCUS, basic lung POCUS, basic abdominal POCUS and basic vascular POCUS (the latter without ultrasound detection of deep venous thrombosis yet). We divided the available time between the different components. Basic cardiac POCUS is the most time consuming and basic lung POCUS the least. Image generation, image interpretation and clinical integration are discussed. Because hands on sessions are done on healthy mannequins there is no exposure to pathology. We conclude that after a basic POCUS course a thorough continuation of POCUS training is warranted, a POCUS portfolio in which the candidates report their own POCUS exams is an important tool to retain and expand POCUS skills.
We shortly discuss the place for computer-based ultrasound simulation solutions, which we consider to be a promising development. Modern simulation solutions can speed up POCUS training and provides exposure to pathology on demand. Finally, we describe the way in which we test the candidates on theoretical and practical knowledge to evaluate the increase and retention of trained POCUS skills.
In **chapter 5** we present the evaluation of two years of basic POCUS training in our hospital. Residents, predominantly IM residents, were trained during four days in basic cardiac, lung, abdominal and vascular POCUS. Cognitive testing was done before (pre-test), on the last day of the course (post-test) and after three months (3 mo-test). Practical testing was done on the last day (post-test) and after three months (3 mo-test). The results of cognitive testing significantly increased from pre-test to post-test and cognitive knowledge was somewhat retained after three months. The

percentages of correct test answers were respectively 54.4%, 66.3% and 62.7%. After three months practical skills were retained. These results show that our course succeeds in increasing POCUS cognitive and practical skills. The biggest challenge however is to motivate residents to keep on using POCUS and future efforts should be directed to consolidation of POCUS skills. The majority of residents used POCUS one to four times per week after finishing the POCUS course. We have set up a system of POCUS portfolios for residents. We aim for a minimum number of personally performed POCUS exams (30 cardiac, 20 lung and 20 abdominal) within nine months.

In **chapter 6** [5] we discuss the possible benefits for internists if they use POCUS and stress the need for general accepted European POCUS standards. POCUS is not only a valuable tool for intensivists but also for internists as they are confronted with acutely ill patients too. We endorse the use of POCUS for internists although studies on outcome parameters such as mortality are scarce but there are ample data on the positive effects of POCUS on diagnostic accuracy, [6-23] selecting the adequate treatment [8, 9, 11, 12, 15, 16, 21, 23, 24] and POCUS increases safety of several invasive procedures. [25] We acknowledge the fact that literature on POCUS training for internists is limited but internists (in training) generally have the ambition to be trained in POCUS. We ask the European Federation of Internal Medicine (EFIM) to set European standards for POCUS training because to this date heterogeneity on this subject exists between the different European countries.

In **chapter 7** we present the results of the METUS study. [26] We found that the use of a thoracic POCUS protocol during MET deployment led to improved diagnostic accuracy. Our results are quite substantial: a significant difference in the percentage of correct diagnosis. Without POCUS 51% of the diagnosis by the MET physician were correct, with POCUS 78%. MET physicians also felt more certain when POCUS was used during MET call deployment. Importantly, in our study MET physicians were residents (IM) who had participated in our POCUS course in advance. We believe that this study indicates that with our integral POCUS approach (training and daily clinical use) residents are able to use POCUS in the right way. Recently our findings were confirmed in a study on the effect of POCUS during MET calls by another research group. [27]

In **chapter 8** we present the results of a study in which we compare the use of ultrasound versus standard chest X-ray after the insertion of a central venous catheter. We show that after ultrasound guided catheter placement, ultrasound is effective in assessing adequate position and possible complications. [28] Our results were confirmed in a larger study and metanalysis. [29, 30] Using a focused ultrasound protocol after central line placement has several advantages over standard chest X-ray. Both techniques are equally able to detect incorrect placement and or complications, but ultrasound is much faster and is without any biohazard. [31]

In **chapter 9** (Probefix study) we describe the use of an external ultrasound holder in intensive care patients. [32] In eight out of ten patients it was possible to measure cardiac output using transthoracic cardiac ultrasound. In this small study we measured cardiac output with and without the use of the Probefix before and after a passive leg raising test to simulate the effect of an intravenous fluid bolus. This study is a possible first step in using ultrasound for continuous non-invasive cardiac output measurements in intensive care patients.

Discussion and future perspectives

1. How should we define POCUS, what is the essential content, are different levels possible, is there a uniform nomenclature and what are the training requirements?

In our view POCUS is an important tool for all physicians active in acute medicine and should therefore be an integral part of training including staff members. If we concentrate on basic POCUS skills as described in this thesis it can be done in a time efficient way with high yield in terms of direct usable skills.

Basic cardiac POCUS focuses on four questions:

1. Is the left ventricle dilated and is the function good, moderate or poor?
2. Is the right ventricle dilated and is the function good, moderate or poor?
3. Is pericardial fluid present; yes, no, or if yes are there signs of tamponade?
4. Does the IVC shows signs of fluid overload or underfilling?

Basic Lung POCUS focusses on ruling out life threatening pulmonary syndromes using the BLUE protocol.

Basic abdominal POCUS focusses primarily on the presence of intraperitoneal fluid and renal outflow obstruction.

Basic vascular ultrasound focusses on the detection of deep venous thrombosis.

Furthermore, most ICU related invasive procedures (such as the insertion of a central venous catheter and drainage of intraabdominal or pleural fluid) should be done under real time ultrasound guidance.

After a first basic introduction POCUS course a thorough follow up program is needed, in which the acquired POCUS skills are continuously monitored. Regular appointments should be scheduled to evaluate the recorded POCUS exams, the minimum number of personally performed POCUS exams as laid down in the CCM statement (Critical Care Ultrasound.pdf (lww.com) should be strived for within a reasonable time period (one year maximum).

In our view ultrasound training should start as early in medical training as possible. First of all, it could be helpful for medical students in learning the basic human anatomy and make medical students acquainted with ultrasound. Subsequently, depending on the specialty, POCUS should be

trained during residency, in this way in the near future all staff members in acute medicine are POCUS proficient.
Regarding the issue of advanced POCUS skills, recommendations may vary based on local circumstances. It is probably wise for all ICUs to have one or more staff members with advanced POCUS skills. If that is not achievable adequate back up from cardiology and or radiology colleagues should be arranged.
There is no Dutch guideline for intensivists on the subject of POCUS. We aim for a position paper describing what is expected from a Dutch intensivist (in training) in terms of POCUS skills. A group of POCUS experts from the major university intensive care departments has been asked to join in a Delphi structured assessment to define POCUS requirements for the Dutch intensivist (in training) in the near future.
2. What are the necessary steps needed for implementation of POCUS in the ICU and how do we organize POCUS training?
Regarding the implementation process there are few examples in the scientific literature. In this thesis we present an example which could be useful for other colleagues.
On the matter of organizing POCUS training, we show in chapters 3-6 that heterogeneity in studies on POCUS training exists (this was also concluded in three systematic reviews). [33-35] However, when a concise curriculum is used most POCUS courses will succeed in training basic POCUS skills in ultrasound naïve candidates. [34, 35] LoPresti et all described a road map for POCUS training for IM residents. The results published in this thesis meet and confirm the recommendations done by LoPresti et al. Our course for residents has been fit into the tight residency schedule and is now running for five years. It combines short tutorials with ample time for hands on training in a candidate instructor ratio of 3: 1. We selected the POCUS applications we deemed necessary for our residents, only the basics are trained, and we designed a follow up plan to consolidate the trained POCUS skills. Ultrasound is used during clinical rounds and all candidates receive a list of appointments during which their stored POCUS exams are discussed with one of the local POCUS supervisors. Candidates are stimulated to record all POCUS exams and the target numbers of POCUS exams set by the Society of Critical Care Medicine. It is difficult to design a POCUS follow up program based on literature guidance 33 because there is no best practice but a follow up program as we have developed is of the essence, POCUS skills will vanish after nonuse [36-38] and using POCUS after only a basic course without some sort of supervised follow up is unwanted. [39] We were able to train some residents to the level of POCUS instructor and they participate in the POCUS course as instructors. The fact that there is a lack in POCUS supervisors is acknowledged by many others and is seen as a possible barrier in the expansion of POCUS. [40, 41]
Our course evaluation (described in chapter 5) showed that we were able to increase cognitive and motor POCUS skills. Residents who participated in the METUS trial (chapter 7) were able to use POCUS in order to increase

the number of correct diagnoses during a MET call after completion of the POCUS course. The combination of a basic POCUS course, daily POCUS use during clinical duties and a robust follow up program using a POCUS portfolio is possibly the preferred strategy for POCUS training for the short and long term.
To sum up our recommendations for POCUS training:

1. a basic POCUS course should consist of multiple days, length depending on the number of applications trained.
2. train the basics.
3. combine short tutorials with ample time for hands on training.
4. candidates should be tested in cognitive and practical skills also after a longer period to assess skill retention or decay.
5. integrate the use of POCUS into daily clinical practice.
6. use a POCUS portfolio aiming at the number of required POCUS exams as set by the SCCM and schedule POCUS evaluation meetings with candidates.
7. aim to train candidates to the level of new POCUS instructors to increase the POCUS faculty.

In the near future some new developments will possibly change POCUS training practice.
Ultrasound training has already set foot in medical school. Ultrasound helps for instance in learning anatomy and physical examination [42, 43] and also in the Netherlands the first ultrasound supported curricula have started. The University of Nijmegen Medical school for instance has an ultrasound program (56 hours) in the second year of the bachelor curriculum (MED-KRAD1 - Studiegids 2021 Faculteit der Medische Wetenschappen (ru.nl)). This will certainly mean that in due time all physicians will have had some ultrasound experience during medical school meaning that ultrasound curricula thereafter should possibly be designed differently.
Other new developments such as computer-based simulation solutions and internet-based curricula will become increasingly important. So called high fidelity simulators can be used during POCUS training reducing the need and expense of live models and allowing evaluation of normal and pathologic scenarios in a standardized setting. [44] The use of simulation accelerates the POCUS learning curve and will lead to earlier competency in POCUS. [45, 46] The main limitation of these simulators nowadays are the costs and the need for regular maintenance but we have seen in the last years that purchase costs of digital equipment are decreasing and therefore simulation techniques will become a standard part of POCUS training. We have the ambition to design a well-equipped POCUS skill station where novices can practice their POCUS skills on demand with the use of simulation solutions. Fully equipped ultrasound labs already exist in the Netherlands (Ultrasound labs | Technisch Medisch Centrum | Universiteit Twente (utwente.nl). We stress the need to have facilities like these not only in the University centers but also in other teaching hospitals were most residents set their first steps in clinical experience. Computer based

simulators can also be helpful during POCUS training and consolidation of POCUS skills.

3. Will POCUS result in improved patient care?

It is still difficult to prove the beneficial effect of POCUS in acute medical settings (ER, ICU and MET) in terms of outcome parameters such as mortality. Also, most studies on this topic are relatively small and heterogenic in design. In the introduction section of this thesis we have summarized the existing evidence in favor of the use of POCUS in acute medical situations in the ER and ICU setting. In the ED setting multiple studies on non-traumatic hypotensive patients and dyspneic patients show that the use of POCUS substantially improves diagnostic accuracy (14-30% improvement) and also often results in changes in clinical management (in 24-47% of the cases). [7, 9, 11, 13, 14, 17-20, 47-51] In addition to this, POCUS resulted in an increase in confidence of the treating physician, narrowing of the differential diagnosis and detection of life-threatening diagnoses that would have been missed otherwise. Likewise, in the ICU setting the use of POCUS improves patient care and in this group of patients there is also an indication that mortality is decreased when cardiac POCUS is deployed. [52] Furthermore, the application of POCUS is beneficial for patients who are newly admitted to ICU due to respiratory symptoms or hypotension, but also unselected patients may benefit from it. There is an increase in diagnostic accuracy that changes the primary diagnosis in 21 to 25,6%. While less additional imaging techniques are necessary, clinical management is directly affected in 39,2 to 61% of cases. [6, 8, 10, 12, 15, 16, 21-24, 53, 54] There is also some proof that routine use of POCUS in assessing general ward patients leads to better diagnostic accuracy and less additional investigations as was reported in three studies. [55-57] Until now few studies focused on the effect of the use of POCUS during MET calls. [27, 58] We also found that during MET calls the use of POCUS increased diagnostic accuracy and that using POCUS increased the physician’s certainty. The question is whether other outcome studies (for instance on mortality) on the use of POCUS are feasible or that we should embrace the fact that a positive outcome starts with a right diagnosis or as Paul Mayo has put it in 2013: “some truths are so self-evident, that we must hold them to be true”. [59] In our view incorporation of POCUS in acute medicine is supported by enough evidence and should be endorsed. An extensive review paper in which clinical studies on the use of POCUS during acute medical settings are collected is warranted.

Regarding the use of ultrasound guidance during and after certain interventions including the insertion of central venous catheters the common opinion nowadays is that ultrasound increasers safety and improves the first-time success rate. For central venous catheters this is most endorsed for the internal jugular location. [60] Ultrasound can also be used for the evaluation of catheter position and peri-insertion complications. [31] Also for drainage purposes of abdominal and pleural fluid the use of ultrasound guidance is advocated. [61, 62] We consider this discussion to be closed and endorse the use of ultrasound guidance for interventions and to use ultrasound to look for position and complications after central venous catheter placement.

Future perspectives

What other developments will influence the use of POCUS?
Technical developments are speeding up. Within a short period, hospitals around the world will see more and more doctors equipped with a small handheld echo (HHE) attached to their mobile phone. In the United States medical schools are increasingly stimulating the use of HHE and some provide a HHE to all incoming students for free (UC Irvine Medical School gifts Butterfly handheld ultrasounds to its whole class of 2023 | MobiHealthNews) and there is discussion whether HHE's will replace the stethoscope in the end. [63] Narula et al argue that the stethoscope was "grandfathered into medical practice without the usual critical review that new diagnostic technologies must face". [64] Compared to physical examination only, bedside ultrasound is better than physical examination. This has been shown in multiple studies on various ultrasound applications. [65-68] Even in the hands of medical students bedside ultrasound was more secure in diagnosing abdominal aneurysms compared to physical examination done by experienced vascular surgeons. Vascular surgeons performed with a sensitivity and specificity of respectively 66.7 and 94.4 % while medical students with ultrasound scored 93.3 and 100% in the detection of abdominal aneurysms. [69] It might well be that the use of ultrasound will become a standard part of physical examination or as Narula et al put it: time to add a fifth pillar to bedside physical examination: inspection, palpation, percussion, auscultation and insonation (ultrasound). [64] HHE has the right profile to be the instrument for this fifth pillar. HHE's are suited for POCUS because of their small size, their adequate technical characteristics for POCUS and HHE's are easy to operate. [70, 71] The exact place of these POCUS instruments in clinical care needs to be assessed. Will routine deployment of HHE influence patient care and how could we design studies to evaluate this development in the right way? Finally, cost effectiveness should also be studied because HHE's may decrease the number of additional exams and lead to earlier diagnoses thereby reducing length of stay.
Machine learning and artificial intelligence (AI) have also set foot in ultrasound. AI can help during ultrasound image acquisition, image interpretation and during ultrasound education. In combination with the recent entry of three-dimensional (3D) ultrasound the process of creating standardized images, hemodynamic calculations and so on will be made easier. [71, 72] AI could for instance lower the workload for POCUS trainers by automatically classifying POCUS exams in different POCUS applications. [73] Is there a role for these new techniques in performing POCUS? On first sight

it seems contradictory to use complex 3D technology when especially for basic POCUS simple ultrasound strategies are propagated.
Also augmented reality (AR) could be used in combination with ultrasound. [71] AR can allow remote teleguidance on aspects of correct probe placement, obtaining adequate images and image interpretation. Ultrasound can also be combined with other video techniques, video-glasses assisted ultrasound guidance (VAUG) is one of them. In the current ultrasound guided procedure for the insertion of central venous catheters the operator has to divide his/her attention between the image on the ultrasound machine and the patient. Ideally the user should be able to see both the patient and the ultrasound image in one view. VAUG provides a possible solution to this problem. These video glasses are designed to provide procedure stability, unobstructed readability and ergonomic comfort while using ultrasound during interventions. [74]
Monitoring and evaluation of the POCUS exams can be done face to face but for this purpose digital solutions can also be used. If a POCUS exam is stored in a system that is accessible to others, evaluation can be done digitally. At this moment there are already systems that use the cloud for saving POCUS exams, which makes it possible to view each other's exams anytime, anywhere. [71] This method is also interesting to use in remote areas. [75]
Other developments are the constant improvement of ultrasound workflow by features like fewer dropdown menus, less keystrokes, faster processing times and the automation or semi-automation of measurements, all aimed at easier use.
POCUS has become an indispensable tool in acute medicine. Using POCUS increases diagnostic accuracy, helps in choosing the right (first) treatment, is better than physical examination alone and makes the care for the patient safer. With the ongoing technical developments POCUS will be available for almost all caregivers (physicians, physicians assistants, nurses, students and so on) and POCUS will definitely change the current training curricula for physicians and nurses in the near future.

Conclusions

The main conclusions of this thesis are listed below.
The best term for ultrasound delivered at the bedside is Point-of-care ultrasound (POCUS).
POCUS can be divided into a basic and an advanced level.
Multiple and heterogeneous recommendations/guidelines regarding POCUS exist, all with limited scientific support.
For POCUS implementation we advise close cooperation with cardiologists and radiologists.
We recognize the difference between a limited POCUS exam and a full cardiological or radiological ultrasound exam.

POCUS is an important tool in acute medicine and its training is warranted for physicians active in this field.
Basic POCUS training should focus on acquiring basic POCUS skills, especially in cardiac POCUS.
After a basic POCUS course a thorough follow up program (portfolio) is essential.
POCUS training for residents leads to a substantial increase in POCUS knowledge and skills.
Scientific evidence shows that the use of POCUS improves diagnostic accuracy and changes treatment in ER, ICU and ward patients.
The use of POCUS during MET calls leads to an increase in the number of correct diagnoses.
POCUS is essential in guiding invasive procedures such as the insertion of central venous catheters.
After insertion of a central venous catheter POCUS should be used to check for position or complications in stead of a standard chest X-ray.
New developments like the increasing use of HHE’s, AI, machine learning, simulation solutions and other technical developments will have a significant influence on POCUS.
Every medical student should be exposed to ultrasound training during the bachelor phase of the curriculum, so in the future physicians will no longer be “ultrasound naïve“.

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Chapter 11: Samenvatting en discussie

In dit proefschrift wordt een aantal aspecten van spoedechografie, verder te noemen POCUS (point-of-care ultrasound), besproken. Echografie is een medische beeldvormende techniek. Op de Wikipedia pagina Echografie wordt echografie als volgt omschreven: *Echografie, ook wel echoscopie genoemd, is een techniek die gebruikmaakt van geluidsgolven die zich door het lichaam verplaatsen en op grensvlakken tussen zachte en hardere structuren reflecteren. Deze techniek stelt medici onder meer in staat om organen in beeld te brengen. Zo kunnen ze zicht krijgen op de grootte, structuur en de eventuele pathologische afwijkingen ervan. Ze vindt binnen de geneeskunde toepassingen in onder meer de radiologie, chirurgie, cardiologie, urologie, podologie, anesthesie, huisartspraktijk en verloskunde-gynaecologie. Ook buiten de geneeskunde zijn er overigens veel toepassingen.*

Tot vrij recent was het niet gebruikelijk dat intensivisten zelfstandig echografisch onderzoek uitvoerden, met de komst van POCUS is dit aan het veranderen. Met behulp van POCUS kan de intensivist aan het bed direct belangrijke klinische informatie verkrijgen, van belang voor het snel stellen van de juiste diagnose en het (direct) inzetten van de juiste behandeling. Echografie is zonder biologische schade en kan vaak worden herhaald. De afgelopen jaren is er een toename in interesse naar het gebruik van POCUS op de intensive care, onder andere af te lezen aan een grote stijging van het aantal wetenschappelijke publicaties over dit onderwerp. Met dit proefschrift hopen we een bijdrage geleverd te kunnen hebben aan het POCUS gerelateerd wetenschappelijk onderzoek en hopen we behulpzaam te zijn voor collega’s die op hun eigen afdelingen POCUS zouden willen implementeren. Wij denken dat POCUS een zeer belangrijke ontwikkeling is die de zorg voor acuut zieke patiënten veiliger en beter kan maken.

Hoofdstuk 1 In de inleiding van dit proefschrift wordt achtergrondinformatie over POCUS beschreven. Tevens wordt in dit hoofdstuk uiteengezet wat de doelstellingen van dit proefschrift zijn:

1. Wat is POCUS precies (definitie, content en training)?
2. Hoe kan POCUS worden geïmplementeerd op de intensive care en getraind?
3. Leidt het gebruik van POCUS tot betere patiëntenzorg?

Regelmatig verschijnen van diverse (internationale) wetenschappelijke verenigingen richtlijnen voor het gebruik van echografie voor intensivisten. Deze richtlijnen zijn niet eenduidig. **In hoofdstuk 2** hebben we een aantal verschillende richtlijnen op een rij gezet. Na bespreken van deze richtlijnen kwamen we tot de conclusie dat:

1. Point-of-care ultrasound (POCUS) de beste naam is voor spoedechografie. POCUS kent verschillende applicaties waarvan hart, longen, buik en bloedvaten het meest worden gebruikt.
2. POCUS het best verdeeld kan worden in twee niveaus; basis en gevorderd (advanced).
3. POCUS goed getraind kan worden door artsen ook in het geval artsen nog geen echografie ervaring hebben.

In hoofdstuk 3 beschrijven we een mogelijke handleiding voor basale hart en long POCUS. Aan de hand van specifieke vragen betreffende hartfunctie, het inschatten van de vullings- toestand (is er bij de patiënt een overschot, een tekort of voldoende circulerend bloedvolume), aanwezigheid van vocht in het hartzakje en longafwijkingen.

Hoofdstuk 4 gaat vervolgens in op de vraag hoe POCUS kan worden geïmplementeerd op een Nederlandse intensive care afdeling en beschrijven we het echografie onderwijs voor arts assistenten dat we in het Rijnstate ziekenhuis hebben opgezet. Er is in de wetenschappelijke literatuur weinig bekend over hoe POCUS het best kan worden geïmplementeerd en hoe POCUS het best kan worden getraind. Allereerst zijn we in het Rijnstate ziekenhuis begonnen met een gelijktijdige POCUS training voor de gehele medische staf met als resultaat dat alle stafleden van onze intensive care afdeling tegelijkertijd basale POCUS kennis opdeden. POCUS implementatie werd ook mogelijk gemaakt door een goede samenwerking met collega's die al bedreven waren in echografie (radiologen en cardiologen). Gebruik maken van hun kennis en kunde was en is zeer belangrijk. Verder bevelen wij aan dat voor goede implementatie een intensive care afdeling dient te beschikken over eigen echoapparatuur. Vervolgens hebben wij een basis POCUS cursus opgezet voor arts-assistenten. In deze cursus wordt gedurende 4 dagen (in één week) de basis getraind van hart, long, buik en vaat POCUS. We verdelen de beschikbare tijd voor de verschillende onderdelen aan de hand van de in de literatuur bekende moeilijkheidsgraad. Hart en buik POCUS nemen de meeste tijd, long en vaat POCUS minder. Gedurende de basiscursus worden korte voordrachten afgewisseld met veel hands-on training waarbij de cursisten elkaar als model gebruiken. Op deze manier is er veel tijd om te oefenen, echter er worden in deze cursus geen ziektebeelden gezien. Om dat aspect toch aandacht te geven maken wij gebruik van een computersimulatie model (SonoSim^{R}) waarbij het wel mogelijk is om ook ziektebeelden met echo te bekijken. Wij zien een toenemende rol voor computersimulatie voor POCUS trainingen in de nabije toekomst. De ambitie is er om ook in het Rijnstate ziekenhuis echo simulatie een prominentere rol in het POCUS onderwijs te geven door het verwezenlijken van een goed uitgerust skills centrum.

De grootste uitdaging is om na de basiscursus de cursisten te stimuleren door te gaan met het gebruik van POCUS, hiervoor is een goed follow-up systeem met het bijhouden van een echo portfolio essentieel. We leggen in

hoofdstuk 4 ook uit hoe de cursisten voor, aan het eind van de cursus en na 3 maanden worden getoetst op theoretische en praktische POCUS vaardigheden.
Wij hopen dat met het weergeven van dit praktijkvoorbeeld collega's (in Nederland) kunnen worden geholpen met het zelf opzetten van POCUS op hun intensive care afdeling en het opzetten van een eigen POCUS onderwijsprogramma. We benadrukken goede samenwerking met radiologen en cardiologen als een belangrijke voorwaarde voor het slagen van POCUS implementatie.
In hoofdstuk 5 beschrijven wij de evaluatie van 2 jaar POCUS cursus in ziekenhuis Rijnstate. In 4 dagen worden basale POCUS vaardigheden voor hart, longen, buik en vaten geleerd. Naast korte presentaties is er veel tijd voor praktijktraining waarbij de kandidaten elkaar gebruiken als model. Deze cursus is gestart voor artsen (niet) in opleiding (AIOS en ANIOS) werkzaam op de intensive care en afdeling interne geneeskunde van ziekenhuis Rijnstate. Er wordt een schriftelijke toets afgenomen kort voor de cursus, op de laatste dag van de cursus en na 3 maanden. De resultaten lieten zien dat na de cursus de toets 15 % beter werd gemaakt en dat dit na 3 maanden daalde naar nog ongeveer een 10% betere score. Er wordt ook een praktijktoets afgenomen; op de laatste cursusdag en na 3 maanden. In 10 minuten dienen de cursisten een aantal onderdelen van longen, hart en buik in beeld te brengen, waarbij naast snelheid ook wordt gelet op kwaliteit van de beelden en ergonomie. Alle cursisten waren in staat om aan het eind van de cursus adequate beelden te maken en dit was na 3 maanden nog steeds zo. Wij denken dat deze cursus voldoet aan de eisen van een goede basiscursus maar ook dat de grootste uitdaging is het op een goede manier incorporeren van POCUS in de dagelijkse praktijk met zorg voor kwaliteit en goede begeleiding. Een gebrek aan ervaren POCUS supervisors wordt niet in Nederland alleen maar over de hele wereld gezien. In de cursus evaluatie krijgt deze cursus een zeer hoog waarderingscijfer van de cursisten (gemiddeld 8.6 op een schaal van 10).
Hoofdstuk 6 bestaat uit een kleine zijstap. Op verzoek van de Europese Internisten Vereniging schreven we een kort overzichtsartikel waarin we aangeven dat het van belang is om binnen Europa dezelfde opleidingseisen voor POCUS te hanteren bij de POCUS training van artsen in opleiding tot internist. Bij Europese arts-assistenten leeft de wens om in POCUS te worden getraind. We erkennen dat het wetenschappelijk bewijs naar het nut van POCUS beperkt is (er zijn weinig studies met zogenaamde harde eindpunten zoals overleving) maar dat desalniettemin in alle Europese landen wordt erkend dat ook voor internisten (in opleiding) POCUS van toegevoegde waarde is.
Hoofdstuk 7 gaat over de METUS-studie waarin we het effect op het stellen van de juiste diagnose tijdens een Spoed Interventie Team (SIT) oproep in ons ziekenhuis onderzochten. De arts-assistenten hebben gedurende een jaar alle patiënten voor wie de hulp van het SIT werd ingeroepen geïncludeerd. Gedurende de even weken werd een hart/long POCUS

protocol gebruikt en in de oneven weken niet en achteraf werd de diagnose die de SIT-arts noteerde gecontroleerd door een onafhankelijk onderzoeker. Er werden 100 patiënten geïncludeerd en met behulp van POCUS was het aantal juiste diagnoses 78% versus 51% wanneer POCUS niet werd gebruikt. Dit is een klinisch en statistisch significant verschil. De arts-assistenten gaven ook aan zich met POCUS zekerder te voelen. Deze resultaten komen overeen met de resultaten van een recent gepubliceerde vergelijkbare studie. Wij menen dat, mits goed geschoold, SIT-artsen er beter aan doen om POCUS te gebruiken tijdens een SIT oproep. (In de Engelse literatuur wordt de afkorting MET gebruikt: Medical Emergency Team in plaats van SIT).
In hoofdstuk 8 vergelijken wij 2 methoden om na het plaatsen van een groot infuus (een zogenaamde centrale lijn) de positie van dat infuus te controleren en om te controleren of er sprake is van complicaties van het inbrengen. Tot nu toe wordt ter controle na de plaatsing altijd een zogenaamde longfoto (X-thorax) gemaakt en we vergeleken deze methode met een echografie protocol. Echografie bleek net zo betrouwbaar te zijn als de X-thorax en bovendien veel sneller gereed. Deze resultaten werden vervolgens in een groter onderzoek waarbij meerdere ziekenhuizen in Nederland, waaronder ook ons ziekenhuis, betrokken waren bevestigt. Ook een meta-analyse (de verzamelde resultaten van alle bekende studies over dit onderwerp) had dezelfde uitkomst.
De mogelijkheid om met behulp van echografie continu het hart minuutvolume (cardiac output) te meten komt dichterbij met de uitvinding van de Probefix. We beschrijven het gebruik hiervan in **hoofdstuk 9**. Met behulp van een externe echohouder kan op dezelfde plaats op het lichaam het hartminuutvolume gemeten worden. We beschrijven de eerste 10 patiënten in de wereld die op de intensive care hiermee werden gemeten. Van deze 10 patiënten was het in 8 patiënten daadwerkelijk mogelijk goede echobeelden te maken. Dit is een volgende stap in de ontwikkeling van echografisch continu gemeten hartminuutvolume. Het grote voordeel van deze methode is dat er geen noodzaak is tot het inbrengen van een (groot) infuus in een slagader maar dat het meten van het hartminuutvolume met echo aan de buitenkant van de patiënt gebeurt. Inmiddels zijn we druk bezig om met de afdeling technische Geneeskunde van de Universiteit van Twente een eerste prototype van een echografisch gemeten continue hartminuutvolume meter te maken.

Discussie
1. Wat is POCUS precies (definitie, content en training)?
Volgens ons is POCUS belangrijk voor alle dokters die betrokken zijn bij de acuut zieke patiënt en het is dan ook belangrijk dat deze dokters (in opleiding) in POCUS worden geschoold. Basic POCUS skills kunnen op een tijd efficiënte manier worden getraind.
Basis hart POCUS wordt gebruikt om 4 vragen te beantwoorden:

1. Is de linker hartkamer vergroot: j/n/?, is de functie goed, matig, slecht of niet in te schatten (?)
2. Is de rechter hartkamer vergroot: j/n/?, is de functie goed, matig, slecht of niet in te schatten (?)
3. Is er vocht aanwezig in het hartzakje: j/n/? en zo ja zijn er echografisch tekenen van tamponade?
4. Laat de Vena Cava Inferior tekenen zien van teveel vocht in de bloedcirculatie, te weinig vocht in de bloedcirculatie of is dit niet in te schatten?

Basis long POCUS wordt gebruikt om een aantal belangrijke longziekten aan te tonen of uit te sluiten. Dit gebeurt met behulp van het zogenaamde Blue protocol (bedacht door de Frans arts Daniel Lichtenstein) waarin op een hele schematische manier long POCUS wordt beschreven.

Basis buik POCUS wordt gebruikt om vrij vocht in de buikholte aan te tonen en om te zien of er sprake is van afvloedbelemmering van de nieren (stuwing).

Tevens wordt POCUS gebruikt om bepaalde handelingen veiliger te laten verlopen omdat met POCUS direct gezien kan worden wat men aan het doen is. Dit geldt bijvoorbeeld voor het inbrengen van centrale lijnen of het aanprikken van vocht in de buik of de borstkas.

Na een eerste basis POCUS training is een degelijk follow-up programma noodzakelijk waarin de opgedane kennis wordt gemonitord. Het is belangrijk om regelmatig afspraken in te plannen waar de opgenomen echo onderzoeken worden besproken. Er zijn minimumaantallen afgesproken voor alle POCUS onderdelen, deze zijn gedefinieerd door de Critica Care Society in 2017, het streven is om deze aantallen te halen in een periode van maximaal 1 jaar (Critical Care Ultrasound.pdf (lww.com). Naar onze mening kan echografie onderwijs niet vroeg genoeg in de opleiding beginnen. Allereerst kan echografie gedurende de bachelor fase helpen bij het anatomie onderwijs en op deze manier raken de studenten al gewend aan het gebruik van echografie. Vervolgens dient, afhankelijk van het vervolg specialisme, tijdens de opleiding tot specialist POCUS training plaats te vinden zodat na verloop van tijd alle dokters actief in de acute geneeskunde POCUS beheersen.

Wat betreft advanced POCUS skills zijn de aanbevelingen afhankelijk van lokale omstandigheden. Het is waarschijnlijk verstandig dat op iedere intensive care een of meer stafleden beschikken over advanced POCUS skills. Als dat niet haalbaar is dient goede back-up geregeld te worden met de collega's van de radiologie en cardiologie.

Vooralsnog is er geen Nederlandse richtlijn waarin beschreven staat wat er aan POCUS skills wordt verwacht van een intensivist (in opleiding). Er liggen plannen klaar om voor de Nederlandse situatie met behulp van een Delphi-methode op te schrijven wat de vereisten zijn op het gebied van POCUS skills voor de Nederlandse intensivist (in opleiding).

2. Hoe kan POCUS worden geïmplementeerd op de intensive care en getraind?

Er zijn weinig voorbeelden in de medische vakliteratuur over hoe POCUS het best kan worden geïmplementeerd. We hopen dat met dit proefschrift een voorbeeld wordt gegeven op welke manier implementatie van POCUS kan worden gerealiseerd.

Wat betreft POCUS training hebben we laten zien in hoofdstukken 3-6 dat er sprake is van grote verschillen tussen verschillende studies zoals eerder werd gemeld in 3 systematische reviews. Echter wanneer een beknopte basale POCUS cursus wordt gegeven is het in algemene zin mogelijk om iedereen op een tijd efficiënte manier te trainen. De resultaten die in dit proefschrift worden gepubliceerd komen overeen met wat in een groot overzichtsartikel (van loPresti en anderen 2019) eerder werd geadviseerd. De door ons in het Rijnstate ziekenhuis ontworpen echo cursus past in het drukke opleidingsschema van artsen in opleiding en wordt inmiddels 5 jaar gegeven. Tijdens de cursus worden korte voordrachten afgewisseld met lange zogenaamde hands-on sessies met een ratio van het aantal instructeurs ten opzichte van cursisten van 1:3. De onderwerpen die tijdens de cursus worden behandeld zijn afgestemd op wat er in de dagelijkse klinische praktijk nodig is, alleen de basis wordt getraind. Er is een follow-up schema om de opgedane POCUS kennis te consolideren. POCUS wordt dagelijks gebruikt tijdens de visite en alle cursisten krijgen afspraken om met een POCUS supervisor de zelfgemaakte POCUS onderzoeken te bespreken. De cursisten worden gestimuleerd om de POCUS onderzoeken op te slaan en het streven is om ons te houden aan het aantal zelf gedane POCUS onderzoeken zoals voorgesteld door de Society of Critical Care Medicine (SCCM). Ook voor het opstellen van een goed follow-up programma zijn weinig voorbeelden beschreven in de medische literatuur maar aangetoond is in ieder geval dat POCUS skills verdwijnen als niet regelmatig POCUS wordt gebruikt, tevens is het onwenselijk dat cursisten na een basiscursus zelf met POCUS aan de slag gaan zonder gedegen supervisie. Het is ons inmiddels gelukt een aantal cursisten te trainen tot het niveau van POCUS instructeur en een aantal artsen in opleiding helpen inmiddels mee tijdens de POCUS cursus als instructeur. In de hele wereld wordt overigens gezien dat er een gebrek is aan POCUS instructeurs en dit zou een van de redenen kunnen zijn dat het vooralsnog met de implementatie van POCUS traag gaat. Wij hebben laten zien (in hoofdstuk 5) dat met onze cursus de theoretische en praktische POCUS kennis wordt vergroot. Tevens lieten wij zien in de METUS-studie (hoofdstuk 7) dat de arts-assistenten die onze cursus hadden doorlopen vaker in staat waren om met POCUS een juiste diagnose te stellen tijdens een SIT oproep. Waarschijnlijk is het zo dat de combinatie van een basale POCUS cursus, dagelijks gebruik van POCUS in de kliniek en een robuust follow-up programma de beste strategie is voor optimale POCUS training.

Samenvattend:

1. Een basale POCUS cursus kan het best bestaan uit meerdere dagen, lengte afhankelijk van het aantal POCUS items dat wordt getraind.
2. Train de basale skills.

3. Combineer korte voordrachten met veel tijd voor hands-on training.
4. Test de cursisten op theoretische en praktische kennis, ook na een langere periode om retentie van kennis te evalueren.
5. Integreer POCUS in de dagelijkse klinische werkzaamheden.
6. Gebruik een POCUS portfolio om de zelf verrichte POCUS onderzoeken te verzamelen, streef naar de aantallen zoals voorgesteld door de SCCM en plan afspraken met cursisten in.
7. Probeer een aantal cursisten op te leiden tot POCUS instructeurs om het aantal instructeurs te vergroten.

Nieuwe ontwikkelingen zullen binnenkort de praktijk van POCUS training veranderen. Echografie heeft inmiddels ook een plaats gekregen in de bachelor fase van de geneeskunde studie op sommige Nederlandse universiteiten. Echografie kan helpen bij anatomie onderwijs en het leren van het lichamelijk onderzoek. Bij de geneeskunde opleiding aan de Radboud Universiteit is inmiddels een echografie programma gestart (56 uur) in het tweede jaar van de bachelor fase. Dit betekent dat in verloop van de tijd iedere arts die afstudeert in aanraking zal zijn geweest met echografie. Hierdoor zullen waarschijnlijk in de toekomst POCUS cursussen veranderen.

Andere ontwikkelingen zoals computer-based simulatie mogelijkheden en internet-based trainings-curricula zijn ook belangrijk. Er zijn tegenwoordig zogenaamde highfidelity echosimulatoren beschikbaar die gedurende POCUS cursussen kunnen worden gebruikt. Daarmee zijn niet alleen minder echo modellen noodzakelijk maar kunnen ook echte ziektes in beeld worden gebracht. Inmiddels is aangetoond dat met het gebruik van echosimulatoren de leercurve versneld wordt en er eerder POCUS competentie kan worden bereikt. Vooralsnog zijn deze simulatoren duur maar de verwachtingen zijn dat de prijzen voor echosimulatoren in de loop van de komende jaren zullen dalen. Wij zouden graag ook in ons ziekenhuis gebruik maken van echosimulatoren voor POCUS training, uitgebreide simulatie centra bestaan al bijvoorbeeld in het echo skills-center van de Twente Universiteit. We benadrukken het belang voor het toegankelijk maken van echosimulatoren voor alle ziekenhuizen waar artsen in opleiding worden getraind. In deze ziekenhuizen immers zetten artsen in opleiding vaak hun eerste stappen in de klinische praktijk.

3. Leidt POCUS tot betere patiëntenzorg?

Het is nog steeds moeilijk om het positieve effect van het gebruik van POCUS in acute geneeskunde (Spoedeisende Hulp, Intensive Care en Spoed Interventie Teams) in uitkomstmaten zoals mortaliteit aan te tonen. De meeste studies naar dit onderwerp zijn klein en ook heterogeen in opzet. In het introductie hoofdstuk van dit proefschrift wordt een opsomming gegeven van het bestaande bewijs voor het gebruik van POCUS in de acute geneeskunde. In artikelen over het gebruik van POCUS op de Spoedeisende Hulp wordt gezien dat bij benauwde patiënten en patiënten met een lage bloeddruk het gebruik van POCUS leidt tot substantieel meer accurate diagnoses dan wanneer POCUS niet wordt gebruikt (14-30% verbetering).

Tevens leidt het gebruik van POCUS vaak tot aanpassingen in de behandeling (in 24-47 % van de gevallen). Daarboven op maakt POCUS de Spoedeisende Hulp arts zekerder van een diagnose, vermindert POCUS het aantal mogelijke diagnoses en worden met POCUS levensbedreigende diagnoses gezien die zonder gebruik van POCUS zouden zijn gemist. Vergelijkbare resultaten zijn er bij studies naar gebruik van POCUS op de intensive care. Bij intensive care patiënten werd er in 1 studie wel een positief effect gezien van het gebruik van POCUS op mortaliteit. Bij intensive care patiënten leidt gebruik van POCUS tot een verandering in diagnose in 21-25.6 % van de gevallen. Tevens leidt het gebruik van POCUS tot minder andere aanvullende onderzoeken (zoals röntgenfoto's) en verandert de behandeling na POCUS in 39.2 -61% van de gevallen.
Ook bij patiënten op de gewone verpleegafdeling zijn er aanwijzingen dat het gebruik van POCUS nuttig is.
Tot nu waren er slechts 2 studies die keken naar het effect van het gebruik van POCUS tijdens een behandeling door een Spoedinterventie Team (in het Engels: MET). In onze METUS-studie zagen ook wij dat het gebruik van POCUS leidde tot een hoger aantal correcte diagnoses. Ook werden de SIT-dokters zekerder van hun diagnose als POCUS was gebruikt. Wellicht is het niet mogelijk om studies naar het effect van POCUS op "harde" eindpunten zoals mortaliteit uit te voeren. Wellicht dienen we te beseffen dat een goede uitkomst voor de patiënt begint met het stellen van een juiste diagnose of zoals Paul Mayo het verwoordde in 2013: sommige waarheden zijn zo vanzelfsprekend dat we ze ook voor waar kunnen houden. Wij denken dat er thans genoeg bewijs is waaruit blijkt dat het verstandig is om POCUS te gebruiken in de acute geneeskunde. Een goed overzichtsartikel waarin al dit bewijs op een rij wordt gezet is wenselijk.
Wat betreft het gebruik van POCUS tijdens het inbrengen van een centraal veneuze lijn (CVL) is de heersende opinie op dit moment al, dat met behulp van POCUS de veiligheid van de procedure wordt bevorderd en dat er een grotere kans is dat met 1 poging succes vol de CVL kan worden geplaatst. POCUS kan ook worden gebruikt om na het inbrengen van de CVL te controleren of de CVL in de juiste positie zit en of er complicaties van het inbrengen (zoals een klaplong) zijn ontstaan. Ook voor andere interventies zoals het aanprikken van vocht in de borstkas of buikholte is het gebruik van POCUS aan te raden. Wij denken dat deze discussie is geslecht, en wij ondersteunen dan ook het gebruik van POCUS aan tijdens en na het doen van interventies.
Mogelijke toekomstige ontwikkelingen
Welke andere nieuwe ontwikkelingen kunnen invloed hebben op het gebruik van POCUS in de toekomst?
De technische ontwikkelingen op echo gebied gaan snel. Binnenkort zullen steeds meer dokters in het ziekenhuis rondlopen met een zogenaamde handheld echo (HHE) aangesloten op een mobiele telefoon of tablet. In de Verenigede Staten wordt het gebruik van HHE's op Medical Schools Gestimuleerd. Er zijn zelfs opleidingen waar aan beginnende studenten

geneeskunde geen stethoscoop meer wordt uitgedeeld maar een HHE (UC Irvine Medical School gifts Butterfly handheld ultrasounds to its whole class of 2023 | MobiHealthNews) en in de medische literatuur is inmiddels de discussie ontstaan of HHE de stethoscoop op termijn niet zal gaan vervangen. Het is volgens Narula en anderen moeilijk uit te leggen dat de stethoscoop zonder kritische evaluatie nog steeds in de geneeskunde wordt gebruikt terwijl nieuwe ontwikkelingen zoals POCUS veel strenger worden geëvalueerd. In meerdere studies is reeds aangetoond dat gebruik van echografie naast alleen lichamelijk onderzoek leidt tot betere diagnostiek. Dit is bijvoorbeeld aangetoond in een studie waarbij studenten geneeskunde met behulp van echografie beter in staat waren om verwijdingen van de grote buikslagader aan te tonen in vergelijking met ervaren vaatchirurgen die alleen het lichamelijk onderzoek tot hun beschikking hadden (93,3 % vs 66,7% sensitiviteit). Het zou dus kunnen dat echografie/POCUS wordt toegevoegd aan het standaard lichamelijk onderzoek. Narula en anderen verwoordden het zo: tijd om een vijfde pilaar aan het lichamelijk onderzoek toe te voegen: inspectie, palpatie, percussie, auscultatie en insonatie (echografie). HHE's zouden hier heel goed voor gebruikt kunnen gaan worden. HHE's zijn klein, handzaam en hebben de juiste technische mogelijkheden voor adequate beeldvorming. De exacte plek voor HHE's in de geneeskunde dient nog wel te worden bepaald. Hoe gaan HHE's invloed hebben op de patiëntenzorg en hoe gaan we dat meten? Interessant is ook of gebruik van HHE's leidt tot kostenbesparing. Men zou kunnen verwachten dat vroegtijdig echografisch onderzoek zal leiden tot minder extra aanvullende onderzoeken en wellicht ook tot een korter verblijf in het ziekenhuis doordat met echografie eerder een juiste diagnose kan worden gesteld.

Machine learning en artificial intelligence (AI) hebben ook hun intree gedaan binnen de echografie. AI kan helpen bij het maken van de juiste echobeelden en interpretatie van de echobeelden. Met behulp van nieuwe 3-dimensionale echotechnieken en AI zal het mogelijk zijn om makkelijker juiste beelden en bepaalde echo- berekeningen te maken. Er is al ervaring met het gebruiken van AI bij POCUS training.

Bij POCUS wordt gebruik gemaakt van relatief simpele echobeelden en bijbehorende klinische vragen. Het is de vraag of nieuwe technieken zoals meer ingewikkelde 3-dimensionale echotechnieken een rol hebben in POCUS, dit kan goed een onderwerp zijn van nieuw wetenschappelijk onderzoek.

Nog een andere nieuwe ontwikkeling is "augmented reality" AR. Met AR is het bijvoorbeeld mogelijk om van een afstand met echografie mee te kijken. Dit heeft bijvoorbeeld toepassing in POCUS opleiding, de trainer hoeft er dan niet meer naast te staan maar kan van een afstand de cursist begeleiden en superviseren. Als AR wordt gecombineerd met videotechnieken ontstaat er Video Augmented Ultrasound Guidance (VAUG). Met het tegelijktijdig gebruiken van een videobril tijdens echografie

kan bijvoorbeeld een interventie zoals het inbrengen van een centrale lijn worden vergemakkelijkt.
Ook het monitoren en evalueren van POCUS onderzoeken kan inmiddels digitaal worden ondersteund. In de meeste ziekenhuizen worden echobeelden al in een digitaal platform opgeslagen, er zijn ook mogelijkheden om echobeelden op te slaan in de "cloud". Dit laatste betekent dat het mogelijk is om op iedere plek wanneer dan ook om elkaars echografiebeelden in te kunnen zien. In afgelegen gebieden waar weinig echografie supervisie mogelijk is het gebruik maken van cloud toepassingen interessant.
Nieuwe echomachines zullen zich ontwikkelen op gebeid van gebruiksgemak, snellere procestijd, en (semi)automatische echografische berekeningen, dit alles gericht op een toenemend gebruikersgemak.
POCUS is een onmisbaar gereedschap geworden in de acute geneeskunde. Het gebruik van POCUS leidt tot betere diagnostische accuratesse, helpt bij het inzetten van de juiste behandeling, is beter dan alleen lichamelijk onderzoek en maakt de patiëntenzorg veiliger. Met de huidige technische ontwikkelingen is POCUS binnen handbereik voor bijna alle zorgverleners (dokters, physician assistants, verpleegkundigen, studenten enzovoort) en POCUS zal zeker de onderwijscurricula voor dokters en verpleegkundigen in de nabije toekomst veranderen.
Conclusies
De beste term voor spoedechografie is Point-of-care ultrasound (POCUS.)
POCUS bestaat uit 2 niveaus: basis en gevorderd (advanced).
Er bestaan meerdere (internationale) aanbevelingen en richtlijnen voor POCUS, allen gebaseerd op beperkt wetenschappelijk bewijs.
Voor het implementeren van POCUS adviseren wij goede samenwerking met radiologen en cardiologen.
We erkennen het verschil tussen een POCUS onderzoek en een volledige cardiologisch of radiologisch echo onderzoek.
POCUS is een belangrijk instrument voor artsen actief in acute geneeskunde en POCUS training is gewenst voor alle artsen actief in dit vakgebied.
Een basis POCUS cursus dient gericht te zijn op het verkrijgen van basis kennis, met name bij cardiale POCUS.
Na een basis POCUS cursus is een follow-up programma met het gebruik van een echo portfolio essentieel.
Het trainen van arts-assistenten in POCUS leidt tot een significante stijging in POCUS kennis en kunde.
Wetenschappelijk bewijs toont aan dat het gebruik van POCUS in acuut zieke patiënten op de spoedeisende hulp, intensive care en gewone verpleegafdeling leidt tot meer correcte diagnoses en tot verandering in het klinisch beleid.
Het gebruik van POCUS tijdens een oproep van het Spoedinterventie Team leidt tot een toename van het aantal correcte diagnoses.
Het gebruik van POCUS tijdens invasieve procedures zoals het inbrengen van een centrale lijn is essentieel.

Na het inbrengen van een centrale lijn kan POCUS de traditionele gewone röntgen foto vervangen als middel om lijnpositie en complicaties te beoordelen.
Nieuwe ontwikkelingen zoals het toenemende gebruik van HHE's, AI, machine learning, simulatie oplossingen voor training en andere technische ontwikkelingen zullen een belangrijke invloed hebben op de verdere ontwikkeling van POCUS.
Iedere student geneeskunde dient tijdens de bachelor fase in aanraking te komen met echografie zodat in de toekomst geen dokter meer afstudeert zonder enig begrip van echografie.

Chapter 12: Appendices. Abbreviations

A2C	Apical 2 Chamber
A4CH	Apical 4 Chamber
A5C	Apical 5 Chamber
AAD	Acute Admission Department
ACCP	American College of Chest Physicians
ACEP	American College of Emergency Physicians
ACF	Acute Circulatory Failure
AECOPD	Acute Exacerbation of Chronic Obstructive Pulmonary Disease
AHF	Acute Heart Failure
AO	Aorta
APM	Anterior Papillary Muscle
AR	Augmented Reality
ARDS	Acute Respiratory Distress Syndrome
AUC	Area Under the Curve
AV	Aortic Valve
AW	Anterior Wall
BCU	Bedside Cardiac Ultrasound
BK	Bram Kok
BLUE	Bedside Lung Ultrasound in Emergency
BMI	Body Mass Index
BP	Blood Pressure
CCE	Critical Care Echocardiography
CCM	Critical Care Medicine
CCUS	Critical Care Ultrasound
CO	Cardiac Output
CO	Carbon monoxide (chemical formula)
COPD	Chronic Obstructive Pulmonary Disease
COVID-19	COrona VIrus Disease-19
CPD	Continuous Professional Development
CPR	CardioPulmonary Resuscitation
CRF	Case Research Form
CT	Computed Tomography
CU	Cardiac Ultrasound
CVC	Central Venous Catheter
CXR	Chest X-Ray
ED	Emergency Department
e-FAST	extended Focused Assessment with Sonography in Trauma
EACVI	European Association of CardioVascular Imaging
ECG	Electro CardioGram

ED	Emergency Department
EDEC	European Diploma in EchoCardiography
EE	Emergency Echo
EEG	Electra EncephaloGram
EFIM	European Federation of Internal Medicine
EM	Emergency Medicine
EMM	Estimated Marginal Means
EPA	Entrustable Professional Activity
ER	Emergency Room
ESC	European Society of Cardiology
ESICM	European Society of Intensive Care Medicine
EUMS	European Union of Medical Specialties
F	Female
FAST	Focused Assessment with Sonography in Trauma
FB	Frank Bosch
FCCE	Focused Critical Care Echocardiography
FCU	Focused Cardiac Ultrasonography
FoCUS	Focused Cardiac Ultrasound
GCCUS	General Critical Care Ultrasound
GDPR	General Data Protection Regulation
GI	Gastro Intestinal
GRADE	Grading of Recommendation, Assessment, Development and Evaluation
HHE	Handheld Echo
IC-LUS	International Conference on Lung Ultrasound
ICU	Intensive Care Unit
ILC-LUS	International Liaison Committee on Lung Ultrasound
ILD	Interstitial Lung Disease
IQR	inter-Quartile Range
IM	Internal Medicine
IVC	Inferior Vena Cava
IVC-RA	Inferior Vena Cava - Right Atrium
IVS	Interventricular Septum
LA	Left Atrium
LE	Limited Echocardiography
LUS	Lung UltraSound
LV	Left Ventricle
LVOT	Left Ventricle Outflow Tract
LW	Left Ventricular Lateral Wall
M	Male
MB	Michael Blans
MET	Medical Emergency Team

METUS	Medical Emergency Team UltraSound
MEWS	Modified Early Warning Score
MHz	Mega Herz
Min	Minutes
MRI	Magnetic Resonance Imaging
MV	Mitral Valve
N	Number
NIV	Nederlandse Internisten Vereniging (Dutch Society of internal medicine)
NVIC	Nederlandse Vereniging voor Intensive Care (Dutch Society of intensive care)
ONSD	Optic Nerve Sheat Diameter
PEEP	Positive End Expiratory Pressure
PLAPS	PosteroLateral Alveolar and/or Pleural Syndrome
PLAX	Parasternal Long Axis
PLR	Passive Leg Raising
PNX	PNeumothoraX
POCUS	Point-of-Care Ultrasound
PPM	Posterior Papillary Muscle
PSAX	Parasternal Short AXis
PW	Posterior Wall
RA	Right Atrium
RACE	RapidAssessment of Cardiac Echo
RV	Right Ventricle
S4CH	Subcostal 4 CHamber view
SC	SubCostal
SCCM	Society of Critical Care Medicine
SC-IVC	SubCostal Inferior Vena Cava
SD	Standard Deviation
SE	Standard Error
Sec	Seconds
SRLF	La Société de Réanimation de Langue Française
SVV	Stroke Volume Variation
TAPSE	Tricuspid Annular Plane Systolic Excursion
TEE	Trans Esophagal Echocardiography
TTE	TransThoracic Echocariography
TV	Tricuspid Valve
US	UltraSound
USA	United States of America
VAUG	Video-glasses Assisted Ultrasound Guidance
VAS	Visual Analogue Scale
VIM	hospital system for medical errors

VTI	Velocity Time Integral
WBC	White Blood Cell count
WINFOCUS	World Interactive Network Focused on Critical Ultrasound

Chapter 12: Appendices. Biography

Michaël Justinus Blans (roepnaam: Michiel) werd geboren in 1966 te Leiderdorp. In 1984 begonnen met de studie geneeskunde in Leiden om in 1993 arts-examen af te leggen. Na kleine omzwervingen werd gestart met de opleiding tot internist in het Elisabeth Ziekenhuis te Tilburg in 1995 en tot internist-intensivist in het Radboud UMC (afgerond oktober 2001). Na stafplekken in het Spittaal te Zutphen en het Elisabeth Ziekenhuis Tilburg is Michiel sinds 2007 als internist-intensivist werkzaam in het Rijnstate Ziekenhuis te Arnhem. Michiel is getrouwd met Aleid van der Wal en samen hebben ze twee kinderen, Puck en Jelle.

Chapter 12: Appendices. List of publications – Research trajectory

Research portfolio Drs. M..J. Blans

Start promotion trajectory: 1 -1 2014 (as "buitenpromovendus" verbonden aan Ziekenhuis Rijnstate).
Promotores: Prof. Dr. F.H. Bosch en Prof. Dr. J.G. van der Hoeven
Training: GCP-WMO herregistratie 20-11-2020
Co-investigator multicenter studies:
Routine (research on the survival and quality of life after reanimation in the hospital)
Telstar: (research on the value of treating status epilepticus after reanimation)
COACT: (research on the added value of immediate percutaneous intervention after reanimation in patients without myocardial infaction on ECG)
Combux: (research on the added value of lung X-ray after insertion of central catheter in comparison with ultrasound)
Cracking Coma: (research on the prognostic value of MRI after reanimation)
Supervisor M2and M3 internships Technical Medicine, University of Twente

Publications

This thesis

Chapter 2. A practical approach to critical care ultrasound.
Blans MJ, Bosch FH, van der Hoeven JG.
J Crit Care 2019 Jun;51:156-164
Chapter 3. Instructions for the use of critical care ultrasound in Dutch daily practice: the Rijnstate ICU manual, ready for broad acceptance? Slegers CAD, **Blans MJ** and Bosch FH.
Neth J Crit Care June 2014;18(3): 4-18
Chapter 4. The implementation of POCUS and POCUS training for residents: the Rijnstate approach
Blans MJ, Pijl MEJ, van de Water JM, Poppe HJ, Bosch FH.
Neth J Med. 2020 Apr;78(3):116-124.
Chapter 5. Evaluation of a 4 days ultrasound course for residents in internal medicine in the Netherlands
Blans MJ, Kok B, van Gils-Poppe HJ van der Hoeven JG and Bosch FH. Submitted
Chapter 6. Ultrasound in acute internal medicine; time to set a European standard
Blans MJ and Bosch FH.
Eur J Intern Med. 2017 Nov;45:51-53

Chapter 7. A point-of-care thoracic ultrasound protocol for hospital medical emergency teams (METUS) improves diagnostic accuracy
Blans, MJ, Bousie E, van der Hoeven JG and Bosch FH.
Ultrasound J. 2021 June 4, 13 (1): 29
Chapter 8. The use of ultrasound during and after central venous catheter insertion versus conventional chest X-ray after insertion of a central venous catheter
Blans, MJ, Endeman H and Bosch FH.
Neth J Med. 2016 Oct;74(8):353-357.
Chapter 9. The use of an external ultrasound fxator (Probefx) on intensive care patients: a feasibility study
Blans MJ, Bosch FH and van der Hoeven JG.
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