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Review article

Effect of prehospital ultrasound on clinical outcomes of non-trauma patients—A systematic review☆

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ABSTRACT

Background: Advances in technology have made prehospital ultrasound (US) examination available. Whether US in the prehospital setting can lead to improvement in clinical outcomes is yet unclear.
Objective: The aim of this systematic review was to assess whether prehospital US improves clinical outcomes for non-trauma patients.
Method: We conducted a systematic review on non-trauma patients who had an US examination performed in the prehospital setting. We searched MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials and the ISI Web of Science and the references of the included studies for additional relevant studies. We then performed a risk of bias analysis and descriptive data analysis.
Results: We identified 1707 unique citations and included ten studies with a total of 1068 patients undergoing prehospital US examination. Included publications ranged from case series to non-randomized, descriptive studies, and all showed a high risk of bias. The large heterogeneity between the different studies made further statistical analysis impossible.
Conclusion: There are currently no randomized, controlled studies on the use of US for non-trauma patients in the prehospital setting. The included studies were of large heterogeneity and all showed a high risk of bias. We were thus unable to assess the effect of prehospital US on clinical outcomes. However, consistent reports suggested that US may improve patient management with respect to diagnosis, treatment, and hospital referral.

Contents

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1. Introduction

The use of point of care ultrasound (US) in the emergency settings has developed over the past decades. Ultrasound has been studied extensively in a variety of clinical settings and is now considered an essential diagnostic adjunct in both the emergency department and in the intensive care unit for managing patients with cardiopulmonary instability.[1–5] Ultrasound is considered a class I recommendation in a variety of emergency clinical situations.[1,3,4] Studies have demonstrated that integration of a focused US examination in the patient assessment results in a more accurate initial diagnosis with an improved patient management.[6,7]

Advances in technology have made prehospital US possible and physicians, paramedics, and aeromedical crews worldwide are currently using US as an adjunct to clinical assessment in trauma patients, cardiac arrest, hemodynamic instability, respiratory failure, suspected abdominal aortic aneurysm, intracranial pathology, fetal monitoring and vascular access.[8–14] The medical indications for performing emergency US do not differ between the in- and the prehospital care setting. However, less diagnostic possibilities are present prehospitally, hence the indication for performing an US can be different from the in-hospital assessment (e.g. X-ray detection of pneumothorax). Furthermore, the prehospital US performance is even more focused than the in-hospital US, and should only be performed if there is a potential change in triage or immediate treatment, as opposed to the in-hospital US where the triage between hospitals has already been done, and there is a need for a precise diagnosis. Moreover a number of factors distinguish prehospital care from in-hospital settings. Environmental factors such as noise, limited workspace in ambulance and helicopters, weather, light and limited resources. The need for rapid transport to advanced diagnostics and definitive care mandates the prehospital care providers to decrease on-scene time and any new prehospital diagnostic adjunct should also be evaluated in this context. The 2010 European Resuscitation Council guidelines on cardiopulmonary resuscitation recognize ultrasound as a potential valuable diagnostic tool and in a consensus report a European expert group has identified prehospital US as one of the top five research priorities in physician-provided pre-hospital critical care.[15,16]

Whether US in the prehospital setting can lead to improvement in diagnosis, triage or treatment is uncertain. A systematic review of the literature is warranted to guide evidence based triage decisions, prehospital interventions, and public policies regarding prehospital US.

2. Objectives

The aim of this systematic review was to determine, whether prehospital US examinations affect outcomes in non-trauma patients. The specific clinical research question addressed was: “Does prehospital US improve survival for non-trauma patients (primary outcome). Does prehospital US change the diagnosis, treatment, transfer decision, or hospital response (secondary outcomes)”.

3. Methods

3.1. Protocol and registration

We developed a protocol using the PRISMA guidelines[17] and it was registered in the PROSPERO database (www.crd.york.ac.uk/PROSPERO), registration number: CRD42012002632, before the search was conducted.

3.2. Eligibility criteria

The selected studies included non-trauma patients of all ages who had an US examination performed in the pre-hospital setting. Eligible studies accepted for further evaluation were interventional studies (randomized and non-randomized), observational controlled and uncontrolled cohort studies and case series.

3.3. Outcome measures

The primary outcome measure was survival within the study period in each study evaluated. The secondary outcomes were change of the on-scene treatment; change in the decision of where to transfer the patient, or change in the hospital response as a consequence of the prehospital US.

3.4. Information sources

Searches were restricted to 1992 and forward since we found that the use of prehospital US was unlikely before this date. Searches were not restricted by language. Only published studies were included. Assistance was provided from the Medical Research Library at Copenhagen University Hospital, Rigshospitalet. We searched the following databases: MEDLINE (Ovid SP) (to 24th July 2012), EMBASE (Ovid SP) (to 24th July 2012) and Cochrane Central Register of Controlled Trials (to 24th July 2012). Furthermore, we searched ISI Web of Science: Science Citation Index Expanded (SCIEXPANDED) for any studies citing the included studies and the references of the included studies were searched for any relevant papers.

3.5. Search strategy

The search was conducted by 3 reviewers (SR, CS, MK) on the 24th of July 2012 using the strategies descripted in Appendix 1.

3.6. Study selection

Search results from databases were screened individually and papers collated and merged into a single bibliographic database using Mendeley Desktop version 1.8-reference manager software (Mendeley Ltd., 2008–2013) and duplicates were identified and removed. Two reviewers (SR and CS) independently screened and included relevant papers by title and abstract. These two reviewers then independently assessed studies based on their full text version for eligibility according to eligibility criteria as mentioned. Disagreement was resolved in discussion with a third part arbiter (MK).

3.7. Data collection process

Two reviewers (CS, SR) independently extracted information on study characteristics and results into a standardized spreadsheet. Data extracted included: last name/first initial of the first author, publication year, study design, participants, number of participants, type of ultrasound examination, duration of follow-up, definition of patient population, description of intervention, data for each intervention–outcome comparison, funding, estimate of effect with confidence intervals and *p*-values. Contact to the authors of the included studies was attempted in cases of missing data. If the authors failed to respond, we considered the data missing.

3.8. Assessment of risk of bias in individual studies

We intended to use the Cochrane Risk of Bias Assessment Tool for randomized controlled trials. However, no randomized trials were identified. We instead used the SIGN 50 checklist to assess the risk of bias, as this is considered the best validated tool for risk of bias assessment of observational studies.[18,19] The SIGN 50 checklist's section on risk of bias has 14 individual questions related to the five domains (study question, selection of participants, outcome assessment, confounding and data analysis). Each question was assessed as well covered, adequately addressed, poorly addressed, not addressed, not reported or not applicable. Two other reviewers (RH, MK) independently assessed the risk of bias of the included studies. Disagreement was resolved by discussion including a third part arbiter (SR).

3.9. Data analysis

Due to the heterogeneity of study designs and the reporting of results we were unable to conduct a meta-analysis. Instead we report our results descriptively.

4. Results

4.1. Study selection

The MEDLINE search yielded 1031 hits; the EMBASE search yielded 574 hits; output from the CENTRAL search yielded 102 hits (Fig. 1). A total of 1707 unique papers were identified and screened by title and abstract of which 1654 was excluded. Fifty three papers were retrieved in full text and assess for eligibility. Of these 43 were excluded (Table 1).[8–10,14,20–58] Ten studies were included in this review including a total of 1068 patients (Table 2).[13,59–67] Our searches of Web of Science and the reference lists of the included studies did not lead to identification of additional eligible studies. One author was contacted, but failed to respond.

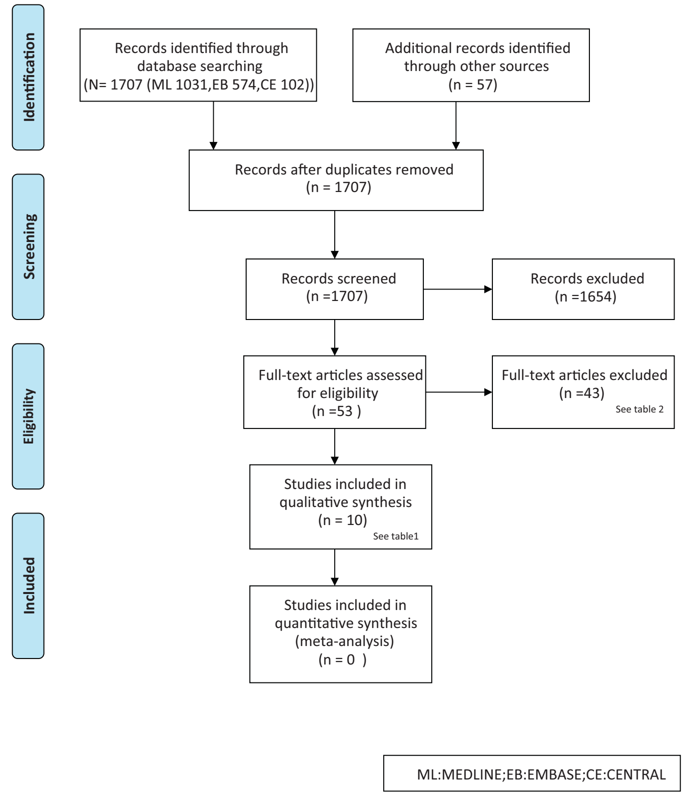

Fig. 1. PRISMA flow diagram.

4.2. Study characteristics

If studies were pooled, a total of 1068 non-trauma patients were included. Studies were carried out both in urban, suburban and rural settings and investigated patients in cardiac arrest, circulatory failure, acute dyspnea, suspected stroke, suspected ruptured abdominal aortic aneurism, pneumothorax, pelvic infections, pregnancy related symptoms, renal colic, gallstones, and US for central venous access. The personnel performing the ultrasound US examinations ranged from US novices to physicians specialist with extensive US knowledge and skills. No radiologists participated in any of these studies. In most studies the US examination as part of the normal EMS response. In one study the investigators worked in a “Rendez-vous”-system with the Emergency Medical Services (EMS)[67]; in another as part of a physician team in a remote medical clinic in the Amazon jungle clinic.[60]

4.3. Findings of individual studies

Reports and findings of individual studies are summarized in Table 1.

4.3.1. Improvement in survival

Three of the studies identified patients in whom US potentially could alter outcomes regarding survival after out of hospital cardiac arrest (OHCA).[59,61,65] Breitzkreutz et al. studied 204 patients (100 OHCA; 104 in shock)[61]; 35% of patients with *electrocardiographic* asystole actually had *echocardiographic* cardiac activity and in that respect “true” asystole was not present. Likewise patients in pulseless electrical activity (PEA) arrest with echocardiographic coordinated cardiac activity – termed “pseudo PEA” – could be identified. Both of these patient groups had significantly better survival to admission when compared to patients with asystole and PEA and no cardiac activity on US (55% vs. 8%). The difference was

Table 1
Characteristics of the included studies.

First author	*N*	Methods	Aims	Type US	Results
Aichinger[59]	24	Observational–prospective longitudinal	Primary endpoint was ROSC in the field and arrival in the emergency dept. with spontaneous circulation. The secondary study endpoint was survival to hospital discharge	Cardiac	Results support the use of prehospital US and may be used to change management
Blaivas[60]	25 (24 non-trauma)	Observational–prospective cross sectional	Change in differential diagnosis, certainty in diagnosis, disposition	Abdominal, vaginal, renal, liver and FAST	In remote locations, portable US provide a significant benefit that can alter the disposition and treatment in patients who otherwise require evacuation
Breitkreutz[61]	230	Observational–prospective longitudinal	Feasiblity of FEEL US, incidence of potentially treatable conditions of OHCA/shock, influence on patient management	Cardiac and lung	FEEL is feasible, can identify reversible causes and alter treatment. May potentially alter outcome
Heegaard[62]	100 (48 non-trauma)	Observational–prospective cross sectional	Feasibility, sensitivity and specificity reported were analyzed post case by a doctor as goldstandard	FAST, aorta, pelvic and obstetric	US by air medical crew is feasible and has a high specificity and sensitivity when compared with physician post case analysis.
Lapostolle[63]	169	Observational–prospective CrossSectional	Usefulness of US by use of the ultrasound usefulness score	Lung, cardiac, aorta & FAST	Prehospital US significantly increased diagnostic performance
Mazur[13]	48	Other/unsure	Report experiences	Aorta, lung, vascular and other	Not reported
Neesse[64]	62	Observational–prospective longitudinal	Incidence of diagnosis in included patients, feasibility of US algorithm, diagnosis, technical challenges	Cardiac and lung	Algorithm is helpful, pleural effusion may be a useful prehospital marker of decompensated congestive heart failure in patients with dyspnea
Prosen[65]	248	Observational–prospective longitudinal	To determine the diagnostic accuracy of bedside lung ultrasound, NT-proBNP and clinical assessment in differentiating heart failure-related acute dyspnea from COPD/asthma-related acute dyspnea in the prehospital setting	Lung	US alone, or in combination with proBNP, had a high diagnostic accuracy
Prosen[66]	84	Observational–prospective longitudinal	ICU admission (primary) ROSC in the field, survival at 24 h and survival to hospital discharge (secondary)	Cardiac	16 patients with pseudo PEA had significantly higher survival to hospital discharge
Schlachetzki[67]	113	Observational–prospective longitudinal	Identification of middle cerebral artery occlusion in stroke patients	Transcranial Doppler	High sensitivity and specificity of mainly middle cerebral artery occlusions

FAST, focused assessment sonography in trauma; US, ultrasound; COPD, chronic obstructive pulmonary disease; OHCA, out-of-hospital cardiac arrest; FEEL, focused echocardiographic evaluation in life support; B-NP, B-type natriuretic peptide; ICU, intensive care unit; PEA, pulseless electrical activity.

Table 2
Excluded studies and reasons for exclusion.

	Study	Reason for exclusion
1	Bendinelli C, Easton R. Focused assessment with sonography for trauma (FAST) after successful cardiopulmonary resuscitation.[21]	Letter to the editor
2	Blaivas M. Ultrasound confirmation of nasogastric tube placement in the pre-hospital setting: So why is this of any interest?[22]	Editorial
3	Grmec, Š, Prosen. Continuous capnography and focused echocardiographic evaluation during resuscitation–additional criteria for cessation of treatment out-of-hospital-cardiac arrest.[36]	Letter to the editor
4	Grmec S, Hajdinjak E, Zadel S. Continuous capnography and ultrasound-based airway management.[35]	Letter to the editor
5	Knudsen L, Sandberg M. Ultrasound in pre-hospital care.[39]	Editorial
6	Krarup NH. Risen from the dead: a case of the Lazarus phenomenon-with considerations on the termination of treatment following cardiac arrest in a prehospital setting.[40]	Letter to the editor
7	Ward D. Prehospital point-of-care ultrasound use by the military.[57]	Letter to the editor
8	Rempell J, Noble VE. Using lung ultrasound to differentiate patients in acute dyspnea in the prehospital emergency setting.[51]	Commentary
9	Backlund B, Bonnett CJ, Faragher JP et al. Pilot study to determine the feasibility of training Army National Guard medics to perform focused cardiac ultrasonography.[20]	Did not include relevant outcomes
10	Blaivas M, Tsung JW. Point-of-care sonographic detection of left endobronchial main stem intubation and obstruction versus endotracheal intubation.[23]	Inhospital study
11	Breitkreutz R, Walcher F, Seeger F. Focused echocardiographic evaluation in resuscitation management: concept of an advanced life support-conformed algorithm.[24]	Inhospital study and did not include relevant outcomes
12	Brooke M, Walton J, Scutt D. Paramedic application of ultrasound in the management of patients in the prehospital setting: a review of the literature.[25]	Review and did not include relevant outcomes
13	Brooke M, Walton J, Scutt D. Acquisition and interpretation of focused diagnostic ultrasound images by ultrasound-naive advanced paramedics: trialling a PHUS education programme.[26]	Did not include relevant outcomes
14	Busch M. Portable ultrasound in pre-hospital emergencies: a feasibility study.[8]	Did not include relevant outcomes
15	Chin E, Chan CH, Mortazavi R et al. A pilot study examining the viability of a Prehospital Assessment with UltraSound for Emergencies (PAUSE) protocol.[28]	Did not include relevant outcomes
16	Duchateau F, Gauss T, Burnod A et al. Feasibility of cardiac output estimation by ultrasonic cardiac output monitoring in the prehospital setting.[29]	Did not include relevant outcomes
17	Fagenholz P, Gutman A, Murray AF. Chest ultrasonography for the diagnosis and monitoring of high-altitude pulmonary edema.[30]	Inhospital study
18	Fagenholz P, Murray AF, Noble VE et al. Ultrasound for high altitude research.[31]	Review and did not include relevant outcomes
19	Galinski M, Petrovic T, Rodrigues A et al. Out-of-hospital diagnosis of a ruptured ectopic pregnancy: myometrial embryo implantation, an exceptional diagnosis.[32]	Case report
20	Garrett P, Boyd S, Bauch T et al. Feasibility of real-time echocardiographic evaluation during patient transport.[33]	Inhospital study and did not include relevant outcomes
21	Gilman L, Kirkpatrick AW. Portable bedside ultrasound: the visual stethoscope of the 21 st century.[34]	Review and did not include relevant outcomes
22	Heegaard W, Hildebrandt D, Spear D et al. Prehospital ultrasound by paramedics: results of field trial.[9]	Did not include relevant outcomes
23	Holscher T, Schlachetzki F, Zimmermann M et al. Transcranial ultrasound from diagnosis to early stroke treatment. 1. Feasibility of prehospital cerebrovascular assessment.[37]	Did not include relevant outcomes
24	Hoyer HX, Vogl S, Schiemann U et al. Prehospital ultrasound in emergency medicine: incidence, feasibility, indications and diagnoses.[37]	Did not include relevant outcomes
25	Lyon M, Shiver SA, Walton P. M-mode ultrasound for the detection of pneumothorax during helicopter transport.[41]	Non-human experimental study
26	Lyon M, Walton P, Bhalla V et al. Ultrasound detection of the sliding lung sign by prehospital critical care providers.[42]	Cadaver study
27	Mazur SM, Sharley P. The use of point-of-care ultrasound by a critical care retrieval team to diagnose acute abdominal aortic aneurysm in the field.[14]	Case report
28	McBeth PB, Crawford I, Blaivas M et al. Simple, almost anywhere, with almost anyone: remote low-cost telementored resuscitative lung ultrasound.[43]	Did not include relevant outcomes
29	Melanson SW, McCarthy J, Stromski CJ et al. Aeromedical trauma sonography by flight crews with a miniature ultrasound unit.[44]	Did not include relevant patient population
30	Nelson BP, Melnick ER, Li J. Portable ultrasound for remote environments, Part I: Feasibility of field deployment.[46]	Review and did not include relevant outcomes
31	Nelson BP, Melnick ER, Li J. Portable ultrasound for remote environments, part II: current indications.[45]	Review and did not include relevant outcomes
32	Noble VE, Lamhaut L, Capp R et al. Evaluation of a thoracic ultrasound training module for the detection of pneumothorax and pulmonary edema by prehospital physician care providers.[47]	Inhospital study
33	Otto C, Hamilton DR, Levine BD et al. Into thin air: extreme ultrasound on Mt Everest.[48]	Did not include relevant outcomes
34	Plummer D, Heegaard W, Dries D et al. Ultrasound in HEMS: its role in differentiating shock states.[10]	Did not include relevant outcomes
35	Price S, Uddin S, Quinn T. Echocardiography in cardiac arrest.[49]	Review and did not include relevant outcomes
36	Querellou E, Leyral J, Brun C et al. In and out-of-hospital cardiac arrest and echography: a review.[50]	Review and did not include relevant outcomes
37	Rognas L, Christensen EF, Sloth E et al. Prehospital ultrasound.[52]	Review and did not include relevant outcomes
38	Slikkerveer J, Kleijn SA, Appelman Yrter et al. Ultrasound enhanced prehospital thrombolysis using microbubbles infusion in patients with acute ST elevation myocardial infarction: pilot of the Sonolysis study.[53]	Inhospital study
39	Snaith B, Hardy M, Walker A. Emergency ultrasound in the prehospital setting: The impact of environment on examination outcomes.[54]	Did not include relevant outcomes
40	Steiger H, Rimbach K, Muller E et al. Focused emergency echocardiography: lifesaving tool for a 14-year-old girl suffering out-of-hospital pulseless electrical activity arrest because of cardiac tamponade.[55]	Case report
41	Tsung J, Blaivas M. Feasibility of correlating the pulse check with focused point-of-care echocardiography during pediatric cardiac arrest: a case series.[56]	Inhospital study
42	Zechner PM, Aichinger G. Rigaud M et al. Prehospital lung ultrasound in the distinction between pulmonary edema and exacerbation of chronic obstructive pulmonary disease.[58]	Case report
43	Chenaitia H, Squarcioni C, Marie BP et al. Ultrasound to confirm gastric tube placement in prehospital management.[27]	Did not include relevant outcomes

pronounced when a reversible cause for cardiac arrest was identified. Likewise Prosen et al. identified 16 out 52 with non-shockable rhythm with pseudo-PEA by US and subsequently subjected to a modified treatment algorithm.[65] Fifteen of the 16 patients studied regained spontaneous circulation (ROSC), of which 50% had a good neurological outcome. Compared with historical data, pseudo PEA was associated with significantly higher rates of ROSC, survival to discharge and good neurological outcome. In an Austrian study of 42 patients with OHCA the investigators found that of the 32 patients who had cardiac standstill on the initial US examination, only one (3.1%) survived to hospital admission, whereas 4 of 10 (40%) patients with cardiac movement on the initial US examination survived to hospital admission ($p = 0.008$).[59]

4.3.2. Change in diagnosis

The overall usefulness of US as a diagnostic tool in the prehospital setting has been evaluated in a prospective study by Lapostolle et al.[63] A total of 169 patients with suspected pleural, peritoneal, or pericardial effusion, deep venous thrombosis, or arterial flow interruption were included. After prehospital examination, a likely diagnosis was assigned on visual analog scale (VAS). An US examination was carried out, and a second likely diagnosis was assigned on a VAS. The potential usefulness of US was evaluated by calculating an *Ultrasound Usefulness Score*. The US examination improved diagnostic accuracy in 67% of all cases, decreased it in 8% of cases, and did not alter in 25% of cases. In a subgroup where initial prehospital diagnosis was uncertain ($n = 115$) US improved diagnostic accuracy in 90% of cases ($n = 103$).

Differential diagnoses in acute dyspnea have been studied in two prospective trials. Using a structured algorithm Neesse et al. screened 56 patients with acute dyspnea for pleural and pericardial effusion, right heart distension, and pneumothorax in the prehospital setting and confirmed these findings by chest radiography, US, and clinical follow-up in the emergency department.[64] In 59% of cases dyspnea was accredited to acute coronary syndrome (ACS) (21%), decompensated congestive heart failure (CHF) (20%), or chronic obstructive pulmonary disease (COPD) (18%). As pleural effusion was present in all patients with CHF, but only in 17% of ACS patients and in 20% of COPD patients, the investigators proposed that the pleural effusion may constitute a significant parameter in the differential diagnosis between CHF and COPD. In a Slovenian study of 248 patients with acute dyspnea, the diagnostic accuracy of lung US using the *B-line artifact* was used in distinguishing between dyspnea due to acute heart failure-related (HF) conditions ($n = 129$) or COPD/asthma ($n = 89$).[66] Patients underwent lung US examinations, along with basic laboratory testing, rapid NT-proBNP testing and chest X-rays. The investigators found the combination of US and NT-proBNP had 100% sensitivity, 100% specificity, 100% negative predictive value (NPV) and 100% positive predictive value (PPV) for the diagnosis of HF; US alone provided a 100% sensitivity, 95% specificity, 100% (NPV) and 96% PPV for the diagnosis of HF, whereas the prehospital examination provided 85% sensitivity, 86% specificity, 80% NPV and 90% PPV.

Schlachetzki et al. investigated the diagnostic accuracy of transcranial doppler US (TCD) assessment in patients with symptoms of stroke.[67] The middle cerebral arteries were examined at the site of the emergency or during patient transport. Findings were compared to CT or magnetic resonance angiography. A middle cerebral artery occlusion was diagnosed in 10 of 102 (9.8%) patients where stroke was considered likely by prehospital examination. The overall sensitivity of TCD US for the diagnosis of middle cerebral artery occlusion was 90% and the specificity was 98%. The positive predictive value was 90% and the negative predictive value was 98%. The investigators found the TCD assessment to improve the investigators confidence in the diagnosis or to save time in 41 (36%) of 113 cases.

In a broader sense of prehospital care Blaivas et al. investigated the use of a US in the Amazon jungle determining the pre- and post-US differential diagnosis, treatment plan and disposition.[60] The patient population consisted of local tribal people with mixed clinical problems (trauma and non-trauma). A total of 25 US examinations were performed. The US findings significantly altered the diagnosis of 7 (20%) patients. The investigators found that the certainty of the diagnosis improved in 17 out of 25 patients (68%) after US performance, remained the same in 6 out of 25 patients (24%) and decreased in 2 (8%) after US examination.

4.3.3. Change in treatment and referral

In the Breitzkreutz study[61] the US findings changed medical management in 89% of patients undergoing CPR. In addition the US examination changed the hospital referral in a significant number of patients. Likewise Neesse et al. found that US was a helpful tool in $n = 38$ (68%), and additional therapeutic consequences were drawn in $n = 14$ (25%).[64] In the study by Blaivas et al. the US findings altered the disposition of 7 patients, including 4 potentially lethal decisions that were avoided.[60]

4.3.4. Evidence of harm

In Breitzkreutz study US examinations could be performed in compliance with current advanced life support guidelines and did not interfere with treatments of known benefits (i.e. uninterrupted high-quality CPR).[61] Even though Neesse et al. experienced several challenges to overcome, i.e. limited space, and disturbing sunlight, the ability to perform US examinations (both left- and right handed) was unaffected. The routine management and preparations of patient transport were performed simultaneously with the US examination contributing to an optimized time management with no delay in treatment or transport observed.[64]

4.3.5. Time

Neesse at al reported a mean examination time of 2 min (range 1–5 min), but suggested that poor image quality was associated with increased examination time (less than one for excellent image quality, 1.8 min for mediocre image quality, and 3.4 min for poor image quality)[64]; Lapostolle et al. reported a mean time of 6 min (5–10 min)[63]; Prosen et al. reported a mean examination time of 1 min.[65] Schlachetzki et al. reported an average time taken to perform TCD of 5.6 min.[67] Mazuur reported that most of the US examinations were done in-flight to ensure minimal on-scene time.[14]

4.4. Risk of bias within studies

No randomized trials were identified (Table 2). Included studies were all non-blinded observational studies. Risk of bias assessment by use of the SIGN 50 checklist found all studies to have a high risk of bias (Table 3). Furthermore, four of the ten included studies received funding from ultrasound manufactures.[13,60,64,67]

4.5. Risk of bias across studies

Due to the heterogeneity in outcome measures, US procedures performed, study design and risk of bias, we did not find pooling and further analysis of the included studies to be reasonable.

5. Discussion

5.1. Summary of evidence

The main finding of this systematic review regarding the use of US in non-traumatic patients in the prehospital setting was a very large heterogeneity between the identified studies and all

Table 3
Sign50 check list for quality assessment.

			Study									
		In a well conducted cohort study….	Aichinger (59)	Blaivas (60)	Breitkreutz (61)	Heegaard (62)	Lapostolle (63)	Mazur (13)	Neesse (64)	Prosen (65)	Prosen (66)	Schlachetzki (67)
Internal Validity	1.1	The study addresses an appropriate and clearly focused question	Well Covered	Well Covered	Well Covered	Not addressed	Not reported	Not addressed	Adequatly addressed	Adequatly addressed	Poorly addressed	Poorly addressed
	1.2	The two groups being studied are selected from source populations that are comparable in all respects other thatthe factor under investigation	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Poorly addressed	Not applicable
	1.3	The study indicates how many of the people asked to take part didso, in each of the groups being studied	Not reported	Not addressed	Not addressed	Not applicable	Not applicable	Not applicable	Not reported	Well Covered	Not addressed	Not reported
	1.4	The likelihood that some eligible subjects might have the outcome at the time of enrollment isassessed and taken into account in the analysis	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not addressed
	1.5	What percentage of individuals or clusters recruited intoeach arm of the study dropped out before the study was completed	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	1.6	Comparisonis made between full participants and those lost to follow up, by exposure status	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Well Covered	Adequatly addressed
	1.7	The outcomes are clearly defined	Adequatly addressed	Poorly addressed	Poorly addressed	Poorly addressed	Well Covered	Not addressed	Adequatly addressed	Well Covered	Well Covered	Well Covered
	1.8	The assessment of outcome is made blind to exposurestatus	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not reported
	1.9	Where blinding was not possible, there is some recognition that knowledge of exposure status could haveinfluenced the assessment of outcome	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not addressed	Not applicable
	1.10	The measure of assessment of exposure is reliable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not addressed	Not applicable
	1.11	Evidence of other sources is used to demonstrate that the method of outcome assessment isvalid and reliable	Well Covered	Not addressed	Well Covered	Not applicable	Adequatly addressed	Not applicable	Well Covered	Well Covered	Adequatly addressed	Well Covered
	1.12	Exposure level or prognostic factor is assessed more than once	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not addressed	Adequatly addressed	Not addressed	Not addressed
	1.13	The mainpotential confounders are identified and taken into account in the design and analysis	Not applicable	Not applicable	Not applicable	Not reported	Not reported	Not applicable	Poorly addressed	Poorly addressed	Poorly addressed	Poorly addressed
	1.14	Confidence intervalsare provided	Not reported	Not applicable	Not applicable	Not applicable	Not reported	Not applicable	Not reported	Well Covered	Well Covered	Well Covered

Well Covered	(green circle)
Adequatly addressed	(orange circle)
Poorly addressed	(yellow circle)
Not addressed	(red circle)
Not reported	(pink circle)
Not applicable	(blue circle)

included studies had high risk of bias. This precludes a conclusive answer as to whether prehospital US examinations affect outcomes in non-trauma patients. Studies with a design using control groups, preferably randomized trials, are warranted in order to determine the clinical impact of prehospital US.

Nevertheless, it seems reasonable to extrapolate and discuss key elements of the included literature in order to facilitate future studies and guide clinical work.

Treatment of cardiac arrest with non-shockable rhythms is focused on high quality chest compressions while identifying potential reversible causes in order to treat these. Accordingly Breitzkreutz found an increased survival when a reversible cause could be identified with US.[61] Based on the findings by Breitzkreutz, Prosen and Aichinger one could hypothesize that US identification of the “pseudo PEA” state provide may provide another dimension to the prehospital advanced life support, which may challenge our traditional treatment of non-shockable rhythm and potentially lead to improve survival.[59,61,65] However, large scale randomized trials is needed to truly assess this effect and additionally reveal if quality of CardioPulmonary Resuscitation is compromised.

Ultrasound has been shown to improve diagnostics in several in-hospital studies – both in the sense that life-threatening conditions directly can be identified and the number of differential diagnosis can be limited by exclusion.[6,68,69] These findings might be transferred to the prehospital setting, where Lapostolle found that US examination improved diagnostic accuracy when initial prehospital diagnosis was uncertain.[63] Likewise differential diagnoses in acute dyspnea in the prehospital setting may be improved by identification of pleural effusion[64] and the *b-line artifact*[66] may serve as markers to distinguish between a cardiac and pulmonary etiology of dyspnea.

Prehospital identification of non-bleeding stroke seems crucial if thrombolysis is to be part of standard prehospital treatment. In one study the use of transcranial doppler US (TCD) were examined and found to have a high sensitivity and specificity for diagnosis of middle cerebral artery occlusion.[67]

Whether these results can be applied to other prehospital services with non-expert neurosonographers is questionable. In the study by Blaivas et al.,[60] US investigations where conducted in the Amazon jungle. Although not a traditional prehospital setting, we considered this study an analogy to a forward military medical treatment area where patients are being evaluated for emergency procedures and hospital transfer. The US findings significantly altered the diagnosis and the certainty of the diagnosis improved in most patients. An early diagnosis will provide the prehospital physician in rural areas with the knowledge to prioritize the relevant initial treatment.

Improvement in diagnosis may help the physician to alter treatment and to choose the closest appropriate hospital and transportation form. On the contrary, if interpreted wrong, it might hinder a patient in being transported to a higher level of facility. This dilemma seems important to address in designing future studies on prehospital US. In the Breitzkreutz study [61] the study had no independent review of the accuracy of interpretation of the images. However, the US findings changed medical treatment in 78% of patients. In addition the US examination changed the hospital destination in a significant number of patients. Likewise Neesse et al. found that US was a helpful tool in 68% of patients, and additional therapeutic consequences were drawn 25% of patients.[64] In the study by Blaivas et al. the US findings altered the disposition and potentially lethal decisions were avoided.[60]

None of the included studies reported evidence of harm. Ultrasound examinations were performed in the prehospital setting with a low rate of reported technical problems and ultrasound examinations could be performed in compliance with current advanced life support guidelines.[61] Even though Neesse et al. experienced several challenges to overcome, i.e. limited space, and disturbing sunlight, the ability to perform US examinations (both left- and right handed) was unaffected.[64]

In prehospital care prolonged “on scene”-time is generally thought to worsen the outcome for the patient with a time critical diagnosis. As with any new prehospital diagnostic adjuncts US must be evaluated in this context. To counter excessive on scene time Neesse at al set an examination maximum time limit of 5 min; they reported a mean examination time of 2 min (range 1–5 min).[64] Without preset time limits relative short examination times are reported ranging from 1 to 10 min for patients who are not in cardiac arrest.[13,63,65,67] Current CPR guidelines emphasize uninterupted high quality chestcompressions; interruption for pulse checks should be no longer than 10 s. In the Breitzkreutz study[61] echocardiography was implemented during an ALS-conformed interruption of CPR of fewer than 10 s.

6. Limitations

As we did not analyze current and previous literature on critical care ultrasound outside the context of pre-hospital care our analysis and results are not to be generalized or extrapolated to all emergency or critical care ultrasound usage. We were only able to include 10 studies in this review, all of great heterogeneity and high risk of bias. The SIGN 50 checklist[18] was used to assess the risk of bias in the included studies. Although it is possible to assess observational studies by this checklist, the value of our assessment should be interpreted with some caution as this checklist is intended for observational studies with control groups. Most of the included studies had no control group, and as a consequence the “Not applicable” option was the most common option reported. This review had a defined focus of patient outcome and care. Other important issues as logistics, education and cost were not a defined purpose of this review but needs to be considered as well.

7. Conclusions

Based on the current literature on prehospital care US it is not possible to assess whether prehospital US improves outcomes of non-trauma patients, due to a large heterogeneity and high risk of bias. In spite of this current publications consistently suggest US as a helpful tool in prehospital decision-making. Further studies are warranted in order to determine the clinical impact of prehospital US.

Conflict of interest statement

Søren Steemann Rudolph has received a single teaching fee from SECMA, the Danish distributor of Sonosite © ultrasound equipment. Rasmus Hesselfeldt has received a single teaching fee from SECMA, the Danish distributor of Sonosite © ultrasound equipment. Christian Svane, Martin Kryspin Sørensen and Jacob Steinmetz declare no conflict of interest.

Appendix 1. Search strategy

MEDLINE search:

(“Emergency Medical Services”[Mesh]) AND (“Diagnostic Imaging”[Mesh] OR ultrasonic*[tiab] OR ultrasound*[tiab] OR sonograph*[tiab] OR echotomograph*[tiab] OR echocardiograph*[tiab]) AND (“Heart Arrest’[Mesh] OR “Resuscitation”[Mesh] OR “Shock”[Mesh] OR “Hypotension”[Mesh] OR “Hemodynamics”[Mesh] OR “Aortic Aneurysm”[Mesh] OR “Pregnancy”[Mesh] OR “Stroke”[Mesh] OR “Lung Diseases”[Mesh])

EMBASE search:

1. first aid/OR resuscitation/OR emergency health service/OR emergency care/OR prehospital/OR out of hospital
2. diagnostic imaging/OR ultrasonic/or ultrasound/or sonograph/or echotomograph/or echocardiograph
3. exp aorta aneurysm/OR heart arrest/OR resuscitation/OR shock/OR hypotension/OR hemodynamics/OR stroke/OR pregnancy/OR exp critical illness/OR exp lung disease/
4. 1 AND 2 AND 3

CENTRAL search:

1. emergenc* OR prehospital OR pre-hospital OR (out NEXT of NEXT hospital) OR out-of-hospital
2. ultraso* OR sonograph* OR echotomograph* OR echocardiograph*
3. arrest* OR asystol* OR sudden cardiac OR cardiac death OR resuscitation* OR CPR OR life support OR heart massage* OR cardiac massage* OR shock OR circulatory collapse OR circulatory failure OR hypotension OR low blood pressure OR hemodynamic* OR hemodynamic* OR aortic aneurysm* OR aortic rupture* OR pregnan* OR labor* OR labor* OR stroke* OR apoplexy* OR vascular accident* OR cerebrovascular accident* OR CVA OR brain infarct*
4. 1 AND 2 AND 3

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