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Point-of-care ultrasonography for diagnosing thoracoabdominal injuries in patients with blunt trauma (Review)

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[Diagnostic Test Accuracy Review]

Point-of-care ultrasonography for diagnosing thoracoabdominal injuries in patients with blunt trauma

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ABSTRACT

Background

Point-of-care sonography (POCS) has emerged as the screening modality of choice for suspected body trauma in many emergency departments worldwide. Its best known application is FAST (focused abdominal sonography for trauma). The technology is almost ubiquitously available, can be performed during resuscitation, and does not expose patients or staff to radiation. While many authors have stressed the high specificity of POCS, its sensitivity varied markedly across studies. This review aimed to compile the current best evidence about the diagnostic accuracy of POCS imaging protocols in the setting of blunt thoracoabdominal trauma.

Objectives

To determine the diagnostic accuracy of POCS for detecting and excluding free fluid, organ injuries, vascular lesions, and other injuries (e.g. pneumothorax) compared to a diagnostic reference standard (i.e. computed tomography (CT), magnetic resonance imaging (MRI), thoracoscopy or thoracotomy, laparoscopy or laparotomy, autopsy, or any combination of these) in patients with blunt trauma.

Search methods

We searched Ovid MEDLINE (1946 to July 2017) and Ovid Embase (1974 to July 2017), as well as PubMed (1947 to July 2017), employing a prospectively defined literature and data retrieval strategy. We also screened the Cochrane Library, Google Scholar, and BIOSIS for potentially relevant citations, and scanned the reference lists of full-text papers for articles missed by the electronic search. We performed a top-up search on 6 December 2018, and identified eight new studies which may be incorporated into the first update of this review.

Selection criteria

We assessed studies for eligibility using predefined inclusion and exclusion criteria. We included either prospective or retrospective diagnostic cohort studies that enrolled patients of any age and gender who sustained any type of blunt injury in a civilian scenario. Eligible studies had to provide sufficient information to construct a 2 x 2 table of diagnostic accuracy to allow for calculating sensitivity, specificity, and other indices of diagnostic test accuracy.

Data collection and analysis

Two review authors independently screened titles, abstracts, and full texts of reports using a prespecified data extraction form. Methodological quality of individual studies was rated by the QUADAS-2 instrument (the revised and updated version of the original

Quality Assessment of Diagnostic Accuracy Studies list of items). We calculated sensitivity and specificity with 95% confidence intervals (CI), tabulated the pairs of sensitivity and specificity with CI, and depicted these estimates by coupled forest plots using Review Manager 5 (RevMan 5). For pooling summary estimates of sensitivity and specificity, and investigating heterogeneity across studies, we fitted a bivariate model using Stata 14.0.

Main results

We included 34 studies with 8635 participants in this review. Summary estimates of sensitivity and specificity were 0.74 (95% CI 0.65 to 0.81) and 0.96 (95% CI 0.94 to 0.98). Pooled positive and negative likelihood ratios were estimated at 18.5 (95% CI 10.8 to 40.5) and 0.27 (95% CI 0.19 to 0.37), respectively. There was substantial heterogeneity across studies, and the reported accuracy of POCS strongly depended on the population and affected body area. In children, pooled sensitivity of POCS was 0.63 (95% CI 0.46 to 0.77), as compared to 0.78 (95% CI 0.69 to 0.84) in an adult or mixed population. Associated specificity in children was 0.91 (95% CI 0.81 to 0.96) and in an adult or mixed population 0.97 (95% CI 0.96 to 0.99). For abdominal trauma, POCS had a sensitivity of 0.68 (95% CI 0.59 to 0.75) and a specificity of 0.95 (95% CI 0.92 to 0.97). For chest injuries, sensitivity and specificity were calculated at 0.96 (95% CI 0.88 to 0.99) and 0.99 (95% CI 0.97 to 1.00). If we consider the results of all 34 included studies in a virtual population of 1000 patients, based on the observed median prevalence (pretest probability) of thoracoabdominal trauma of 28%, POCS would miss 73 patients with injuries and falsely suggest the presence of injuries in another 29 patients. Furthermore, in a virtual population of 1000 children, based on the observed median prevalence (pretest probability) of thoracoabdominal trauma of 31%, POCS would miss 118 children with injuries and falsely suggest the presence of injuries in another 62 children.

Authors' conclusions

In patients with suspected blunt thoracoabdominal trauma, positive POCS findings are helpful for guiding treatment decisions. However, with regard to abdominal trauma, a negative POCS exam does not rule out injuries and must be verified by a reference test such as CT. This is of particular importance in paediatric trauma, where the sensitivity of POCS is poor. Based on a small number of studies in a mixed population, POCS may have a higher sensitivity in chest injuries. This warrants larger, confirmatory trials to affirm the accuracy of POCS for diagnosing thoracic trauma.

PLAIN LANGUAGE SUMMARY

How accurate is bedside ultrasound for the diagnosis of injuries to the abdomen or chest in patients with blunt injuries?

Background and aims

People who sustain a road traffic crash or fall from a height are at risk for blunt body trauma (i.e. non-penetrating trauma) and multiple injuries. Medical professionals caring for these patients in hospital need to know if vital organs or vessels are damaged, and whether there is any major bleeding that requires immediate intervention. Point-of-care sonography (POCS), a form of ultrasound, is a non-invasive, radiation-free, portable imaging technique that can be used at the patient's bedside. It is frequently used to help diagnose injuries in the emergency department. We reviewed the best scientific evidence about the accuracy of POCS, that is its ability to identify or exclude injuries correctly, compared to other diagnostic tests. We considered computed tomography, laparotomy, and autopsy to be good comparative tests against which to measure the accuracy of POCS.

Study characteristics

We searched for studies from the year in which the first paper about using ultrasound to diagnose trauma patients was published until 15 July 2017. We considered 2296 records and included 34 relevant studies that involved 8635 participants in this review. All 34 studies were published between 1992 and 2017, with the number of participants in each study ranging from 51 to 3181. Ten studies included only children, two studies only adults, and the remaining 22 studies included both children and adults.

Quality of the evidence

In many studies, important information about the selection of participants and choice of the diagnostic tests against which to compare POCS was not reported. We therefore rated the methodological quality of the available evidence mostly as unclear.

Key results

Point-of-care sonography had a sensitivity (i.e. the ability to detect a person with the disease) of 74% and a specificity (i.e. the ability to exclude a person without the disease) of 96%. Sensitivity and specificity varied considerably across studies, which was due in part to variation in study, participant, and injury characteristics. In children, both the sensitivity and specificity of POCS were lower than in an adult or mixed population, meaning that POCS was less able to identify or rule out an injury. Based on our results, we would expect that amongst 1000 patients of a mixed-age population with suspected blunt trauma to the abdomen or chest, POCS would miss 73 patients with injuries, and would falsely suggest the presence of injuries in 29 patients who were unaffected. This result emphasises the need for additional imaging in trauma patients for whom POCS shows no injuries (i.e. a negative result), to check whether they are really injury-free.

SUMMARY OF FINDINGS

Summary of findings 1.

Population	Patients of any age and gender who sustained any type of blunt injury in a civilian scenario
Setting	Clinical evaluation at hospitals of any care level
Index test	Point-of-care sonography (POCS) as the primary imaging tool
Reference standard	Computed tomography (CT), magnetic resonance imaging (MRI), laparotomy, laparoscopy, thoracotomy, thoracoscopy, autopsy
Findings	1. POCS emerged as an integral part of trauma algorithms, and remains the point-of-care imaging tool of choice for screening for thoracoabdominal bleeding in most regions of the world. 2. Determining the diagnostic accuracy of POCS in patients with blunt trauma may provide clinicians with valuable information on the likelihood of chest and abdominal injuries and may contribute to decision making regarding the performance of subsequent diagnostic tests.
Limitations	1. Methodological quality was hampered by severe under-reporting in the included studies. We assessed risk of bias as unclear in more than half of the studies for the domains of patient selection and reference standard, and in one-third of the studies for the index test. 2. There was substantial heterogeneity among the results of the individual studies, which we investigated further by sources of heterogeneity (see Summary of findings 2).

No. of participants (studies)	Summary sensitivity (95% CI)	Summary specificity (95% CI)	Summary LR+ (95% CI)	Summary LR- (95% CI)	Positive predictive value (95% CI)	Negative predictive value (95% CI)	Consequences in a virtual cohort of 1000[a]	
							Missed injuries	Overtreated
8635 (34)	0.74 (0.65 to 0.81)	0.96 (0.94 to 0.98)	18.5 (10.8 to 40.5)	0.27 (0.19 to 0.37)	0.88 (0.81 to 0.94)	0.90 (0.87 to 0.93)	73 (If 280 people suffer an injury through trauma, 207 will be identified as injured, and 73 will be missed.)	29 (If 720 people do not suffer an injury through trauma, 29 will be treated as though they had been injured, i.e. overtreated.)
Sensitivity analysis with a children-only cohort								
1384 (10)	0.62 (0.47 to 0.75)	0.91 (0.81 to 0.96)	6.9 (2.5 to 18.8)	0.42 (0.26 to 0.65)	0.76 (0.53 to 0.89)	0.84 (0.77 to 0.90)	118 (If 310 children suffer an injury through trauma, 192	62 (If 690 children do not suffer an injury through trauma, 62 will be treat-

	will be identified as injured, and 118 will be missed.)	ed as though they had been injured, i.e. overtreated.)	

[a]The median prevalence was 28% for the complete study population and 31% for the children-only cohort.

Abbreviations
CI: confidence interval
LR+: positive likelihood ratio
LR-: negative likelihood ratio

Summary of findings 2. Investigation of heterogeneity

Investigation of heterogeneity	Number of studies	Summary sensitivity (95% CI)	Summary specificity (95% CI)	Chi[2a]	P value[b]
Reference standard					
Single CT	25	0.75 (0.63 to 0.84)	0.97 (0.93 to 0.98)	0.18 (overall)	0.9160 (overall)
CT plus laparotomy	7	0.73 (0.58 to 0.84)	0.95 (0.87 to 0.98)		
Target condition					
Limited to free fluid/free air	22	0.78 (0.68 to 0.85)	0.97 (0.96 to 0.99)	9.10 (overall) 0.06 (sensitivity) 8.08 (specificity)	0.0106 (overall) 0.8100 (sensitivity) 0.0045 (specificity)
Free fluid/free air and organ injuries/vascular lesions	7	0.80 (0.73 to 0.85)	0.88 (0.70 to 0.96)		
Age of participant					
Children	10	0.63 (0.46 to 0.77)	0.91 (0.81 to 0.96)	7.32 (overall) 54.91 (sensitivity) 19.88 (specificity)	0.0258 (overall) 0.0000 (sensitivity) 0.0000 (specificity)
Adults/mixed	24	0.78	0.97		

		(0.69 to 0.84)	(0.96 to 0.99)		
Type of injury					
Abdominal injury	27	0.68	0.95	17.36 (overall)	0.0002 (overall)
		(0.59 to 0.75)	(0.92 to 0.97)	13.22 (sensitivity)	0.0003 (sensitivity)
Thoracic injury	4	0.96	0.99	5.39 (specificity)	0.0202 (specificity)
		(0.88 to 0.99)	(0.97 to 1.00)		

[a]Large values of the Chi^2 statistic indicate that test performance may be associated with the particular covariate.

[b]P values < 0.05 indicate statistical evidence that sensitivity and/or specificity differ between the examined groups.

Abbreviations
CI: confidence interval
CT: computed tomography

BACKGROUND

Target condition being diagnosed

Trauma, including multiple trauma (defined by an Injury Severity Score (ISS) ≥ 16, or, according to the new Berlin definition, by an Abbreviated Injury Scale (AIS) ≥ three for two or more different body regions and one or more additional variables from five physiologic parameters) (Pape 2014), remains a major cause of death and disability worldwide. Severe trauma mainly results from road traffic crashes and falls from a height. In 2010, according to data from the World Health Organization (WHO) Global Burden of Disease Project, motor vehicle crashes ranked eighth in the global death toll (Lozano 2012), and tenth in all sources of disability-adjusted life years (Murray 2012). The WHO and United Nations Decade of Action for Road Safety campaign 2011 to 2020 was launched to raise awareness about this public health concern and to implement simple and effective primary prevention measures.

A 'treat first what kills first' strategy is now in place at most trauma centres across the world, fostered by standardised management algorithms such as Advanced Trauma Life Support (ATLS). Key steps of these algorithms are (Chapleau 2013):

1. maintain airways and establish sufficient oxygenation (i.e. by intubation and tube thoracostomy in case of pneumo- or haematothorax);
2. stop traumatic bleeding (e.g. by tourniquets on extremities, pelvic binders and external fixators, surgical or interventional control of haemorrhage, application of antifibrinolytics such as tranexamic acid, and transfusion of blood products, mainly coagulation factors).

Data from the German Trauma Registry suggest an overall mortality of 10% from severely injured patients managed within organised trauma networks and at high-volume trauma centres (German Trauma Society 2014). There may be a biological threshold in trauma survivability that cannot be overcome by any of the treatment modalities currently available, and extra translational research efforts are needed to make a difference in future. Apart from unsurvivable brain and upper cervical spine injuries, the leading causes of early death in multiple trauma are chest injuries and abdominal and retroperitoneal haemorrhage (Pfeifer 2016). The presence of free fluid surrounding the liver or spleen, capsular tears, organ contusions or lacerations, and vascular lesions influences early decision making in major trauma.

Stabbing (by sharp tools or weapons such as knives) and shooting are associated with a high chance of organ or vessel injury. The distinct location of wounds may point towards significant trauma to the lungs, heart, mediastinum, liver, spleen, thoracic and/or abdominal aorta. The quality and quantity of injuries sustained in civilian settings and armed conflicts differ in many ways (e.g. by type of weapon, gun, or bullet, wound ballistics, protective armour, austere environment (i.e. where medical care is provided under less than optimal sanitary or hospital-like conditions) and others). Most patients with penetrating trauma need immediate surgical exploration (specifically in case of haemodynamic instability), and preoperative imaging has a rather ancillary role in this situation.

In blunt trauma, however, radiographic imaging is an inevitable part of clinical work-up. Physical examination may reveal indirect signs of internal injury (e.g. contusion marks), but these signs are inconsistent and neither sensitive nor specific. Computed tomography (CT) is regarded as the imaging standard in the emergency department and is currently also the undisputed diagnostic reference test in the trauma scenario. If patients are transferred immediately to the operating theatre before CT imaging, emergency laparotomy, laparoscopy, or thoracotomy is the reference standard of choice. If patients die in the emergency department before any imaging or surgical procedure can be undertaken, definitive diagnoses are obtained during pathological or forensic autopsy. Point-of-care sonography (POCS), however, can be performed during resuscitation, repeated wherever and whenever needed, and does not involve exposure to radiation.

Point-of-care sonography has emerged as an integral part of trauma algorithms and is the initial screening modality of choice for thoracoabdominal bleeding in most regions of the world. Like any other imaging procedure or diagnostic test used for screening purposes, it is important to verify that:

1. a negative index test result is reliable for excluding the condition of interest (guaranteeing that episodes of haemodynamic instability during decompressive brain surgery or fixation of spine, pelvic, or femoral fractures are not caused by sudden major abdominal, thoracic, or retroperitoneal bleeding);
2. a positive index test result is reliable for proving the condition of interest (thus minimising the number of negative or unnecessary thoracotomies and laparotomies, or their minimally invasive equivalents).

Both false-negative and false-positive findings of POCS may misguide trauma teams and affect care priorities adversely.

Diagnostic accuracy (or efficacy) is the first level of the Fryback-Thornbury hierarchy of evaluating the utility of a diagnostic test procedure (Fryback 1991). While the value and utility of a certain test cannot be derived from its accuracy alone, it would be absurd to ask for the effectiveness or efficiency of an inaccurate diagnostic test.

Determining accuracy is thus the first indispensable step in health technology assessment of POCS. This review aimed to generate the best available evidence about the diagnostic accuracy of clinical ultrasound imaging protocols in the setting of thoracoabdominal and multiple trauma compared to appropriate reference standards. It will guide clinicians regarding the likelihood of chest and abdominal injuries given certain prior probabilities and ultrasound findings, and may facilitate the decision to perform a CT scan or to schedule patients for emergency laparoscopy or laparotomy, or other interventional procedures.

Given the (higher) potential utility and value of POCS in blunt compared to penetrating trauma, this review considered only original studies that included participants with blunt injuries or, in a mixed population, provided sufficient details to explore the accuracy of POCS in this group.

Another aspect that requires scrutiny is the use of POCS in paediatric trauma algorithms. Children are vulnerable to radiation for diagnostic purposes, and their lifetime-attributable risk (LAR) of cancer due to medical imaging must be kept to the necessary minimum. Still, there may be situations in which acute and potentially life-threatening conditions require radiation-emitting (i.e. multi-detector row computed tomography (MDCT)) rather

than radiation-free imaging techniques (e.g. POCS or magnetic resonance imaging (MRI)).

Index test(s)

Ultrasound has emerged as a standard for bedside imaging in emergency departments worldwide. Technological progress has led to increasingly lighter and mobile (i.e. handheld) equipment (also available in the preclinical setting, e.g. on helicopters or rescue vehicles). Further advancements include colour-duplex, contrast-enhanced imaging, and even three-dimensional (3D) scanning.

In the trauma setting, POCS is typically performed as focused abdominal sonography for trauma (FAST) (Scalea 1999). In its basic form, FAST includes oblique views of the left upper, right upper, left lower, and right lower abdominal quadrants, as well as a sagittal scan of the mid-abdomen and a transverse view of the pelvic region. The key target of the original FAST scan is free fluid as a surrogate of blood or active bleeding.

The genuine FAST protocol has been modified and supplemented in many ways. The most useful and technically simple extensions were to screen for haematothorax (using oblique or intercostal planes, or both) and, by a xiphoid view, for pericardial effusion. Point-of-care sonography has also proved to be reliable in detecting pneumothorax (Blaivas 2005). Skilled examiners may be able to show and grade abdominal organ injury, although this is likely to exceed the diagnostic limits of POCS in the early resuscitation phase.

In this review, we have used the term POCS rather than FAST because of the varying definitions and targets established in different centres and countries. In clinical practice, ultrasound (or ultrasonography) as an imaging technique is commonly abbreviated and understood as sonography. Altogether, the technological evolution of hardware, increasing skills of operators, and significant advancements in picture acquisition and processing have changed the view of healthcare providers about the role of ultrasonography in the critical care setting substantially. Ultrasound has evolved from a rough screening tool to a conclusive imaging modality.

The index test for this review was therefore any clinical POCS application performed in the setting of blunt trauma that is intended to detect direct or indirect signs of injuries of the thoracic, abdominal, or retroperitoneal cavity or space and/or its organs and vessels.

Clinical pathway

Clinical examination alone has little - if any - role in excluding injuries to the chest or abdomen. The presence of external injuries, such as seatbelt marks, may increase the likelihood of visceral tears, but their absence does not exclude important trauma. Currently, all major trauma algorithms incorporate thoracoabdominal POCS as a diagnostic imaging tool. However, the interpretation of ultrasound images depends on the experience and clinical background of individual operators. This subjective component influences decision making, and hampers comparisons between initial and follow-up scans taken by different examiners. In 2013, Van Vugt and colleagues published an evidence-based work-up protocol for blunt trauma that illustrated the benefits of training trauma teams in POCS (FAST) in combination with an ATLS course (Van Vugt 2013).

Alternative test(s)

Currently, POCS is challenged by the liberal early use of MDCT, either as abdominal, thoracic, thoracoabdominal, or whole-body MDCT. The latter has emerged as the diagnostic modality of choice in most European trauma centres, and is used in the USA and other high-income nations as well. The so-called 'pan-scan' usually comprises a native cranial CT, followed by a contrast-enhanced CT from the skull base to the pelvis and/or trochanteric region. Whole-body MDCT is highly specific, thereby minimising false-positive findings (Stengel 2012), and may thus influence care priorities according to the 'treat first what kills first' rule. Data from the German Trauma Registry suggest that the pan-scan improves survival in both unselected trauma cohorts and haemodynamically unstable patients (Huber-Wagner 2013). However, there are concerns regarding excess exposure to radiation caused by uncritical use of the pan-scan at both the individual and population level (Asha 2012). While dose-reducing reconstruction and processing algorithms are available, it is debatable whether they produce images that are similar in quality and diagnostic certainty to those produced by conventional protocols.

The pan-scan is not only a competing imaging tool; it is also regarded as the diagnostic reference standard to which POCS findings must be compared. This leads to an interesting methodological conflict, as it will be almost impossible to compare both imaging modalities in a head-to-head fashion in the trauma scenario.

Rationale

In high-income countries, it is doubtful whether POCS findings influence treatment decisions in severe trauma. This can be illustrated by the following four possible scenarios.

1. POCS is **positive** for free abdominal or thoracic fluid, or both, in a **haemodynamically stable** patient. This will prompt a CT scan (usually a pan-scan) to identify bleeding sources. In most cases, haemostatic transfusion (plus transarterial embolisation (TAE)) and intensive care unit (ICU) monitoring will be the treatment of choice in this setting.
2. POCS is **negative** for free abdominal or thoracic fluid, or both, in a **haemodynamically stable** patient. This will prompt a CT scan (usually a pan-scan) to verify that there are no active bleeding sources that were missed by ultrasound.
3. POCS is **negative** for free abdominal or thoracic fluid, or both, in a **haemodynamically unstable** patient. This will almost always prompt a CT scan (usually a pan-scan) to identify bleeding sources and to decide about TAE or emergency surgery, or both.
4. POCS is **positive** for free abdominal or thoracic fluid, or both, in a **haemodynamically unstable** patient. Currently, it is unlikely that stability could not be achieved by haemostatic resuscitation and other critical care efforts to make patients pan-scan ready.

Scenario 4 is relevant, but rare, in the Western world. There are very few occasions in which all resuscitation efforts fail and patients are scheduled for emergency thoracotomy or laparotomy, or both, based on POCS findings alone. Still, these situations occur, and clinical practice guidelines must include recommendations on how to cope with them.

In middle- and low-income countries, however, POCS (in addition to conventional radiographs) may represent the most sophisticated or only non-invasive diagnostic tool available to detect significant traumatic haemorrhage and guide triage. The Sichuan earthquake in 2008, which killed 69,197 people and left 18,222 missing, was a classic example. Focused abdominal sonography for trauma ultrasound proved to be effective, efficient, and possibly lifesaving under these exceptional circumstances (Zhou 2012). Similar observations were made after the earthquake in Haiti in 2010. The earthquake in Nepal in April 2015 (which killed more than 6000 and left 2.8 million people homeless) demonstrated how FAST can play a role in triaging patients effectively outside the context of clinical research.

OBJECTIVES

To determine the diagnostic accuracy of POCS for detection and exclusion of:

1. free fluid in the thoracic or abdominal cavities;
2. organ injuries with or without bleeding in the thoracic or abdominal cavities;
3. vascular lesions of the thoracic or abdominal aorta, or other major vessels; and
4. other injuries (e.g. pneumothorax);

compared to the following diagnostic reference standards: computed tomography (CT; 'pan-scan'), magnetic resonance imaging (MRI), thoracotomy, laparotomy, laparoscopy, thoracoscopy, autopsy, or any combination of these.

Secondary objectives

The secondary objectives of this review were to investigate the influence of individual study and cohort characteristics such as the:

1. reference standard;
2. target condition;
3. patient age (paediatric versus non-paediatric);
4. patient disease status: type of trauma, type of injury, haemodynamic stability, injury severity or probability of survival;
5. environment;
6. operator's expertise and background;
7. hardware;
8. test thresholds;

on both positive and negative POCS scans.

More details are provided in the Investigations of heterogeneity section of the review.

METHODS

Criteria for considering studies for this review

Types of studies

We included:

1. either prospective or retrospective diagnostic cohort studies that enrolled patients with blunt trauma who:
   a. underwent any type of POCS as primary imaging modality to screen for thoracoabdominal injuries; and
   b. also underwent predefined imaging or invasive reference tests to verify POCS results;
2. studies that provided 2 x 2 tables (or sufficient information to tabulate results) to allow for calculating sensitivity, specificity, and other indices of diagnostic test accuracy.

We excluded:

1. diagnostic case-control studies comparing patients with known case status to healthy controls, as this creates artificial populations and tends to overestimate sensitivity of the index test;
2. case series and case reports;
3. studies with unclear index or reference tests; and
4. studies that did not allow for creating 2 x 2 tables.

Participants

The target population of this review comprised people of any age or gender who sustained any type of blunt trauma in a civilian scenario and were transferred to a hospital of any care level. Also, in order to be eligible participants had to have undergone POCS as the primary imaging tool and to have been followed up either as inpatients or outpatients with different diagnostic modalities to verify whether the condition of interest was present or absent.

Because of clear differences in clinical management, we deliberately excluded people with penetrating injuries, as well as members of armed forces wounded in the battlefield.

Index tests

Any type of POCS performed in a trauma setting (e.g. FAST ultrasonography of the abdomen or thorax, or both, or any advanced ultrasound protocol) intended to detect:

1. free fluid (as a surrogate of bleeding) in the abdomen, retroperitoneal space, or chest;
2. injuries to solid organs such as the liver or spleen (including attempts to grade their severity);
3. lesions of major vessels; and
4. other injuries (e.g. pneumothorax, as indicated by air in the pleural space).

Variation in POCS technology and application (e.g. specification of ultrasound machines and probes and how up-to-date they were, and handling of inconclusive test results) is addressed in the Assessment of methodological quality section of the review. We planned to examine its potential influence on diagnostic accuracy estimates in the Investigations of heterogeneity section of the review.

Target conditions

This review focused on blunt thoracoabdominal and multiple trauma, meaning any blunt, non-penetrating force to the abdomen and chest and both solid and hollow viscera, as well as both major vessels. Target conditions considered by this review included:

1. free fluid in the:
   a. thoracic cavity (uni- or bilateral, where specified);
   b. abdominal cavity (by abdominal quadrant, where specified);
   c. retroperitoneal space;
   d. pericardium; or
   e. mediastinum;
2. organ injuries, defined as:
   a. liver injuries (e.g. capsular tears, haematoma, tissue lacerations);
   b. splenic injuries (e.g. capsular tears, haematoma, tissue lacerations);
   c. injuries to other solid organs (e.g. pancreas, kidneys);
   d. injuries to hollow viscera; or
   e. any other organ laceration detected by ultrasonography;
3. vascular lesions, defined as:
   a. dissection or rupture of the thoracic or abdominal aorta, or both;
   b. rupture of other vessels such as the iliac arteries;
4. other injuries (e.g. pneumothorax, as indicated by air in the pleural space in the thoracic cavity).

We analysed the effect of different types of target conditions as part of our Investigations of heterogeneity. We categorised target conditions into surrogates of blunt trauma (i.e. free fluid and free air, named limited assessment), and both surrogates and direct signs of organ damage (i.e. organ injuries and vascular lesions, named complete assessment).

Reference standards

In order to be accepted as a diagnostic reference standard, the deliberate use (and the reasoning for its use) of the particular method needed to be specified. To avoid verification bias, all participants were required to undergo an independent imaging or invasive test, regardless of the initial POCS scan.

We classified the following tests as reference standards to confirm the presence or absence of the target condition:

1. any type of CT scan of the major body cavities (i.e. chest, abdomen, pelvis), either selective or performed as a whole-body scan. We planned to stratify results for the use of intravenous or oral contrast agents, or both, and the time interval between POCS and CT;
2. any type of MRI of the major body cavities;
3. laparotomy (by a median or transverse approach), or laparoscopy, either diagnostic or therapeutic;
4. thoracotomy (by median sternotomy or a clamshell approach), or thoracoscopy, either diagnostic or therapeutic;
5. autopsy, either done by pathologists or forensic examiners.

Search methods for identification of studies

We developed a reproducible search strategy in major online databases based on recommendations of the Cochrane Diagnostic Test Accuracy (DTA) Group and a systematic review performed previously (Stengel 2005). We sought assistance and advice from the Cochrane Injuries Group and its Information Specialist to create a search algorithm with high sensitivity. We also requested access to the Cochrane Injuries Group Specialised Register and searched the Cochrane Library for relevant studies included in published reviews. Furthermore, we used a snowball procedure to identify related articles and articles cited in the reference lists of individual publications, and used Google Scholar as an additional search tool.

Electronic searches

We searched the following electronic sources.

1. Ovid MEDLINE (1946 to 15 July 2017).
2. PubMed (not MEDLINE) (1947 to 15 July 2017).
3. Ovid Embase (1974 to 15 July 2017).

Search strategies are shown in Appendix 1.

We performed a further search on 6 December 2018; details of the eight potentially relevant studies identified have been added to the Characteristics of studies awaiting classification and Studies awaiting classification sections, and may be incorporated into the review at the next update.

Searching other resources

A systematic review by Scherer and colleagues showed that results from studies that have not been published in a full-text format are systematically different from fully published results (Scherer 2007). We therefore searched the BIOSIS database for conference abstracts to identify potentially relevant studies that had not yet been published in a journal format (see Appendix 1).

We planned to contact authors of individual studies by email, letter, or phone, if we considered their results to be important but needed further explanation or raw data. We guaranteed that any data exchange complied with the International Conference on Harmonisation Good Clinical Practice (ICH-GCP) principles and rules and regulations of data safety and security.

Data collection and analysis

We employed standard operating procedures (SOP) for the selection of studies, data extraction, and recording. This included the following principles:

1. screening of titles, abstracts, and full texts of study reports identified by the search strategy by two review authors working independently;
2. use of a data extraction form (including individual study characteristics, individual patient profiles, definition of procedures, etc.);
3. dual assessment and data entry;
4. dual assessment of methodological quality of individual studies;
5. resolution of conflicts by a third review author.

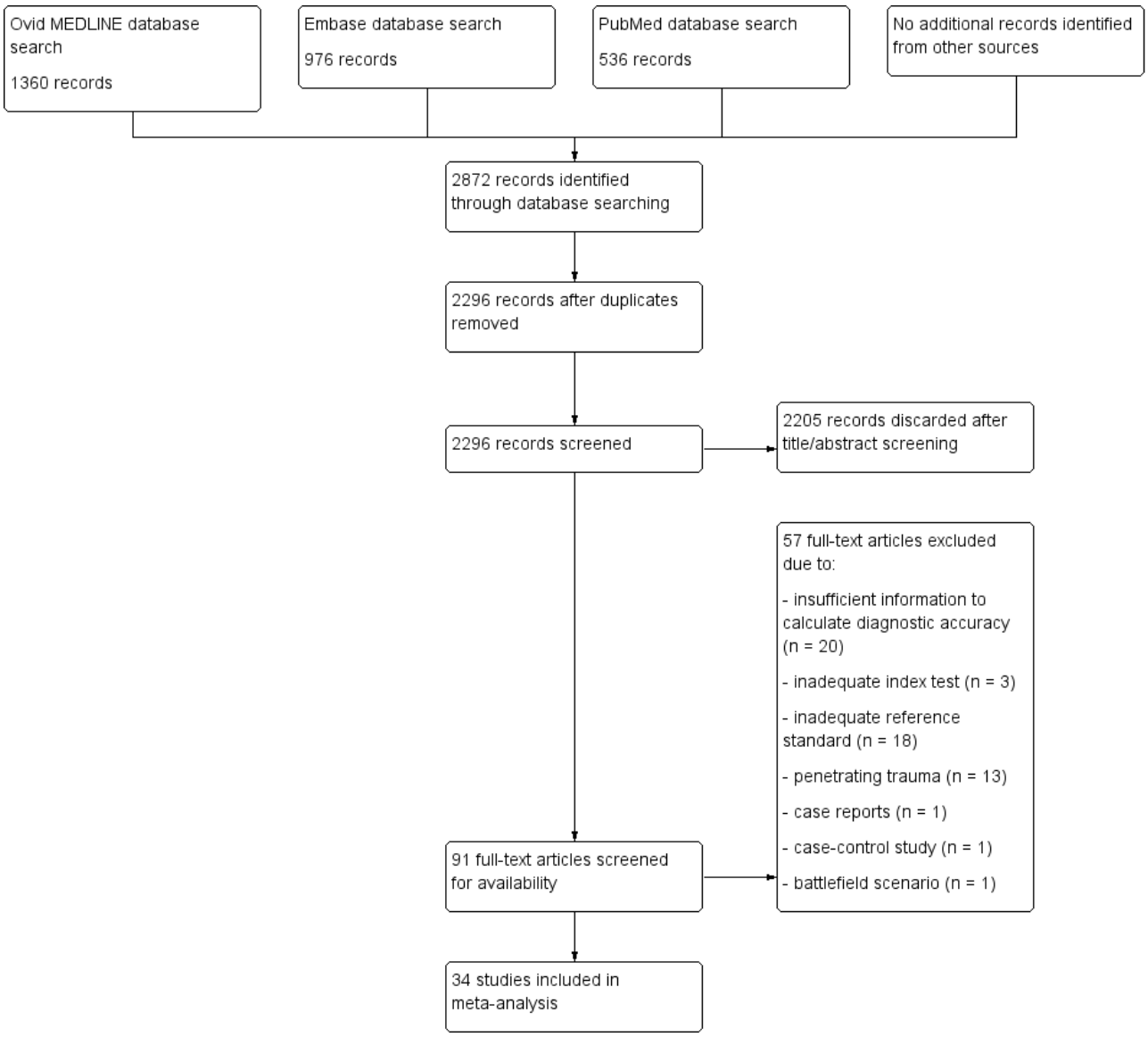
This guarantees transparency and adherence to Cochrane standards and other recommendations (e.g. those issued by the EQUATOR (Enhancing the QUAlity and Transparency Of health Research) group).

Selection of studies

Two review authors (AH, JL) independently screened the titles and abstracts of the identified reports, documenting details of selected studies in a predefined electronic spreadsheet and assessing studies for eligibility in terms of the predefined inclusion and exclusion criteria. If it was not possible to make a decision based on title and abstract alone, the full texts of potentially relevant studies

were assessed. Any disagreements between authors regarding the selection of studies were resolved by a third expert (DS). The study selection process is documented in a detailed flow chart (Figure 1).

Figure 1. Study flow diagram for the search conducted on 15 July 2017.



Data extraction and management

As stated above, we established an SOP for data extraction for systematic reviews, meta-analyses, and health technology assessment (HTA) reports. We adhered to ICH-GCP, Good Epidemiological Practice (GEP), and other relevant rules and recommendations. We have trained personnel on site to record, manage, and audit data, and our data storage modes comply with federal legislation on data safety for research purposes. Two review authors (AH, JL) independently extracted data from original papers in duplicate, and resolved discrepancies by discussion, moderated by a third review author (DS). They extracted the following information from published papers:

1. study characteristics (author, year of study, year of publication, journal reference, study design, inclusion/exclusion criteria, operator characteristics, hardware specifications, index test used, reference test used, general setting (urban/rural), mass casualty (yes/no));
2. patient characteristics (age, gender, type of trauma, type of injury, injury severity, haemodynamic stability, probability of survival);
3. outcome of the index test as assessed in the individual studies by diagnosing the target condition and, if available, the number of participants with inconclusive results or who had no test result;
4. diagnostic 2 x 2 tables, cross-classifying the disease status on the basis of the reference test (i.e. number of true-positive, false-positive, false-negative, and true-negative results).

Diagnostic accuracy was expressed by individual and pooled indicators such as sensitivity and specificity with 95% confidence

intervals (CI), positive and negative likelihood ratios (LR), positive predictive value (PPV), negative predictive value (NPV), and the summary receiver operating characteristic curve (SROC).

Assessment of methodological quality

Two review authors (AH, JL) independently used the QUADAS-2 tool (the revised and updated version of the original Quality Assessment of Diagnostic Accuracy Studies list of items) to assess methodological quality of individual studies (Whiting 2011). Any discrepancies were resolved by discussion, moderated by a third review author (DS). QUADAS-2 includes four main domains, namely: patient selection, index test, reference standard, and flow and timing. We assessed each domain with regard to risk of bias, rating them as 'low', 'high', or 'unclear'. We assessed concerns regarding applicability only for the first three domains, categorising them as 'low', 'high', or 'unclear'. Signalling questions were answered as 'yes', 'no', or 'unclear' (see also Appendix 2). By using tailored review-specific signalling questions we were able to perform a custom-made assessment of the methodological quality of all included studies. We omitted the signalling question "Was any case-control design avoided?" in *Domain 1: Patient selection* since we did not include any case control study, case series, or case reports. We added three signalling questions to *Domain 2: Index test* and two signalling questions to *Domain 3: Reference test* referring to operator's expertise and background, technical features of the hardware, and appropriateness of the ultrasound protocol and reference imaging standard. In *Domain 4: Flow and timing*, we included the signalling question "Did all participants receive a reference standard?" in order to explore the risk of partial verification bias.

Statistical analysis and data synthesis

If at least one of the target conditions was detected (i.e. pneumothorax, free fluid, organ or vessel injury), we considered the patient (participant) to be traumatised or test-positive. Otherwise, we considered the participant to be uninjured or test-negative. Our observational unit of interest was thus the individual participant, not a particular injury, and we did not evaluate single target conditions separately in the primary analysis. We used inconclusive test results as reported in the primary studies. For individual studies, we calculated sensitivity and specificity with 95% CI, tabulated pairs of sensitivity and specificity with CI, and depicted estimates by coupled forest plots using Review Manager 5 (RevMan 5) (Review Manager 2014).

Due to the subjective nature of the interpretation of POCS findings, we expected implicit thresholds in test positivity. We assessed a possible threshold effect visually by plotting true-positive rates (sensitivity) from each study against false-positive rates (1 − specificity) in a receiver operating characteristic (ROC) space and coupled forest plots of sensitivity and specificity. Since the dichotomous operationalisation of the test result does not enable explicit thresholds, we used the bivariate model according to Reitsma 2005, which is a robust statistical model taking the underlying relationship between sensitivity and specificity into account. The random-effects approach allows for calculating sensitivity and specificity estimates while controlling for heterogeneity across studies. We fitted the models in Stata (Stata 2017) using the 'metandi' command and produced SROC plots using RevMan 5. We estimated average sensitivities and specificities using the bivariate model. We obtained likelihood ratios post estimation using the parameters of the bivariate model (see Summary of findings 1).

Investigations of heterogeneity

We assessed heterogeneity visually by inspecting the coupled forest plots and plots of study results in the SROC space. We also investigated possible sources of heterogeneity by adding single covariates to the basic bivariate random-effects model. We conducted fitting of the bivariate model via the 'xtmelogit' command in Stata (Takwoingi 2016). We investigated the effect of adding covariates by conducting a likelihood ratio test that compared the -2 log likelihoods of the basic bivariate model to a model including a single covariate. If a significant reduction in the -2 log likelihood was detected (indicated by a P value of < 0.05), test performance was considered to be associated with the particular covariate. For statistically significant test results, we determined whether the covariate was associated with the estimated sensitivity, specificity, or both (Macaskill 2011), by removing the covariate terms for either sensitivity or specificity, and comparing the fit of each alternative model using likelihood ratio tests.

For tests of heterogeneity, we required a minimum of 10 studies in total and at least four studies per subgroup. We had to dichotomise the covariates we investigated, and differentiate between paediatric and non-paediatric (i.e. adult/mixed populations), surrogates of injury (e.g. air, free fluid) and organ lacerations, abdominal injuries (i.e. injuries exclusively located in the abdomen) or chest injuries (i.e. injuries exclusively located in the chest), and single CT versus CT plus laparotomy used as reference standard (see Summary of findings 2).

Sensitivity analyses

We performed sensitivity analyses to investigate how individual QUADAS-2 key domains (i.e. patient selection, index test, reference standard, and flow and timing) affected accuracy estimates, and to explore whether the different evaluations of the two independent review authors within two original studies influenced pooled sensitivities or specificities, or both, of the index test. Moreover, we examined the impact of participants' age on accuracy estimates by only including paediatric studies.

Assessment of reporting bias

We did not assess reporting bias because there are no accepted ways of doing this for diagnostic test accuracy studies (Deeks 2005).

RESULTS

Results of the search

We conducted the electronic search on 15 July 2017 in Ovid MEDLINE, PubMed, and Ovid Embase, applying the strategy shown in Appendix 1. We identified 2872 publications including 576 duplicates (Figure 1). After screening the titles or abstracts of 2296 records, 91 studies remained for further evaluation according to our predefined inclusion and exclusion criteria (Types of studies). After screening the full texts of these 91 studies, we discarded 57 and included 34. We regarded the published data as sufficient to answer our research questions and so did not require individual author contact.

Included studies

We extracted information from the 34 included studies according to predefined criteria (Characteristics of included studies). The included studies compared POCS to various imaging and surgical standards (i.e. CT, conventional radiography, laparotomy, thoracotomy, and autopsy) and were published between 1992, Tso 1992, and 2017, Calder 2017, with sample sizes ranging from 51 participants in Benya 2000 to 3181 in Becker 2010. Retrospective and prospective designs were equally distributed, and half of all investigations were conducted in the USA. Ten studies enrolled only children and adolescents, with the age of participants ranging from 1 to 18 years (Benya 2000; Calder 2017; Coley 2000; Corbett 2000; Emery 2001; Fox 2011; Menichini 2015; Soudack 2004; Valentino 2010; Zhou 2012). Two studies included only adults (Blaivas 2005; Verbeek 2014), and 22 studies enrolled participants of any age. Four studies addressed thoracic trauma exclusively (Blaivas 2005; Nandipati 2011; Ojaghi 2014; Zhang 2006). Half of all participants were admitted to level I trauma centres.

Excluded studies

Fifty-five studies did not meet the inclusion criteria and were excluded (Characteristics of excluded studies). The main reasons for exclusion were insufficient information to allow for calculating diagnostic accuracy (n = 20), missing specification of or improper reference standards (n = 16, i.e. follow-up ultrasound examination, diagnostic peritoneal lavage (DPL), or clinical observation), or penetrating injuries (n = 13). Reasons for exclusions are summarised in Figure 1.

Methodological quality of included studies

We evaluated the methodological quality of individual studies using the QUADAS-2 tool and summarised quality assessments per fulfilled QUADAS-2 domain (Figure 2; Figure 3). Poor reporting, especially in the patient selection and reference standard domains, hampered conclusive judgements about the risk of bias. Only five studies had a low risk of bias in all four critical domains (Benya 2000; Coley 2000; Emery 2001; Soudack 2004; Verbeek 2014). We rated at least two risk-of-bias domains as unclear or high in 19 studies.

Figure 2. Risk of bias and applicability concerns summary: review authors' judgements about each domain for each included study

Figure 2. (Continued)

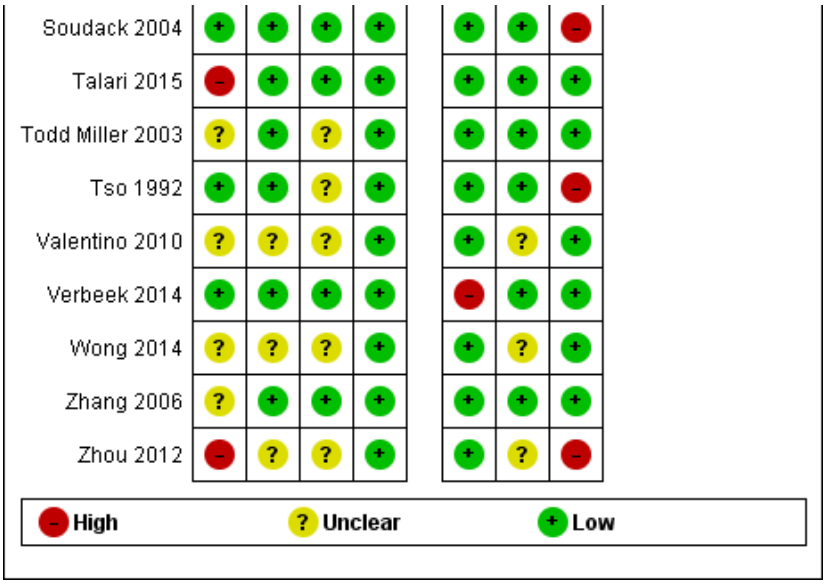
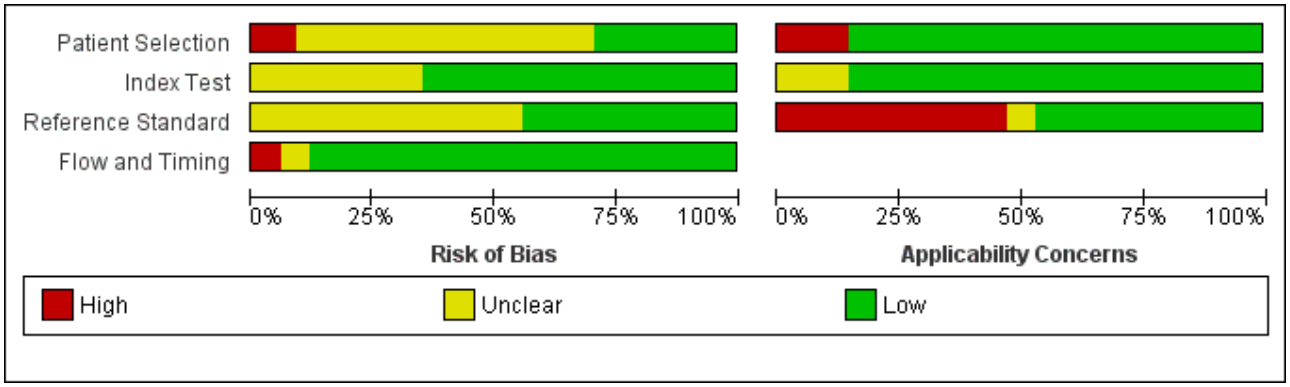


Figure 3. Risk of bias and applicability concerns graph: review authors' judgements about each domain presented as percentages across included studies



Patient selection

Three studies had a high risk of bias with regard to patient selection due to non-consecutive enrolment of participants (e.g. inconsistent availability of designated sonographers, refusal of informed consent) and inappropriate exclusions (e.g. exclusion of patients with underlying diseases associated with intra-abdominal fluid) (Ojaghi 2014; Talari 2015; Zhou 2012). Eleven studies had an unclear risk of bias due to non-consecutive enrolment of patients (Becker 2010; Blaivas 2005; Cheung 2012; Clevert 2008; Corbett 2000; Fox 2011; Hsu 2007; Kendall 2009; Smith 2010; Valentino 2010; Wong 2014). We rated the patient inclusion procedure as unclear for 10 studies (Calder 2017; Catalano 2009; Dolich 2001; Friese 2007; Iqbal 2014; Kärk 2012; McKenney 1994; Nandipati 2011; Todd Miller 2003; Zhang 2006).

Index test

Unclear risk of bias ratings in both index test and reference standard domains originated mainly from missing or unclear information about hardware standards (e.g. machine specifications missing, no information on the number of imaging planes, etc.) or the qualification of operators, or both. Reported qualifications of POCS examiners ranged from attendance of an eight-hour ultrasound course in Hsu 2007 to 10 years of experience in Menichini 2015. We rated eight studies as at unclear risk of bias due to a lack of information regarding the skills of sonographers and insufficient specification about whether index test results were interpreted without knowledge of other imaging test results (Calder 2017; Hsu 2007; Kärk 2012; Kendall 2009; McElveen 1997; McKenney 1994; Wong 2014; Zhou 2012).

Reference standard

We rated 12 studies as having an unclear risk of bias due to missing technical specifications for the reference imaging test (Calder 2017; Cheung 2012; Dolich 2001; Iqbal 2014; Kärk 2012; Kumar 2015; McElveen 1997; Nandipati 2011; Smith 2010; Tso 1992; Wong 2014; Zhou 2012). Information concerning the diagnostic reference standard was generally far scarcer than details about the index test.

Flow and timing

Most studies had a low risk of bias with regard to the examination flow and timing domain. Two studies employed diagnostic reference standards conditional on the result of ultrasound exams in some, McElveen 1997, or all, Menichini 2015, of the examined participants.

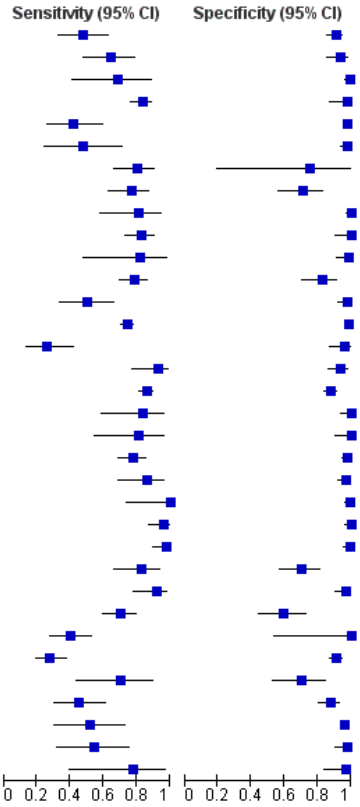
Findings

Diagnostic performance of individual studies comparing POCS with reference standard

Coupled forest plots of individual studies' sensitivities and specificities along with true positives (TP), false positives (FP), false negatives (FN), and true negatives (TN) are depicted in Figure 4. The sensitivity of POCS ranged from 0.26 (95% CI 0.14 to 0.42) to 1.00 (95% CI 0.74 to 1.00). Specificity ranged from 0.59 (95% CI 0.44 to 0.73) to 1.00 (95% CI 0.97 to 1.00). A graphical interpretation of coupled forest plots of individual studies' sensitivities and specificities did not indicate any threshold effect, therefore we considered the bivariate model to be the appropriate pooling procedure.

Figure 4. Coupled forest plots of sensitivity and specificity. TP = true positive; FP = false positive; FN = false negative; TN = true negative

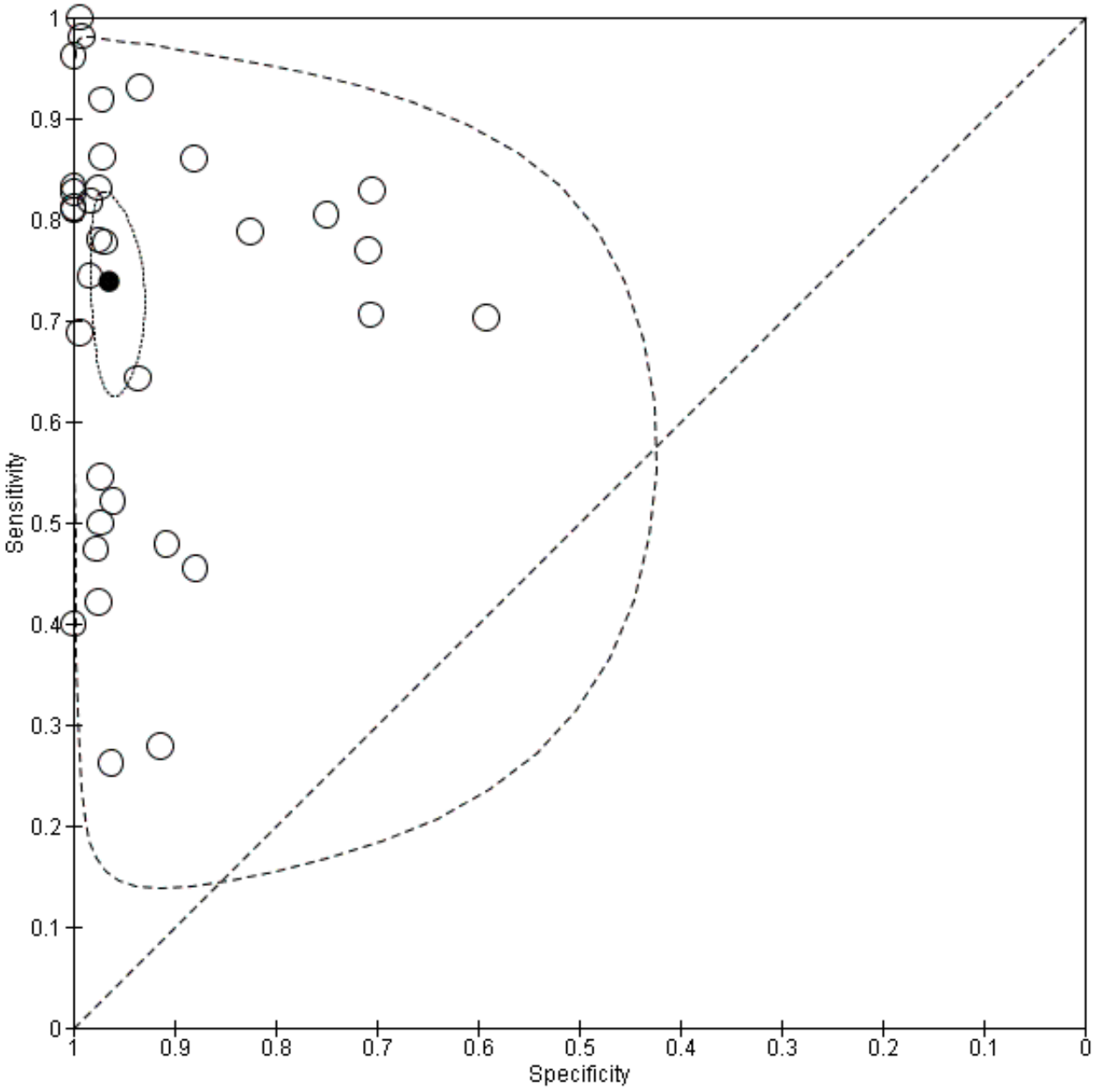
Study	TP	FP	FN	TN	Population	Anatomic region	Sensitivity (95% CI)	Specificity (95% CI)
Wong 2014	23	16	25	157	adults/mixed	abdominal	0.48 [0.33, 0.63]	0.91 [0.85, 0.95]
Verbeek 2014	27	5	15	73	adults/mixed	abdominal	0.64 [0.48, 0.78]	0.94 [0.86, 0.98]
Tso 1992	11	1	5	146	adults/mixed	abdominal	0.69 [0.41, 0.89]	0.99 [0.96, 1.00]
Talari 2015	133	1	27	39	adults/mixed	abdominal	0.83 [0.76, 0.89]	0.97 [0.87, 1.00]
Todd Miller 2003	16	8	22	313	adults/mixed	abdominal	0.42 [0.26, 0.59]	0.98 [0.95, 0.99]
Kendall 2009	9	3	10	130	adults/mixed	abdominal	0.47 [0.24, 0.71]	0.98 [0.94, 1.00]
Kumar 2015	37	1	9	3	adults/mixed	abdominal	0.80 [0.66, 0.91]	0.75 [0.19, 0.99]
Iqbal 2014	40	14	12	34	adults/mixed	abdominal	0.77 [0.63, 0.87]	0.71 [0.56, 0.83]
McKenney 1994	17	0	4	124	adults/mixed	abdominal	0.81 [0.58, 0.95]	1.00 [0.97, 1.00]
Kärk 2012	67	0	14	37	adults/mixed	abdominal	0.83 [0.73, 0.90]	1.00 [0.91, 1.00]
McElveen 1997	9	1	2	58	adults/mixed	abdominal	0.82 [0.48, 0.98]	0.98 [0.91, 1.00]
Catalano 2009	78	10	21	47	adults/mixed	abdominal	0.79 [0.69, 0.86]	0.82 [0.70, 0.91]
Cheung 2012	20	3	20	110	adults/mixed	abdominal	0.50 [0.34, 0.66]	0.97 [0.92, 0.99]
Becker 2010	352	44	121	2664	adults/mixed	abdominal	0.74 [0.70, 0.78]	0.98 [0.98, 0.99]
Friese 2007	11	2	31	52	adults/mixed	abdominal	0.26 [0.14, 0.42]	0.96 [0.87, 1.00]
Ghafouri 2016	27	6	2	85	adults/mixed	abdominal	0.93 [0.77, 0.99]	0.93 [0.86, 0.98]
Dolich 2001	264	37	43	272	adults/mixed	abdominal	0.86 [0.82, 0.90]	0.88 [0.84, 0.91]
Clevert 2008	15	0	3	60	adults/mixed	abdominal	0.83 [0.59, 0.96]	1.00 [0.94, 1.00]
Smith 2010	13	0	3	36	adults/mixed	other	0.81 [0.54, 0.96]	1.00 [0.90, 1.00]
Hsu 2007	78	8	22	302	adults/mixed	other	0.78 [0.69, 0.86]	0.97 [0.95, 0.99]
Zhang 2006	25	3	4	103	adults/mixed	thoracic	0.86 [0.68, 0.96]	0.97 [0.92, 0.99]
Nandipati 2011	12	1	0	146	adults/mixed	thoracic	1.00 [0.74, 1.00]	0.99 [0.96, 1.00]
Ojaghi 2014	50	0	2	98	adults/mixed	thoracic	0.96 [0.87, 1.00]	1.00 [0.96, 1.00]
Blaivas 2005	52	1	1	122	adults/mixed	thoracic	0.98 [0.90, 1.00]	0.99 [0.96, 1.00]
Zhou 2012	29	18	6	43	children	abdominal	0.83 [0.66, 0.93]	0.70 [0.57, 0.81]
Soudack 2004	34	2	3	70	children	abdominal	0.92 [0.78, 0.98]	0.97 [0.90, 1.00]
Valentino 2010	59	20	25	29	children	abdominal	0.70 [0.59, 0.80]	0.59 [0.44, 0.73]
Menichini 2015	26	0	39	6	children	abdominal	0.40 [0.28, 0.53]	1.00 [0.54, 1.00]
Calder 2017	27	21	70	222	children	abdominal	0.28 [0.19, 0.38]	0.91 [0.87, 0.95]
Benya 2000	12	10	5	24	children	abdominal	0.71 [0.44, 0.90]	0.71 [0.53, 0.85]
Emery 2001	20	14	24	102	children	abdominal	0.45 [0.30, 0.61]	0.88 [0.81, 0.93]
Fox 2011	12	13	11	321	children	abdominal	0.52 [0.31, 0.73]	0.96 [0.93, 0.98]
Coley 2000	12	2	10	73	children	abdominal	0.55 [0.32, 0.76]	0.97 [0.91, 1.00]
Corbett 2000	7	1	2	31	children	other	0.78 [0.40, 0.97]	0.97 [0.84, 1.00]



Estimates derived from the bivariate model comparing POCS with reference standard

Figure 5 shows the pooled summary point for sensitivity and specificity derived from the bivariate model with corresponding 95% confidence and prediction regions. Summary estimates of sensitivity and specificity were 0.74 (95% CI 0.65 to 0.81) and 0.96 (95% CI 0.94 to 0.98). Corresponding positive and negative LRs were 18.5 (95% CI 10.8 to 40.5) and 0.27 (95% CI 0.19 to 0.37); PPV was 0.88 (95% CI 0.81 to 0.94); and NPV was 0.90 (95% CI 0.87 to 0.93). The observed median prevalence of blunt thoracoabdominal trauma in the total cohort was 28%. In a virtual population of 1000 patients, assuming the median prevalence of 28%, POCS would miss 73 patients with injuries, and falsely suggest the presence of injuries in another 29 patients.

Figure 5. Summary receiver operating characteristic (ROC) plot of sensitivity and specificity of all 34 included studies. The solid circle represents the summary estimate of sensitivity and specificity. The summary estimate is surrounded by a dotted line representing the 95% confidence region and a dashed lined representing the 95% prediction region.



Heterogeneity

The prediction region around the summary estimate in Figure 5 indicates with 95% confidence where the true sensitivity and specificity of POCS would be expected in a future study. As indicated by the width of the region, there was considerable heterogeneity between studies. Regarding sensitivity, the 95% prediction region varied from 0.14 to 0.98, while the specificity of future studies was estimated to range from 0.42 to 1.00. This marked between-study heterogeneity needs further exploration.

a. Effect of reference standard

Each individual study used CT as confirmative imaging modality, either as a single gold standard or in combination with other reference tests. In 25 studies, target conditions were confirmed exclusively with CT, and in seven studies with CT and laparotomy. There was no difference in POCS sensitivity and specificity when compared with CT or CT plus laparotomy (Chi^2 = 0.18; P value (overall effect) = 0.9160; CT: 0.75 (95% CI 0.63 to 0.84) and 0.97 (95% CI 0.93 to 0.98), CT plus laparotomy: 0.73 (95% CI 0.58 to 0.84) and 0.95 (95% CI 0.87 to 0.98)).

b. Effect of target condition

Twenty-two studies assessed the diagnostic accuracy of POCS targeting surrogate measures like free fluid (18 studies) or air (four studies). Three studies aimed to assess solid organ damage, and another seven studies targeted both free fluid and direct signs of organ injuries. The individual target condition mainly affected specificity estimates (Chi^2 = 9.10; P value (overall effect) = 0.0106). Sensitivity of POCS limited to detecting free fluid/air was 0.78 (95% CI 0.68 to 0.85), compared to 0.80 (95% CI 0.73 to 0.85) for complete assessment (Chi^2 = 0.06; P value (pair-wise) = 0.8100). Related specificities were 0.97 (95% CI 0.96 to 0.99) and 0.88 (95% CI 0.70 to 0.96), respectively (Chi^2 = 8.08; P value (pair-wise) = 0.0045). Coupled forest plots for limited assessment (Figure 6) and complete assessment (Figure 7) show greater variation in specificity in studies targeting both free fluid and direct signs of organ injuries compared to studies aimed only at free fluid or free air.

Figure 6. Coupled forest plots of sensitivity and specificity for studies targeting only free fluid or free air (n = 22). TP = true positive; FP = false positive; FN = false negative; TN = true negative

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Becker 2010	352	44	121	2664	0.74 [0.70, 0.78]	0.98 [0.98, 0.99]
Blaivas 2005	52	1	1	122	0.98 [0.90, 1.00]	0.99 [0.96, 1.00]
Cheung 2012	20	3	20	110	0.50 [0.34, 0.66]	0.97 [0.92, 0.99]
Coley 2000	12	2	10	73	0.55 [0.32, 0.76]	0.97 [0.91, 1.00]
Corbett 2000	7	1	2	31	0.78 [0.40, 0.97]	0.97 [0.84, 1.00]
Emery 2001	20	14	24	102	0.45 [0.30, 0.61]	0.88 [0.81, 0.93]
Fox 2011	12	13	11	321	0.52 [0.31, 0.73]	0.96 [0.93, 0.98]
Friese 2007	11	2	31	52	0.26 [0.14, 0.42]	0.96 [0.87, 1.00]
Ghafouri 2016	27	6	2	85	0.93 [0.77, 0.99]	0.93 [0.86, 0.98]
Hsu 2007	78	8	22	302	0.78 [0.69, 0.86]	0.97 [0.95, 0.99]
Iqbal 2014	40	14	12	34	0.77 [0.63, 0.87]	0.71 [0.56, 0.83]
Kumar 2015	37	1	9	3	0.80 [0.66, 0.91]	0.75 [0.19, 0.99]
Kärk 2012	67	0	14	37	0.83 [0.73, 0.90]	1.00 [0.91, 1.00]
McKenney 1994	17	0	4	124	0.81 [0.58, 0.95]	1.00 [0.97, 1.00]
Nandipati 2011	12	1	0	146	1.00 [0.74, 1.00]	0.99 [0.96, 1.00]
Ojaghi 2014	50	0	2	98	0.96 [0.87, 1.00]	1.00 [0.96, 1.00]
Smith 2010	13	0	3	36	0.81 [0.54, 0.96]	1.00 [0.90, 1.00]
Soudack 2004	34	2	3	70	0.92 [0.78, 0.98]	0.97 [0.90, 1.00]
Talari 2015	133	1	27	39	0.83 [0.76, 0.89]	0.97 [0.87, 1.00]
Todd Miller 2003	16	8	22	313	0.42 [0.26, 0.59]	0.98 [0.95, 0.99]
Verbeek 2014	27	5	15	73	0.64 [0.48, 0.78]	0.94 [0.86, 0.98]
Zhang 2006	25	3	4	103	0.86 [0.68, 0.96]	0.97 [0.92, 0.99]

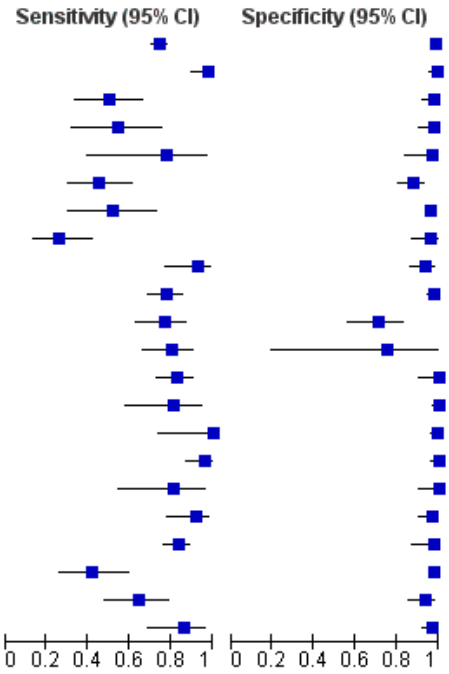
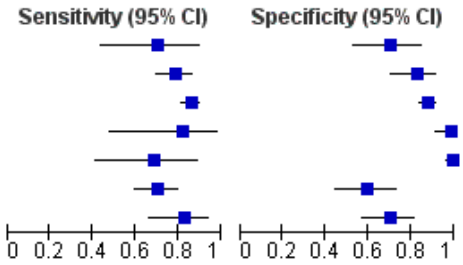


Figure 7. Coupled forest plots of sensitivity and specificity for studies considering both surrogates and organ lacerations (n = 7). TP = true positive; FP = false positive; FN = false negative; TN = true negative

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Benya 2000	12	10	5	24	0.71 [0.44, 0.90]	0.71 [0.53, 0.85]
Catalano 2009	78	10	21	47	0.79 [0.69, 0.86]	0.82 [0.70, 0.91]
Dolich 2001	264	37	43	272	0.86 [0.82, 0.90]	0.88 [0.84, 0.91]
McElveen 1997	9	1	2	58	0.82 [0.48, 0.98]	0.98 [0.91, 1.00]
Tso 1992	11	1	5	146	0.69 [0.41, 0.89]	0.99 [0.96, 1.00]
Valentino 2010	59	20	25	29	0.70 [0.59, 0.80]	0.59 [0.44, 0.73]
Zhou 2012	29	18	6	43	0.83 [0.66, 0.93]	0.70 [0.57, 0.81]

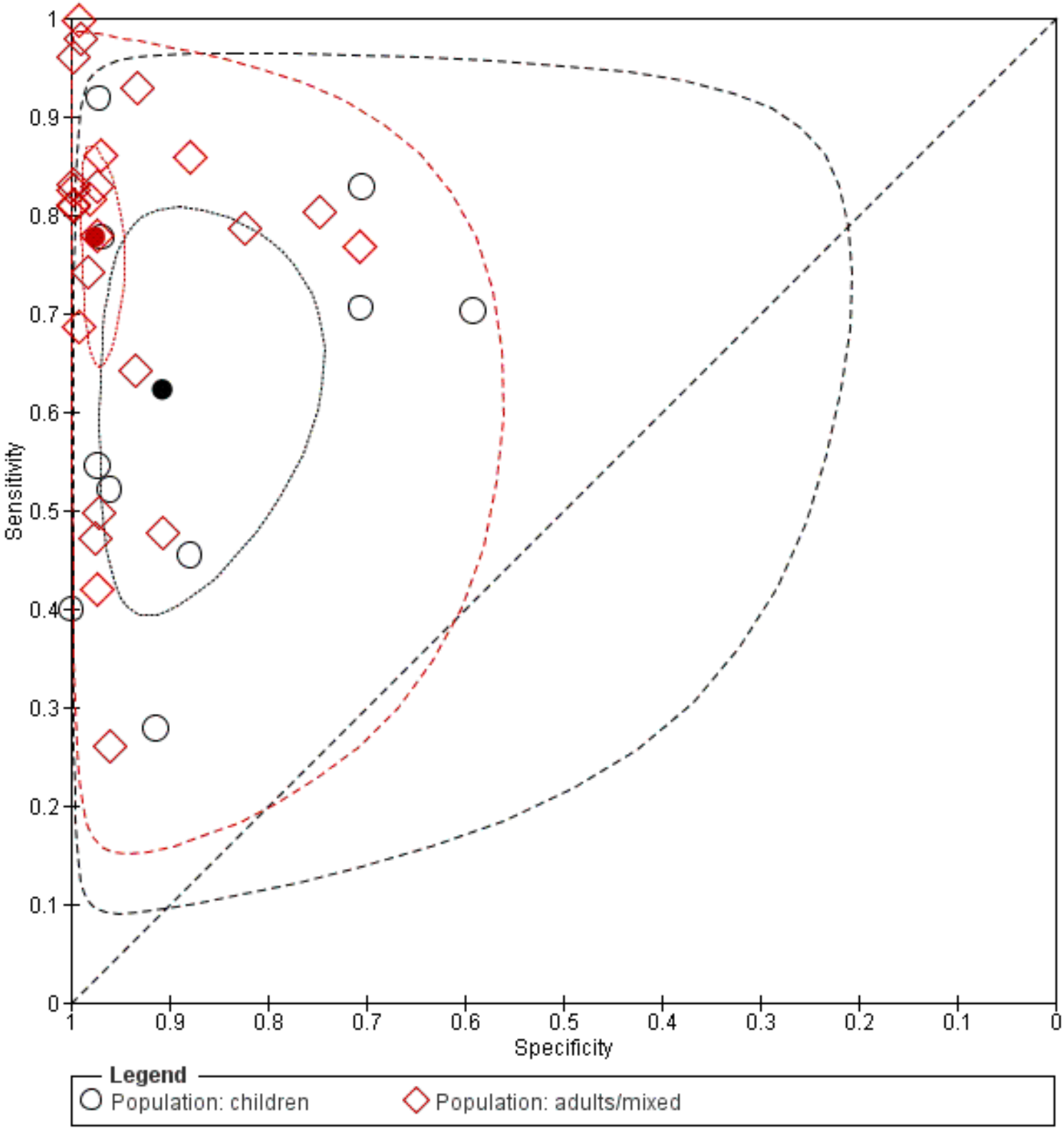


c. Effect of participant age

Ten studies included only children under 18 years of age, whereas 24 studies involved adults or a largely adult population. Participant age was associated with significantly different estimates of both sensitivity and specificity (Chi^2 = 7.32; P value (overall effect) = 0.0258). Pooled sensitivity of POCS was 0.63 (95% CI 0.46 to 0.77) in children and 0.78 (95% CI 0.69 to 0.84) in an adult or mixed population (Chi^2= 54.91; P value (pair-wise) < 0.0001). Associated specificities were 0.91 (95% CI 0.81 to 0.96) and 0.97 (95% CI 0.96 to 0.99) (Chi^2 = 19.88; P value (pair-wise) < 0.0001). Figure 8 depicts individual sensitivity and specificity estimates along with summary points, 95% confidence regions, and 95% prediction regions for both paediatric and non-paediatric studies. Trials including only children are depicted by means of black dots, while trials with a predominantly adult population are shown as red dots. Figure 4 illustrates sensitivities and specificities from individual studies for

non-paediatric (first 24 studies) and paediatric populations (last 10 studies).

Figure 8. Summary receiver operating characteristic (ROC) plot of sensitivity and specificity: paediatric studies (n = 10; indicated in black) versus non-paediatric studies (n = 24; indicated in red). The solid circles represent the summary estimates of sensitivity and specificity. The summary estimates are surrounded by a dotted line representing the 95% confidence region and a dashed lined representing the 95% prediction region.

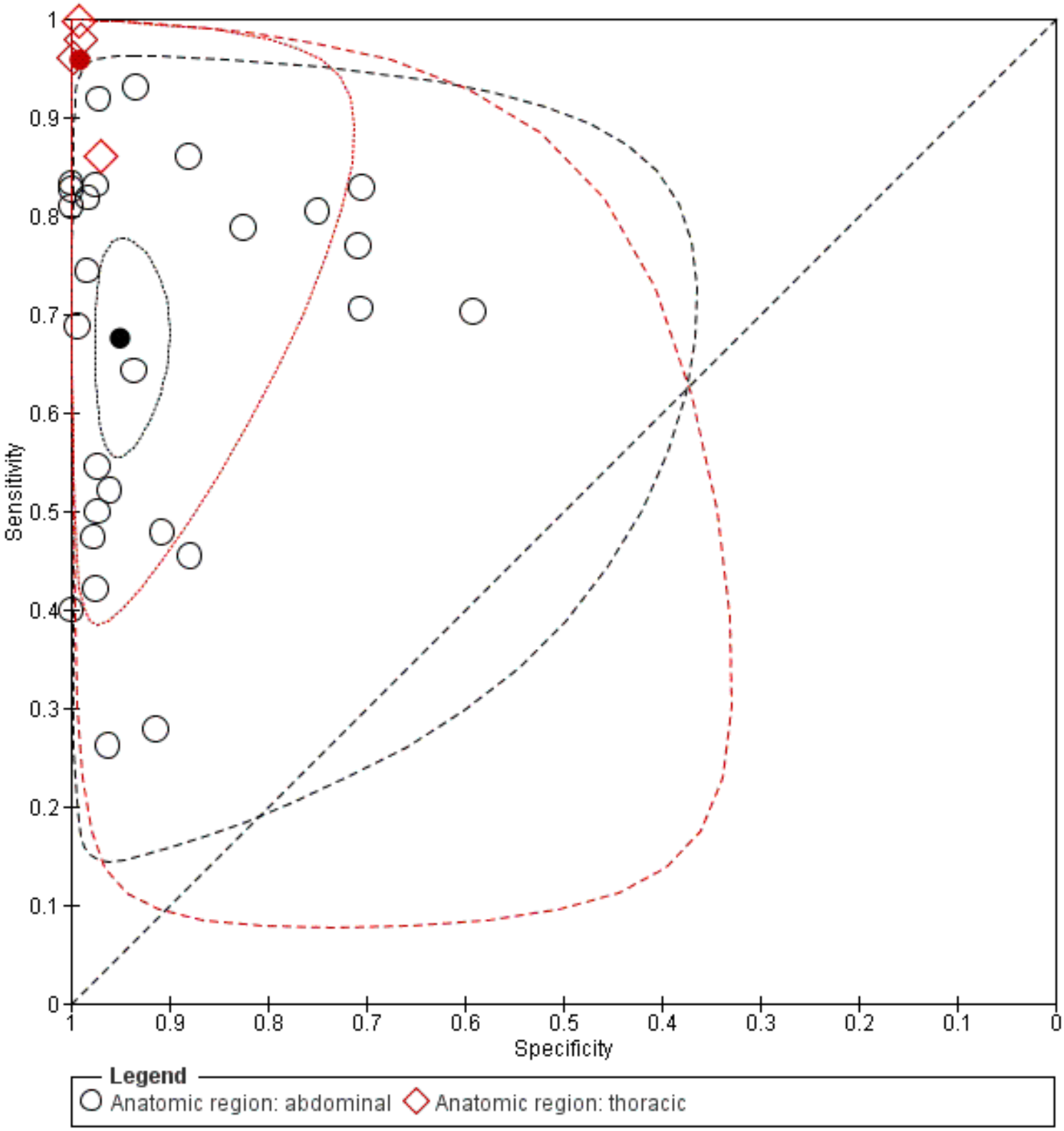


d. Effect of type of injury

Twenty-seven studies targeted abdominal injuries; four studies addressed thoracic trauma; two studies addressed both; and one study examined blunt truncal trauma without further specification. We tested the influence of the anatomic region on the basic model by adding a binary covariate that dichotomised the injury type into thoracic or abdominal trauma. Based on 31 studies, this led to significantly different estimates of sensitivity and specificity (Chi^2 = 17.36; P value (overall effect) = 0.0002). Sensitivity of POCS for abdominal and thoracic trauma was 0.68 (95% CI 0.59 to 0.75) and 0.96 (95% CI 0.88 to 0.99), respectively (Chi^2 = 13.22; P value (pair-wise) = 0.0003). Specificity was 0.95 (95% CI 0.92 to 0.97) and 0.99 (95% CI 0.97 to 1.00), respectively (Chi^2 = 5.39; P value (pair-wise) = 0.0202). Individual sensitivities and specificities for abdominal trauma, thoracic trauma, and trauma that is not exclusively abdominal or thoracic (i.e. both abdominal and thoracic trauma, truncal trauma) are displayed in Figure 4. Individual and average estimates of sensitivity and specificity, and both 95% confidence regions and 95% prediction regions around the summary estimates for thoracic and abdominal studies separately are illustrated in Figure 9. For abdominal trauma, the accuracy values are widely scattered across studies, whereas sensitivity and specificity values are consistently high when targeting only thoracic trauma.

Figure 9. Summary receiver operating characteristic (ROC) plot of sensitivity and specificity: abdominal studies (n = 27; indicated in black) versus thoracic studies (n = 4; indicated in red). The solid circles represent the summary

estimates of sensitivity and specificity. The summary estimates are surrounded by a dotted line representing the 95% confidence region and a dashed lined representing the 95% prediction region.



Sensitivity analysis

a. Effect of study quality

We performed sensitivity analyses to investigate the effect of study quality on diagnostic accuracy estimates separately for each of the QUADAS-2 key domains. Study quality did not have a substantial effect on either sensitivity or specificity estimates in any of the four domains. Sensitivity and specificity estimates for studies with low risk of bias were as follows: patient selection (9 studies) 0.75 (95% CI 0.63 to 0.85) and 0.93 (95% CI 0.83 to 0.98), index test (22 studies) 0.77 (95% CI 0.66 to 0.85) and 0.97 (95% CI 0.94 to 0.98), reference standard (11 studies) 0.77 (95% CI 0.60 to 0.89) and 0.97 (95% CI 0.93 to 0.99), flow and timing (30 studies) 0.74 (95% CI 0.65 to 0.81) and 0.96 (95% CI 0.93 to 0.98).

b. Effect of two independent reviewers within original studies

In two original studies (Benya 2000; Ghafouri 2016), sonograms and CT examinations were evaluated independently by two trialists, resulting in two different accuracy values for each reviewer. In order to analyse the influence of reviewers' decision on pooled accuracy estimates, we added both reviewers' lower accuracy estimates (Main analysis set) to one set and both reviewers' higher accuracy estimates to another set (Sensitivity analysis set) and assessed the differences; we detected no difference in either diagnostic accuracy estimate. The summary estimates of sensitivity and specificity along with CIs were identical in both sets with sensitivity estimates of 0.74 (95% CI 0.65 to 0.81) and specificity estimates of 0.96 (95% CI 0.94 to 0.98). The positive and negative LRs differed marginally with 20.9 (95% CI 12.0 to 36.5) and 0.27 (95% CI 0.20 to 0.37) in the Main analysis set compared with 20.8 (95% CI 11.8 to 36.8) and 0.27 (95% CI 0.20 to 0.37) in the Sensitivity analysis set.

c. Effect of patient age

When including only studies with patients under 18 years of age, sensitivity and specificity values were lower than in the analysis that included adults. In the 10 paediatric studies with 1384 participants, sensitivity was estimated at 0.62 (95% CI 0.47 to 0.75) and specificity at 0.91 (95% CI 0.81 to 0.96) (see Summary of findings 1). Positive LR with 6.9 (95% CI 2.5 to 18.8), PPV with 0.76 (95% CI 0.53 to 0.89), and NPV with 0.84 (95% CI 0.77 to 0.90) were lower, and negative LR was higher with 0.42 (95% CI 0.26 to 0.65) than in the complete set of studies. In a virtual cohort of 1000 children having sustained blunt trauma, thoracoabdominal injuries would be missed in 118 cases (compared to 73 in the overall cohort), and 62 children would be falsely diagnosed as having sustained injuries (compared to 29 in the overall cohort).

DISCUSSION

Summary of main results

(See Summary of findings 1)

In this systematic review, we included 34 studies with 8635 participants that evaluated the diagnostic accuracy of point-of-care sonography (POCS) for diagnosing thoracoabdominal injuries in patients with blunt trauma. Summary estimates of sensitivity and specificity were 0.74 (95% confidence interval (CI) 0.65 to 0.81) and 0.96 (95% CI 0.94 to 0.98). Corresponding positive and negative likelihood ratios were 18.5 (95% CI 10.8 to 40.5) and 0.27 (95% CI 0.19 to 0.37), respectively. There was no threshold effect. We judged risk of bias as largely unclear due to insufficient information, especially in terms of patient selection and reference standard domains.

There was significant heterogeneity in both sensitivity and specificity across studies, which was partly explained by patient age, type of injury, and target condition. In children, the pooled sensitivity of POCS was 0.63 (95% CI 0.46 to 0.77), compared to 0.78 (95% CI 0.69 to 0.84) in an adult or mixed population. Associated specificity was 0.91 (95% CI 0.81 to 0.96) and 0.97 (95% CI 0.96 to 0.99). Pair-wise comparisons for both sensitivity and specificity yielded P values less than 0.0001. Taking into account the rather large number of studies in both groups (i.e. 10 paediatric studies versus 24 non-paediatric studies), this indicates a real difference between both groups that cannot be explained by chance or other characteristics. For abdominal trauma, POCS had a sensitivity of 0.68 (95% CI 0.59 to 0.75) and a specificity of 0.95 (95% CI 0.92 to 0.97). For chest injuries, sensitivity and specificity were 0.96 (95% CI 0.88 to 0.99) and 0.99 (95% CI 0.97 to 1.00), respectively. However, only four studies targeted chest injuries exclusively, none of which enrolled children, for whom accuracy estimates appear to be lower generally. The individual target condition mainly affected specificity estimates, with a specificity of 0.97 (95% CI 0.96 to 0.99) for evaluations limited to free fluid/air and a specificity of 0.88 (95% CI 0.70 to 0.96) for complete assessments that also included direct signs of organ damage.

Summary estimates of sensitivity and specificity remained similar in studies at low risk of bias across all four domains (ranging from 0.74 to 0.77 and 0.93 to 0.97, respectively). When only children were included, summary estimates were lower compared to the main analysis, with a sensitivity of 0.62 (95% CI 0.47 to 0.75) and a specificity of 0.91 (95% CI 0.81 to 0.96).

In a virtual cohort of 1000 patients, assuming the observed median prevalence of thoracoabdominal trauma of 28%, POCS would miss 73 patients with injuries, and falsely suggest the presence of injuries in another 29 patients. In a children-only cohort, POCS would miss 118 patients with injuries, and falsely suggest the presence of injuries in another 62 patients.

Strengths and weaknesses of the review

We performed a comprehensive literature search in major electronic databases using a reproducible retrieval strategy. With 2296 screened records and 34 eligible studies, we are confident the data set constitutes, at minimum, a representative sample and, at best, a complete set of studies investigating the diagnostic accuracy of POCS in patients with blunt trauma. We included diagnostic test accuracy (DTA) filters in our Ovid MEDLINE and Ovid Embase search strategies as suggested by the Information Specialist of the Cochrane Injuries Group and in adherence with the protocol. Methodological search filters are generally used to cut down large numbers of primary studies and to focus the search on the most relevant citations (Lefebvre 2017). Current recommendations do not support the use of methodological filters, as they may impair sensitivity and precision (Beynon 2013). Although we are not aware of any major accuracy study missed by our search algorithm, the use of a methodological search filter might represent a potential limitation in this review.

The relatively large number of investigations allowed for pooling summary estimates of sensitivity and specificity, and for exploring potential sources of heterogeneity. Using tailored review-specific

signalling questions in the QUADAS-2 tool allowed us to perform a custom-made assessment of the methodological quality of all included studies. Unfortunately, assessment of the methodological quality was impeded due to considerable under-reporting in original studies. We investigated the influence of poor study quality by conducting sensitivity analyses separately for each risk-of-bias domain, which showed that study quality did not influence diagnostic accuracy estimates markedly.

There was substantial heterogeneity between studies, visible by the rather wide 95% prediction region in Figure 5. As there are more patients with than without the target condition, the 95% prediction region for sensitivity (0.14 to 0.98) was larger than that for specificity (0.42 to 1.00). However, we were able to explain heterogeneity partly by study characteristics such as participants' age, target condition, and type of injury. The performance of POCS in children remains controversial (Holmes 2007). The lower specificity observed in this review may be explained by the disproportionately larger number of complete assessments of abdominal injuries in paediatric compared to adult studies.

The higher sensitivity and specificity of POCS in studies examining only the thorax in comparison with studies focusing on the abdomen is in agreement with previous reviews (Alrajab 2013; Alrajhi 2012; Ding 2011; Ebrahimi 2014). In our review, an evaluation of both free-fluid and organ injuries by POCS resulted in lower specificity than a complete evaluation, which is in agreement with published results (e.g. Poletti 2003).

Due to missing information, we were unable to explore some characteristics (i.e. environment, operators' expertise and background, hardware, test thresholds) as sources of heterogeneity. Only two studies described the handling of inconclusive results: in Iqbal 2014, inconclusive results were handled as positive test results, and in Dolich 2001, indeterminate results were excluded from sensitivity and specificity calculations, and the percentage of indeterminate results was only 1%. We do not expect the generally low number of inconclusive test results in the primary studies to affect our results. We had to modify our original categorisation of reference standards and participant age to investigate heterogeneity. Since computed tomography (CT) was used as a reference test in every single study, we compared the diagnostic accuracy of POCS to CT and CT plus laparotomy. Given the small number of studies including adults exclusively, we decided to compare children-only cohorts against studies including adults or a mixed-age population. We preferred this approach over splitting data into two parts based on participants' median or mean age.

We classified participants as test positive if any one of the target conditions was detected, irrespective of the fact that target conditions could differ between index test and reference standard. The majority of original studies (i.e. 25 of 34) used similar target conditions for index test and reference standard, and thus did not cause a mismatch. However, non-transparent reporting in the remaining studies prevented us from correlating the source of bleeding between both diagnostic procedures, and may potentially result in a mismatch regarding the target condition. We do not presume a substantial mismatch here, however an effect on test accuracy estimates cannot be excluded.

We restricted suitable reference standards to predefined imaging or invasive tests (i.e. CT, magnetic resonance imaging (MRI), laparotomy, laparoscopy, thoracotomy, thoracoscopy, autopsy), which ensured accurate estimation of sensitivities and specificities of POCS as an index test. However, we were unable to detect investigations that used MRI, laparoscopy, thoracotomy, or thoracoscopy as the single reference standard as specified by our inclusion and exclusion criteria, thus we could not evaluate the diagnostic accuracy of POCS compared to these diagnostic techniques. As a consequence, the diagnostic accuracy of POCS mainly refers to CT as a comparator rather than any other reference standard, and may thus limit the generalisability of this review.

Applicability of findings to the review question

In order to generate clinically realistic and relevant evidence, we kept our inclusion criteria fairly broad. Consequently, individual study and participant characteristics varied substantially, for example in terms of age, affected body region, target conditions, operators' expertise, hardware specification, etc. Unsurprisingly, while this variation led to marked heterogeneity in both sensitivity and specificity estimates between studies, it also enabled us to compare accuracy estimates across various settings and POCS applications.

We assessed concerns about applicability in participant selection, index test, and reference standards by using tailored questions in the QUADAS-2 tool. Of the 34 included studies, 11 were associated with low concern about applicability (Benya 2000; Blaivas 2005; Coley 2000; Emery 2001; Ghafouri 2016; Kendall 2009; Nandipati 2011; Ojaghi 2014; Talari 2015; Todd Miller 2003; Zhang 2006). In the patient selection and index test domains, 29 studies showed low concerns about applicability. In patient selection, we assigned high concerns to five studies because of restricted inclusion criteria (i.e. only pelvic fractures (Friese 2007; Verbeek 2014); only minor, Menichini 2015, or only major trauma, Corbett 2000; or with limited organ lesions only (Kärk 2012)). We judged five studies to have unclear ratings in the index test domain owing to missing information about body areas examined (Calder 2017; Clevert 2008; Valentino 2010; Wong 2014; Zhou 2012). The conditional use of reference standards depending on the results of clinical observation, ultrasound examination, or participants' haemodynamic stability led to 16 high applicability rating concerns in the reference standard domain.

In summary, we rated 85% of all included studies as being of low concern for applicability in the patient selection and index test domains, whereas we rated only 47% of studies as of low concern in the reference standard domains. While the included spectrum of participants in this review may appropriately reflect the intended population, and the index tests used in the included studies may not differ considerably from those in clinical practice, the spectrum of reference standards may not correspond completely to the whole range of tests actually used in the setting of thoracoabdominal trauma.

AUTHORS' CONCLUSIONS

Implications for practice

Following the 'treat first what kills first' principle, any active non-compressible bleeding in the major body cavities and retroperitoneum represents a priority condition to be addressed immediately (e.g. by pelvic stabilisation, haemostatic transfusion, tranexamic acid, etc.). As damage-control resuscitation often

needs a substantial number of precious packed red blood and fresh frozen plasma units, the high specificity of point-of-care sonography (POCS) (0.96, 95% confidence interval (CI) 0.94 to 0.98) may avoid a waste of resources (which is of particular importance in mass casualties), overtreatment, and unnecessary invasive procedures, as false-positive findings are very unlikely (with 266 false positives (i.e. 3.1%) out of 8635 individuals). Also, the accuracy of ultrasonography for identifying chest injuries such as pneumothorax with a sensitivity calculated at 0.96 (95% CI 0.88 to 0.99) and a specificity calculated at 0.99 (95% CI 0.97 to 1.00) based on four studies is remarkable and may replace traditional posteroanterior radiographs.

However, despite the advantage of the high specificity of ultrasonography, multiprofessional trauma care teams need to be aware that a negative examination bears a relevant risk of being false negative (i.e. negative predictive value (0.90, 95% CI 0.87 to 0.93)). Where there is a high prior probability of thoracoabdominal trauma (e.g. because of the injury mechanism), a negative scan may also be caused by centralised circulation and limited arterial perfusion of injured solid organs like the liver or spleen.

Again, it remains important to consider the individual clinical scenario when interpreting POCS findings. While positive results will be almost always trustworthy and should prompt bleeding control measures, negative scans must be confirmed by a reference test like computed tomography (CT), or, in the case of limited resources, by sequential sonograms and clinical observation. This is of particular importance in paediatric trauma, where the sensitivity of POCS is extremely poor (0.62, 95% CI 0.47 to 0.75), potentially resulting in 118 children with missed injuries in a cohort of 1000 children with suspected blunt thoracoabdominal trauma. These accuracy patterns are probably a signature feature of POCS that cannot be overcome even by state-of-the art equipment.

Implications for research

In high-income countries, the availability of fast CT scanners right at or close to the trauma bay, together with whole-body scanning protocols and dose-reducing algorithms, have substantially reduced the clinical importance of POCS in routine trauma care. Additional studies on the accuracy of this technology to detect abdominal injuries may thus have little impact on care processes in all age groups. More accurate reporting of individual study characteristics (e.g. selection of participants, examiner's experience) would help to evaluate potential sources of heterogeneity in the diagnosis of blunt thoracoabdominal trauma better, and to assess the risk of bias. Nonetheless, more and robust data from larger, confirmatory studies using CT as the ultimate reference test are required to define the role of POCS for detecting pneumothorax and haematothorax and facilitating early tube thoracostomy. Studies determining the accuracy and utility of POCS in mass casualty and low- and middle-income countries are needed, however guaranteeing consistent confirmation of POCS findings by objective reference tests in these settings will be challenging.

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CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Becker 2010

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** Miami, USA **Study period:** 2000 to 2005 **Care setting:** level 1 trauma centre **Mass casualty:** no **Participants enrolled:** 3181: 2274 men and 907 women **Participants included in analysis:** 3181 **Age:** mean age 39 ± 19 years **Type of injury:** abdominal trauma **Injury severity:** ISS 22.9 ± 18 **Haemodynamic stability:** stable conditions

Becker 2010 *(Continued)*

	Inclusion criteria: blunt trauma patients who underwent both US as a part of initial assessment and CT scan of the abdomen. Patients were divided into 3 groups according to their ISS: Group 1: ISS 1 to 14; Group 2: ISS 16 to 24; Group 3: ISS ≥ 25 (group allocation is reported as in the published reports - the trialists did not say what happened to patients who had an ISS = 15). Age, gender, mechanism of injury, physiologic parameters, laboratory test results, ISS, radiology reports, and all applied procedures were retrospectively reviewed by the study team. **Exclusion criteria:** penetrating trauma, no US examination or CT scan
Index tests	**Index test:** FAST **US protocol:** trauma team members performed US examinations on all blunt trauma participants in the resuscitation bay. The US was obtained with the participant in supine position by the attending, trauma fellow, or resident. A positive US examination was considered to be a true positive if the CT scan revealed free fluid, and considered to be a false positive if free fluid was not confirmed at the subsequent CT scan. Negative US findings were counted as true negatives if the CT scan was negative and the participant had an uneventful course, and considered to be a false negative if the participant had a negative US and positive CT examination or was operated on and felt to have a therapeutic laparotomy. **Hardware used:** Aloka SSD 1000 (Aloka Co Ltd, Wallingford, CT) with a 3.5-MHz curved probe **Description of imaging technique:** 4 areas were examined: perihepatic, perisplenic, pelvic, and pericardial
Target condition and reference standard(s)	**Target condition:** free fluid **Reference standard:** CT (CT technique not specified), laparotomy **Description of technique:** not reported
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		

Becker 2010 *(Continued)*

If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Unclear		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Unclear		
		Unclear	**Unclear**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Unclear		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Unclear	

Benya 2000

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Chicago, USA **Study period:** October 1996 to October 1997 **Care setting:** not reported **Mass casualty:** no **Participants enrolled:** 51: 35 boys and 16 girls **Participants included in analysis:** 51 **Age:** mean age 6 years 7 months (range 2 weeks to 16 years) **Type of injury:** abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable conditions **Inclusion criteria:** children with blunt abdominal injuries examined with abdominal CT after initial surgical evaluation were examined with sonography. Only those children who did not require emergency surgery were invited to participate. **Exclusion criteria:** not reported
Index tests	**Index test:** US **US protocol:** abdominal sonography was performed after abdominal CT in all participants. The paediatric radiologist or sonographer performing the sonography was not aware of the clinical history, physical examination, or CT and laboratory results. **Hardware used:** 128XP10 or Sequoia (Acuson, Mountain View, CA) using a 2.5- to 8-MHz transducer (Acuson), depending on the child's size and physical build **Description of imaging technique:** US scan locations: longitudinal and transverse images of both upper quadrants of the abdomen and transverse views of the pancreas, bladder, and both lower quadrants to the abdomen to detect intraperitoneal and retroperitoneal fluid. A variable number of supplemental transverse and longitudinal images of the solid organs in the upper abdomen were subsequently obtained.
Target condition and reference standard(s)	**Target condition:** free fluid and organ injury **Reference standard:** abdominal and pelvis CT, helically on a HiSpeed Advantage CT scanner (General Electric Medical Systems, Milwaukee, WI) **Description of technique:** CT examination during dynamic bolus administration of IV contrast material with slice collimation ranging from 5 mm to 10 mm, depending on the size of the child
Flow and timing	**Time between US and reference standard:** < 24 hours
Comparative	

Benya 2000 *(Continued)*

Notes

Methodological quality			
Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	No		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		

Benya 2000 *(Continued)*

		Low	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	No		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Blaivas 2005

Study characteristics	
Patient sampling	Prospective, single-blinded study
Patient characteristics and setting	**Study location:** Georgia, USA **Study period:** September 2003 to May 2004 **Care setting:** level 1 trauma centre **Mass casualty:** no **Participants enrolled:** 176: 100 men and 76 women **Participants included in analysis:** 176 **Age:** > 17 years **Type of injury:** abdominal and chest trauma **Injury severity:** not reported **Haemodynamic stability:** not reported **Inclusion criteria:** blunt trauma patients receiving a FAST examination followed by chest radiography and CT of the chest and/or abdomen and pelvis. Patients who had chest tube placement prior to CT scan were included in the analysis, and the presence of pneumothorax was considered to be verified if a rush of air was heard when the chest tube was inserted. **Exclusion criteria:** no completed examination for any reason
Index tests	**Index test:** FAST **US protocol:** 4 locations of each hemithorax (anterior second intercostal space at the midclavicular line, fourth intercostal space at the anterior axillary line, sixth intercostal space at the midaxillary line, and sixth intercostal space at the posterior axillary line) **Hardware used:** SonoSite 180PLUS (Bothell, WA) using a 4- to 2-MHz microconvex broadband transducer

Blaivas 2005 *(Continued)*

	Description of imaging technique: US images were obtained parallel to ribs at the rib interspaces. Depth settings were minimised to approximately 5 cm to optimise magnification of the superficial structures being imaged. Power Doppler was used to enhance the sonologist's ability to identify pleural sliding whenever the sliding lung sign was not easily detected. Absence of the sliding lung sign at the midclavicular point anteriorly or at the fourth interspace at the anterior axillary line was considered indicative of a small pneumothorax; absence of the sliding lung sign at the midaxillary line, a medium pneumothorax; and absence of the sliding lung sign in the posterior axillary line, a large pneumothorax.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** multigated CT scanner using 5-mm thick slices and portable, supine anteroposterior chest radiographs (technique specification was not reported) **Description of technique:** all examinations (US, CT, radiography) were performed with the participant in the supine position
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do	No		

Blaivas 2005 *(Continued)*

not match generally accepted, established, or practiced rules or recommendations?			
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MD-CT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Calder 2017

Study characteristics	
Patient sampling	Multicentre prospective study
Patient characteristics and setting	**Study location:** USA **Study period:** July 2014 to July 2015 **Care setting:** 14 paediatric level 1 trauma centre **Mass casualty:** no

Calder 2017 *(Continued)*

	Participants enrolled: 2188: gender not reported **Participants included in analysis:** 340 **Age:** 7.8 ± 4.6 years (2188 participants) **Type of injury:** abdominal trauma **Injury severity:** ISS 5 (IQR 1 to 10) **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** children < 16 years of age were enrolled over a 1-year period. The primary purpose of the data collection was to develop a clinical prediction model to determine which children were at very low risk for intra-abdominal injury following blunt abdominal trauma and could safely avoid abdominal CT as a component of their initial evaluation. **Exclusion criteria:** presentation > 6 hours after injury, abdominal CT imaging prior to arrival at the paediatric trauma centre, isolated head or extremity mechanism of injury, same-level falls, penetrating trauma, burns, and hanging injuries
Index tests	**Index test:** FAST **US protocol:** not reported **Hardware used:** not reported **Description of imaging technique:** not reported
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technique specification was not reported) or intraoperative findings, or both **Description of technique:** not reported
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			

Calder 2017 *(Continued)*

Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Unclear		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Unclear		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Unclear		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	Unclear		
		Unclear	**Unclear**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Unclear		
		Unclear	**Unclear**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Catalano 2009

Study characteristics	
Patient sampling	Multicentre prospective study
Patient characteristics and setting	**Study location:** Italy and the UK **Study period:** not reported **Care setting:** 6 centres (type of trauma centre not reported) **Mass casualty:** no **Participants enrolled:** 156: 118 men and 38 women **Participants included in analysis:** 156 **Age:** mean age 39 ± 17 years (range 15 to 90 years) **Type of injury:** solid organ injury after blunt abdominal trauma **Injury severity:** ISS range 0 to 50 **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** > 14 years of age, clinical and laboratory suspicion of blunt or penetrating abdominal trauma, availability of US, CEUS, and CT study performed within 1 hour, availability of a reference standard (CT or surgery) **Exclusion criteria:** not reported
Index tests	**Index test:** US, CEUS **US protocol:** 4 locations of each hemithorax (anterior second intercostal space at the midclavicular line, fourth intercostal space at the anterior axillary line, sixth intercostal space at the midaxillary line, and sixth intercostal space at the posterior axillary line) **Hardware used:** US with an EsaTune (Esaote, Italy), Technos (Esaote, Italy), or ATL HDI 5000 (Philips, the Netherlands), phased-array transducers (2 to 6 MHz). In selected cases, the operator also employed high-frequency probes (5.5 to 10 MHz), power Doppler imaging mode, and/or tissue harmonic imaging mode to maximise diagnostic effectiveness of unenhanced US. CEUS with a 2.5- or 3.5-MHz transducer and a low acoustic power setting (mechanical index 0.05 to 0.1) - 'second-generation' contrast medium SonoVue (Bracco, Milan, Italy) **Description of imaging technique:** in all cases, a rapid but complete survey of all abdominal parenchymas and abdomino-pelvic spaces was obtained by using conventional grey-scale US imaging. A careful search for peritoneal fluid, retroperitoneal fluid, and organ injury was carried out. CEUS studies were carried out with the harmonic, low mechanical index, contrast-specific softwares contrast tuned imaging (CnTI) and pulse inversion. CEUS was always performed immediately after the baseline US. SonoVue volume (4.8 mL) was fractionated into 2 x 2.4 mL doses, each injected as a quick bolus through an antecubital vein and a 18- to 20-gauge catheter followed by 5 mL to 10 mL normal saline (0.9% NaCl) flush through a 3-way stopcock. Immediately after the first contrast medium injection, the right-sided organs (the right kidney, and possibly adrenal first and the liver subsequently) were explored for 1 to 3 minutes. Thereafter, the second SonoVue dose was administered, focusing on left-side organs (the left kidney, and possibly adrenal first, the pancreas, and finally the spleen) for another 3 to 4 minutes.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT and/or surgery, CT Somatom Plus 4 system (Siemens AG, Germany), Emotion system (Siemens), PQ6000 system (Picker International, USA), LightSpeed Ultra system (GE Healthcare, USA), and Sensation 16-row tomograph (Siemens)

Catalano 2009 *(Continued)*

	Description of technique: no participant received oral contrast medium, and most had a pre-contrast acquisition series. The contrast-enhanced study was carried out using 5- or 8-mm collimation, 5- or 7.5-mm/s table speed, 120 kVp, 5-mm reconstruction interval. A non-ionic contrast medium (a combination of iomeprol 350 mgI/mL, Iomeron, Bracco-iopamidol 300 mgI/mL, Iopamiro, Bracco-iohexol 350 mgI/mL, Omnipaque, produced by Amersham Health) was administered via 18– to 20-gauge angiocatheter and power injector. A volume of 100 mL to 150 mL was injected at 2 mL/s to 4 mL/s. When a 2-phase technique was employed, delay ranged from 40 s to 50 s for the first contrast-enhanced acquisition and from 80 s to 120 s for the second acquisition. Participants undergoing single-phase acquisition were scanned at 60 s to 90 s from contrast injection (2 mL/s). A true positive was defined as the presence of an abdominal lesion based on both US and the truth standard. A true negative was defined as the absence of an abdominal lesion based on both US and the truth standard.
Flow and timing	**Time between US and reference standard:** < 60 minutes
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		

Catalano 2009 *(Continued)*

		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Low	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Cheung 2012

Study characteristics

Cheung 2012 *(Continued)*

Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** Hong Kong, China **Study period:** January 2005 to December 2010 **Care setting:** emergency department (type of trauma centre not reported) **Mass casualty:** no **Participants enrolled:** 302 **Participants included in analysis:** 156: 103 men and 50 women **Age:** mean age 48.6 years (range 3 to 94 years) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** all the blunt abdominal trauma patients identified in the hospital trauma registry and managed by the hospital trauma team in the emergency department **Exclusion criteria:** death at the emergency department after initial resuscitation; known ascites or peritoneal dialysis before the injury; blunt abdominal trauma patients who did not undergo FAST or standard confirmatory test; those with incomplete FAST findings
Index tests	**Index test:** FAST **US protocol:** FAST procedures followed the standard recommendation. Scanning was done on supine participants at 6 sites. **Hardware used:** ALOKASSD-500 (probe model UST-934N-3.5, 3.5-MHz convex sector probe) and GE Medical Logiq P5 Premium Ultrasound Console (probe model 4C 1.8-4.0/D2.9MHz, curvilinear probe) **Description of imaging technique:** during the study period, there was no formal guideline in the hospital on how and when to perform the FAST. However, it was usual practice for FAST to be done by the emergency physicians or surgeons in charge of the trauma team in the emergency department, who had to be certified advanced trauma life support providers. 6 views were evaluated: the 4 quadrants of the abdomen and the suprapubic and subxiphoid region.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** laparotomy, CT (technical specification was not reported), autopsy **Description of technique:** laparotomy started within 4 hours of admission was used as a gold standard confirmatory test for presence of intraperitoneal bleeding in blunt abdominal trauma participants for whom surgical exploration was clinically indicated. If the participant did not require laparotomy, abdominal CT scan was taken as the gold standard when the participant was still treated in the emergency department. Autopsy, in addition to CT scan if available, was used as surrogate standard test for participants who died during hospital stay without laparotomy performed.
Flow and timing	**Time between US and reference standard:** < 4 hours

Cheung 2012 *(Continued)*

Comparative
Notes

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	No		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MD-CT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		

Cheung 2012 *(Continued)*

Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Clevert 2008

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Germany **Study period:** January 2005 to January 2007 **Care setting:** not reported **Mass casualty:** no **Participants enrolled:** 78: 48 men and 30 women **Participants included in analysis:** 78 **Age:** mean age 56 years **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** not reported **Inclusion criteria:** all blunt abdominal trauma patients who were examined by conventional US, CEUS, and MSCT **Exclusion criteria:** not reported
Index tests	**Index test:** US, CEUS, and MSCT **US protocol:** a conventional B-scan followed by colour-coded duplex sonography. The colour gain was set just high enough to avoid overwriting artefacts (i.e. colour pixels outside

Clevert 2008 *(Continued)*

	the perfused lumen of the vessel). Additionally, an automatic image gain optimisation could be selected. **Hardware used:** Siemens ACUSON Sequoia 512 (Siemens Medical Systems, Forchheim, Germany) using a curved array 4-MHz multifrequency transducer **Description of imaging technique:** for CEUS examinations the Sequoia system was equipped with contrast pulse sequence software that detects the microbubbles' fundamental non-linear response. Depending on participant size and the target organ, a bolus intravenous injection of 1.2 mL to 2.4 mL of a second-generation blood pool contrast agent (SonoVue, Bracco, Milan, Italy) consisting of stabilised microbubbles of sulphur hexafluoride was administered into an antecubital vein through an 18-gauge needle and was followed by a flush of 10 mL saline solution (0.9% NaCl). CEUS employed continuous low mechanical index (0.15 to 0.19) real-time tissue harmonic imaging (Cadence) contrast pulse sequence imaging. Sonography and contrast-enhanced sonography findings were considered true positives if CT revealed evidence of the parenchyma injury, and false positives if the injury was not confirmed on subsequent CT. Negative sonography findings were declared as true negatives if CT findings were negative and the participant had an uneventful clinical course; findings were declared as false negatives if CT revealed parenchyma injury. A solid organ injury on sonography was reported if an intraparenchymal hyper- or hypoechoic area or a distortion of the normal echoic structure was seen.
Target condition and reference standard(s)	**Target condition:** organ injuries/vascular lesions **Reference standard:** CECT, Scanner Somaton Sensation 16 or 64, Siemens Medical Systems, Forchheim, Germany **Description of technique:** the entire study population underwent contrast-enhanced CT examinations using a standard arterial and venous phase protocol with a 16- or 64-detector CT scanner. For the Sensation 64, collimation and table feed were 64 × 0.6 mm, rotation time 0.33 s, pitch 0.9, slice thickness 0.75 mm, and reconstruction interval 0.5 mm. Tube voltage was set to 120 kV, and the exposure time × tube current product was 200 mAs using Care Dose 4-D. For the Sensation 16, collimation and table feed were 16 × 0.75 mm, rotation time 0.5 s, pitch 1, slice thickness 0.75 mm, and reconstruction interval 0.6 mm. Tube voltage was set to 100 kV, and the exposure time × tube current product was 220 mAs using Care Dose 4-D. The contrast agent was injected into an antecubital vein as a bolus, using a dual-head power injector with a flow rate of 5 mL/s. 120 mL of Solutrast (Bracco, Milan, Italy) with an iodine concentration of 300 mg/mL was administered, followed by 50 mL saline. The appropriate scan delay for the arterial and venous phase after contrast agent administration was determined by semiautomatic bolus tracking on the thoracic aorta.
Flow and timing	**Time between US and reference standard:** < 60 minutes
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**

Clevert 2008 *(Continued)*

DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it prespecified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Unclear		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	Unclear		
		Low	**Unclear**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			

Clevert 2008 *(Continued)*

Was there an appropriate interval between index test and reference standard?	Yes	
Did all patients receive the same reference standard?	Yes	
Were all patients included in the analysis?	Yes	
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes	
		Low

Coley 2000

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** USA **Study period:** July 1997 to August 1998 **Care setting:** level I paediatric trauma centre **Mass casualty:** no **Participants enrolled:** 107: 68 boys and 38 girls **Participants included in analysis:** 97 **Age:** mean age 95 months ± 51 months (range 2 to 216 months) **Type of injury:** blunt abdominal trauma **Injury severity:** GCS 12.5 ± 4.2, PTS 8.0 ± 2.8 **Haemodynamic stability:** stable conditions **Inclusion criteria:** all children suffering blunt abdominal trauma who required a CT scan for evaluation of potential injury based on the surgical team leader's clinical judgement **Exclusion criteria:** haemodynamically unstable, and required immediate operative intervention
Index tests	**Index test:** FAST **US protocol:** immediately before CT scan, the in-house on-call paediatric radiologist performed the FAST scan and rendered a decision regarding the absence or presence and location of any free fluid. If participants had a Foley catheter placed, this was clamped as soon as possible to allow the bladder to fill, facilitating detection of free fluid in the pelvis. **Hardware used:** Acuson 1283 P10 system (Mountain View, CA) by using 2- to 5-MHz transducers, depending on participant body habitus

Coley 2000 *(Continued)*

	Description of imaging technique: 4 specified locations were evaluated: the right upper quadrant, left upper quadrant, subxyphoid region, and pelvis
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CECT, third-generation spiral scanner (High Speed Advantage, General Electric, Milwaukee, WI) with IV but without oral contrast (more technical specifications were not reported) **Description of technique:** CT scans were evaluated for the absence or presence of fluid, its location, and the presence of any visceral injury
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		

Coley 2000 *(Continued)*

Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Corbett 2000

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** California, USA **Study period:** June 1995 to February 1996 **Care setting:** level I paediatric trauma centre **Mass casualty:** no **Participants enrolled:** 81: gender specification not reported **Participants included in analysis:** 47 **Age:** mean age 9 years (range 2 to 7 years) **Type of injury:** abdominal and pelvic trauma **Injury severity:** ISS 9.0 (IQR 2.5 to 13) **Haemodynamic stability:** not reported

Corbett 2000 *(Continued)*

	Inclusion criteria: all children for whom paediatric trauma service consultation was requested and for whom a designated ultrasonographer was available were included. Trauma service consultation was requested on those with moderate to severe injuries judged by the emergency physician to require additional evaluation. **Exclusion criteria:** conversely, patients ≥ 18 years, those receiving minor trauma that was not felt to require trauma service evaluation, and those for whom a designated ultrasonographer was not available
Index tests	**Index test:** US **US protocol:** consecutive children requiring further emergency department evaluation by the paediatric trauma service received a rapid emergency department US examination during their initial resuscitation. US examinations were performed by 17 different emergency medicine residents and attending physicians. **Hardware used:** Scanner 200 (Pie Medical, Boca Raton, FL) using a 3.5 or 5.0 curvilinear probe **Description of imaging technique:** 7 views were examined: subxiphoid, right upper quadrant oblique and coronal, left upper quadrant oblique and coronal, pelvic transverse and pelvic longitudinal
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technique specification not reported), laparotomy **Description of technique:** the decision to take a participant for laparotomy or to the CT scanner was made by the trauma team captain based on the usual clinical, laboratory, and radiographic (but not US) findings. CT scans were considered positive if the presence of free fluid was recorded in the radiologists' interpretation. Laparotomies were considered positive if free fluid was noted in the operative note. Other surgical or diagnostic procedures capable of showing the presence of free fluid were also reviewed.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**High**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		

Corbett 2000 *(Continued)*

If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	No		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	No		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MD-CT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Dolich 2001

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** USA **Study period:** 30-month period ending July 1997 **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 2576: 1880 men and 696 women **Participants included in analysis:** 616 **Age:** mean age 38 years (range 1 to 94 years) **Type of injury:** blunt abdominal trauma **Injury severity:** GCS ≤ 12 **Haemodynamic stability:** stable and unstable condition **Inclusion criteria:** all patients had abdominal US in the evaluation of blunt abdominal trauma and were entered into a trauma US database. This database was analysed to determine the utility of US in the evaluation of blunt abdominal trauma. **Exclusion criteria:** not reported
Index tests	**Index test:** US **US protocol:** real-time US images were interpreted by an attending radiologist or senior radiology resident in conjunction with the trauma surgery attending or fellow, or both. The evidence of free intraperitoneal fluid or parenchymal injury was considered a positive result. US was considered negative if the above were absent on a technically satisfactory examination. US examinations were deemed to be indeterminate if they revealed questionable free fluid or solid organ injury, or were technically limited. **Hardware used:** Accuson 128X P/10 (Mountain View, CA) with a 3.5-MHz sector transducer **Description of imaging technique:** with the participant in the supine position, views of the pericardium, bilateral subphrenic spaces, Morison's pouch, perisplenic region, and pelvis were examined for the presence of free intraperitoneal fluid or solid organ injury
Target condition and reference standard(s)	**Target condition:** free fluid, solid organ injury **Reference standard:** CT (technical specifications not reported), exploratory laparotomy (DPL, observation) **Description of technique:** in general, unstable participants with a positive US were taken to the operating room for exploratory laparotomy. Participants with a positive US who remained haemodynamically stable during the initial assessment in the resuscitation area underwent abdominal CT scan to evaluate further the extent and nature of intra-abdominal injury. For statistical analysis, a true-positive result was defined as a positive US with confirmation of injury by CT scan, DPL, or exploratory laparotomy. A negative US with confirmation by observation, CT scan, DPL, or laparotomy was deemed a true negative. A false-positive result was defined as a pos-

Dolich 2001 *(Continued)*

	itive US with subsequent absence of intra-abdominal injury by CT scan, DPL, or laparotomy. A false-negative result was defined as a negative US in a participant with intra-abdominal injury, as documented by CT scan, DPL, or exploratory laparotomy.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	No		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Unclear		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		

Dolich 2001 *(Continued)*

Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MD-CT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Emery 2001

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** California, USA **Study period:** 1 February 1997 to 30 June 1998 **Care setting:** level I paediatric trauma centre **Mass casualty:** no **Participants enrolled:** 491 **Participants included in analysis:** 160: 95 boys and 65 girls **Age:** mean age 9 years 5 months (range 1 month to 18 years) **Type of injury:** blunt abdominal trauma **Injury severity:** ISS 5 (IQR 1 to 13) **Haemodynamic stability:** stable conditions

Emery 2001 *(Continued)*

	Inclusion criteria: all haemodynamically stable paediatric trauma victims referred for abdominal CT initially underwent rapid screening sonography looking for free fluid **Exclusion criteria:** not reported
Index tests	**Index test:** FAST **US protocol:** scans were usually done immediately before the CT scan (< 15 minutes) **Hardware used:** Acuson unit (Mountain View, CA), 3- to 5-MHz sector or curved transducer **Description of imaging technique:** locations: each of the 4 abdominal quadrants and the pelvis (2 longitudinal and transverse images in each of the upper quadrants and 1 longitudinal and transverse image in each of the lower quadrants and midline pelvis). No specific epigastric or pericardial view was obtained. The study was focused to identify free fluid. The amount of fluid (none, trace, small, moderate, or large), location(s), and the degree of bladder filling (empty, partially filled, or full) were recorded.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** GE HiSpeed Advantage helical CECT (General Electric Medical Systems, Milwaukee, WI) using non-ionic IV contrast (Optiray 320 (Mallinckrodt, St Louis, MO)) **Description of technique:** all CT scans included the abdomen and pelvis using a CT and non-ionic IV contrast in a standard dose of 2 mL/kg administered in bolus fashion. Slice collimation was either 7 mm or 10 mm depending on the participant's size with a pitch of 1.3:1.
Flow and timing	**Time between US and reference standard:** < 15 minutes
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		

Emery 2001 *(Continued)*

Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Fox 2011

Study characteristics	
Patient sampling	Prospective study

Fox 2011 *(Continued)*

Patient characteristics and setting	**Study location:** California, USA **Study period:** 2004 to 2007 **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 475 **Participants included in analysis:** 357: 230 men and 127 women **Age:** range 0 to 17 years (more graduation in study) **Type of injury:** blunt abdominal trauma **Injury severity:** IQR ISS 4 to 12 **Haemodynamic stability:** not reported **Inclusion criteria:** patients with blunt trauma as falls, motor vehicle crashes, automobile versus pedestrian collisions, non-accidental blunt trauma, and battery **Exclusion criteria:** no consent to study inclusion, no confirmation of FAST results by CT, penetrating injuries, accidental blunt trauma
Index tests	**Index test:** FAST **US protocol:** the FAST exams were performed by emergency medicine residents (62% of total, 51% of total by third-year emergency medicine residents), attending emergency physicians (21%), and US fellows and surgeons (8% each) **Hardware used:** B+K Hawk 2102 (Copenhagen, Denmark), SonoSite Titan, or SonoSite Micromaxx (Bothell, WA) US machine with 3.5- to 5.0-MHz curved array (Hawk), 2- to 4-MHz convex array (Titan), or 2- to 4-MHz phased array transducers **Description of imaging technique:** locations evaluated for free fluid: around the heart and 3 areas of the abdominal–pelvic cavity (hepatorenal, splenorenal, suprapubic)
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CECT (technique specifications not reported) or laparotomy **Description of technique:** by protocol, all eligible participants had FAST at arrival followed by CT of the abdomen and pelvis within 30 minutes, or underwent laparotomy. All participants had CT with IV contrast; oral contrast was routinely used for the first 18 months of the study, but not thereafter.
Flow and timing	**Time between US and reference standard:** < 30 minutes
Comparative	
Notes	
Methodological quality	

Fox 2011 *(Continued)*

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Low	**High**
DOMAIN 4: Flow and Timing			

Fox 2011 *(Continued)*

Was there an appropriate interval between index test and reference standard?	Yes
Did all patients receive the same reference standard?	No
Were all patients included in the analysis?	Yes
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes
	Low

Friese 2007

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** Texas, USA **Study period:** November 2003 to February 2005 **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 126 **Participants included in analysis:** 96: 47 men and 49 women **Age:** mean age 42.3 ± 22.5 years **Type of injury:** pelvic trauma **Injury severity:** not reported **Haemodynamic stability:** increased risk for haemorrhage **Inclusion criteria:** "the trauma registry was queried for all patients admitted to the trauma service through our emergency department during the study period with the diagnosis of pelvic fracture and the presence of at least one of the following risk factors for haemorrhage: age 55 years, the presence of haemorrhagic shock (systolic blood pressure 100 mm Hg), or an unstable fracture pattern. Additional inclusion criteria were the use of the FAST examination to evaluate the peritoneal space for the presence of haemoperitoneum on arrival to the emergency department and a confirmation of the presence or absence of haemoperitoneum by laparotomy or abdominopelvic computed tomography (CT) scan." **Exclusion criteria:** "DPL performed before confirmatory evaluation and treatment at an outside facility before arrival at our emergency department."
Index tests	**Index test:** FAST **US protocol:** all FAST examinations were performed by surgery residents (postgraduate year 3 or higher) who were required to complete the American College of Surgeons course on the use of ultrasound in the acute setting. The trauma bay protocol specifies that all FAST examinations were performed as an adjunct to the primary trauma survey, which meant that the FAST examination was completed within 5 to 10 minutes of participant arrival in the emergency department. A true-positive FAST examination was de-

Friese 2007 *(Continued)*

	fined as free intraperitoneal fluid detected on US and haemoperitoneum confirmed at laparotomy or abdominopelvic CT scan. A true-negative FAST examination was defined as no free fluid noted on abdominal US and the absence of haemoperitoneum noted at laparotomy or abdominopelvic CT scan. A false-positive FAST examination was defined as free intraperitoneal fluid detected on US and the absence of haemoperitoneum on laparotomy or abdominopelvic CT scan. A false-negative FAST examination was defined as no free intraperitoneal fluid detected on abdominal US and haemoperitoneum found at laparotomy or abdominopelvic CT scan. **Hardware used:** portable 2102 HAWK ultrasound unit (B&K Medical, Willmington, MA) with a low-frequency (3.5-MHz) transducer and a curvilinear array **Description of imaging technique:** standard 4-view FAST examination
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technical specifications not reported), laparotomy **Description of technique:** all operative and abdominopelvic CT scan reports were also reviewed for documentation of the presence of haemoperitoneum. CT scan and operative findings were based on the final dictated and transcribed reports placed in the permanent medical record from the attending radiologist and attending surgeon. Special information about the technique of the reference standard was not reported.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**High**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		

Friese 2007 *(Continued)*

Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Ghafouri 2016

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Iran **Study period:** February 2011 to January 2012 **Care setting:** university hospital **Mass casualty:** no **Participants enrolled:** 102: gender ratio male:female = 3:1 **Participants included in analysis:** 102 **Age:** mean age 33 ± 16.6 years **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** all patients with abdominal blunt trauma evaluated for abdominal fluid **Exclusion criteria:** not reported
Index tests	**Index test:** FAST **US protocol:** all US evaluations were performed using the FAST technique during the primary survey of ATLS guidelines **Hardware used:** SonoSite180, handheld system, curvilinear probe (2 to 4 MHz) **Description of imaging technique:** positive findings included the presence of abdominal fluid in any of the abdomino-pelvic spaces
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CECT (technique specification not reported), laparotomy **Description of technique:** abdominal CT with IV and oral contrast as the gold standard for all participants. Since some participants had been transferred directly to the operating room and underwent laparotomies without undergoing abdominal CT scans, a combination of laparotomy (if performed) and abdominal CT scan were used as gold standards.
Flow and timing	**Time between US and reference standard:** < 4 hours
Comparative	
Notes	
Methodological quality	

Ghafouri 2016 *(Continued)*

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		

Ghafouri 2016 *(Continued)*

Did all patients receive the same reference standard?	No
Were all patients included in the analysis?	Yes
Did all participants receive a reference standard? (Risk of partial verification bias)	Unclear
	Unclear

Hsu 2007

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Australia **Study period:** September 1999 to December 2004 **Care setting:** emergency department of teaching hospital **Mass casualty:** no **Participants enrolled:** 463 **Participants included in analysis:** 357: 71% men and 29% women **Age:** mean age 37 ± 23 years **Type of injury:** blunt truncal trauma **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** any trauma patient who came through the emergency department underwent a FAST study if the appropriate personnel were available **Exclusion criteria:** those who did not have US results confirmed by either CT or laparotomy
Index tests	**Index test:** FAST **US protocol:** all participants were examined with US in areas mentioned below. No attempt was made to delineate solid organ injury. **Hardware used:** B-K Medical Panther (Scan Medics, Chatswood NSW Australia, distributor for B-K Medical, Herlev Denmark) US system with a 3.5- to 5.0-MHz curvilinear transducer **Description of imaging technique:** the standard 4 areas were examined for the presence of free intraperitoneal fluid, namely: Morison's pouch, the splenorenal recess, the pelvis, and the pericardial area
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technical specification not reported), laparotomy

Hsu 2007 *(Continued)*

	Description of technique: all included studies with the radiologist's formal CT scan report, or the surgeon's operative notes. There was no quantitative measurement of free fluid seen on CT scans at the study institution.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	No		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		

Hsu 2007 *(Continued)*

Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Iqbal 2014

Study characteristics	
Patient sampling	Cross-sectional validation study
Patient characteristics and setting	**Study location:** Islamabad, Pakistan **Study period:** January 2010 to December 2011 **Care setting:** emergency department of a teaching hospital **Mass casualty:** no **Participants enrolled:** 100: 88% men and 12% women **Participants included in analysis:** 100 **Age:** mean age of 31.52 ± 16.79 years (range 2 to 71 years) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** patients with a history of or mechanism of injury suggestive of blunt abdominal injury, any subjective complaints of abdominal or flank pain, presence of abdominal tenderness to palpation, presence of abdominal distension, external signs of injury such as abdominal wall bruising ('seat-belt sign'), or elicitation of any peritoneal signs **Exclusion criteria:** patients with penetrating abdominal injuries
Index tests	**Index test:** FAST **US protocol:** FAST was performed as part of the primary or secondary survey of the participant in the emergency department. Using a portable US machine, the

Iqbal 2014 *(Continued)*

	scans were performed and interpreted by a radiologist within 1 hour of the participant arriving at the hospital. All participants in the study underwent a FAST scan. **Hardware used:** live 2-D mode (rapid B-mode) and transducer frequencies between 3 and 6 MHz (no technique specification reported) **Description of imaging technique:** bedside US is an integral component of trauma management that is primarily used to detect free intraperitoneal fluid after blunt trauma. The trauma US examination focuses on dependent intraperitoneal sites where blood is most likely to accumulate: the hepatorenal space (i.e. Morison's pouch), the splenorenal recess, and the inferior portion of the intraperitoneal cavity (including pouch of Douglas).
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technique specification not reported), laparotomy (DPL) **Description of technique:** all participants underwent either CT or ELAP depending on their clinical condition. FAST examination results, which were recorded as positive or negative and were compared with the findings on CT or exploratory laparotomy, which were considered definitive. CT was recommended for the evaluation of haemodynamically stable participants. Haemodynamically unstable participants were evaluated further for other causes of haemorrhage by DPL and, if indications were fulfilled, underwent a laparotomy.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		

Iqbal 2014 *(Continued)*

Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Kendall 2009

Study characteristics	
Patient sampling	Prospective cohort study

Kendall 2009 *(Continued)*

Patient characteristics and setting	**Study location:** USA **Study period:** July 1998 to June 1999 **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 164 **Participants included in analysis:** 152: 95 men and 57 women **Age:** mean age 34 (range 6 to 91 years) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** not reported **Inclusion criteria:** a convenience sample of patients who presented to the emergency department following blunt abdominal trauma and who subsequently received CT scans of the chest or abdomen during their evaluations **Exclusion criteria:** transferred from another facility with known solid organ injury; if the CT was interrupted or not completed; if performing the secondary US would delay necessary patient care; or if the trauma was not a blunt mechanism
Index tests	**Index test:** FAST **US protocol:** US examinations were performed by emergency medicine residents or attending physicians experienced in the use of US for detecting haemoperitoneum. Ultrasonographers determined the presence or absence of liver or spleen injury prospectively. The specific purpose of the secondary US was to evaluate the liver and splenic parenchyma for solid organ injury. The secondary US consisted of long- and short-axis scans through both organs. **Hardware used:** Toshiba SSH-140A (Toshiba, San Francisco, CA) with a 3.75-MHz phased array transducer **Description of imaging technique:** a 4-view US examination to detect haemoperitoneum or pericardial effusion
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technique specification not reported) **Description of technique:** the criterion diagnostic standard was made using CT. All CT interpretations were performed by attending radiologists who were blinded to the results of the secondary US examination.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	
Methodological quality	

Kendall 2009 *(Continued)*

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	No		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			

Kendall 2009 *(Continued)*

Was there an appropriate interval between index test and reference standard?	Yes
Did all patients receive the same reference standard?	Yes
Were all patients included in the analysis?	Yes
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes
	Low

Kumar 2015

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** New Delhi, India **Study period:** April 2004 to May 2006 **Care setting:** hospital emergency department **Mass casualty:** no **Participants enrolled:** 50: 42 men and 8 women **Participants included in analysis:** 50 **Age:** mean age 28.62 years (range 3 to 65 years) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** 50 consecutive patients with history of blunt abdominal trauma presenting in the emergency department **Exclusion criteria:** those who presented with unrecordable blood pressure or in shock, with an indication for an immediate laparotomy
Index tests	**Index test:** FAST **US protocol:** a FAST examination was done during initial resuscitation in the emergency department. Haemodynamically stable participants with a positive FAST for free fluid underwent an abdominal CT scan with IV and oral contrast. Participants who were haemodynamically unstable and not responding to resuscitation, or if there was any other indication for laparotomy, underwent immediate surgery without any further investigation. FAST was performed by the resident radiologist in the emergency department before CECT, laparotomy, or autopsy. **Hardware used:** Sonoline Versa Pro, Siemens, Germany, curvilinear/sector probe of 3.5 MHz

Kumar 2015 *(Continued)*

	Description of imaging technique: FAST is a limited US examination that is aimed primarily at the identification of the presence of free intraperitoneal or pericardial fluid.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CECT (technique specification not reported), laparotomy, autopsy **Description of technique:** for participants in whom non-operative management was decided, a CECT scan of the abdomen and pelvis including lower chest was performed to confirm the findings of FAST. No further details of the CECT technique were reported. The CECT scan was done in haemodynamically stable participants or those who responded to resuscitation and for whom a non-operative management was planned with no immediate indication for laparotomy.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**

Kumar 2015 *(Continued)*

DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Kärk 2012

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** Denmark **Study period:** January 2003 to December 2010 **Care setting:** hospital emergency department **Mass casualty:** no **Participants enrolled:** 405: gender specification not reported **Participants included in analysis:** 118 **Age:** not reported for 118 participants

Kärk 2012 *(Continued)*

	Type of injury: blunt abdominal trauma, liver injury **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** this study included all patients admitted to the institution registered with the ICD-10 code S36.1 'Injury of the liver or gallbladder' as defined by the WHO, especially abdominal blunt trauma patients **Exclusion criteria:** patients with iatrogenic lesions of the biliary system
Index tests	**Index test:** FAST **US protocol:** the majority of participants were examined by radiologists trained in general abdominal US, and a minority by surgeons trained in FAST **Hardware used:** not reported **Description of imaging technique:** recorded findings of intraperitoneal free fluid (if possible in 4 different areas: Morison's pouch in the right upper quadrant, the perisplenic space in the left upper quadrant, the pericardium of the epigastric region, and the pelvis)
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technique specification not reported), explorative laparotomy **Description of technique:** not reported
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**High**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		

Kärk 2012 *(Continued)*

Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Unclear		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

McElveen 1997

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Virginia, USA

McElveen 1997 *(Continued)*

	Study period: not reported **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 82 **Participants included in analysis:** 70 **Age:** mean age 38 (range 1 to 82 years) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** not reported **Inclusion criteria:** 82 consecutive patients with a diagnosis of blunt abdominal trauma presenting to the trauma resuscitation room when either of the 2 authors was present **Exclusion criteria:** not reported
Index tests	**Index test:** FAST **US protocol:** US was performed concurrently with inital resuscitation and prior to other studies **Hardware used:** 3.0-MHz sector probe, Johnson & Johnson Ultrasound 280SL **Description of imaging technique:** the examination consisted of an evaluation of the pericardial area, right upper quadrant, left upper quadrant, and pouch of Douglas. In addition, the liver and spleen were evaluated for parenchymal injury. The examination was considered to be positive if there was any free intraperitoneal fluid present or visceral injury was identified. The examination was considered to be negative if no intraperitoneal fluid or visceral injury was seen.
Target condition and reference standard(s)	**Target condition:** free fluid and air, organ injury **Reference standard:** CT (technique specification not reported), laparotomy (DPL) **Description of technique:** criteria for positive CT findings were visceral injury or fluid in the peritoneal cavity. More technical specifications of CT were not reported.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			

McElveen 1997 *(Continued)*

Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	No		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		

McElveen 1997 *(Continued)*

Did all participants receive a reference standard? (Risk of partial verification bias)	No
	High

McKenney 1994

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** USA **Study period:** October 1992 to June 1993 **Care setting:** level 1 trauma centre **Mass casualty:** no **Participants enrolled:** 200: 142 men and 58 women **Participants included in analysis:** 145 **Age:** mean age 37 (range 11 to 92 years) **Type of injury:** blunt abdominal trauma **Injury severity:** GCS ≤ 12 **Haemodynamic stability:** stable conditions **Inclusion criteria:** patients with blunt abdominal trauma and trauma criteria (systolic blood pressure < 90 mmHg) - see Table 1 in study **Exclusion criteria:** none
Index tests	**Index test:** FAST **US protocol:** emergency US performed in the resuscitation room at the discretion of the attending surgeon. The US study was performed by a radiology fellow, an attending physician, or a technologist. **Hardware used:** Accuson 128X P/10 (Mountain View, CA), Toshiba 140A (Norcross, GA), or an ATL Mark (Seattle, WA) with a 3.5-MHz sector or curvilinear transducer **Description of imaging technique:** the US examination consisted of evaluation of the subphrenic space, subhepatic space (Morison's pouch), paracolic gutters, and the pelvis for evidence of free intraperitoneal fluid. The liver and spleen were evaluated for parenchymal injury.
Target condition and reference standard(s)	**Target condition:** free fluid and air, organ injury **Reference standard:** CT (technique specification not reported), DPL, laparotomy

McKenney 1994 *(Continued)*

	Description of technique: criteria for positive CT findings were visceral injury or significant fluid in the peritoneal cavity. All studies were interpreted by a radiologist either from real-time images or from hard copies.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	No		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		

McKenney 1994 *(Continued)*

Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Menichini 2015

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** Rome, Italy **Study period:** October 2012 to October 2013 **Care setting:** department of emergency radiology **Mass casualty:** no **Participants enrolled:** 73: 51 boys and 22 girls **Participants included in analysis:** 73 **Age:** mean age 8.7 ± 2.8 years (range not reported) **Type of injury:** low-energy blunt abdominal trauma (minor trauma) **Injury severity:** not reported **Haemodynamic stability:** stable conditions **Inclusion criteria:** male or female, aged 0 to 16 years, haemodynamically stable children with a history of minor blunt abdominal trauma **Exclusion criteria:** > 16 years of age, haemodynamical instability, history of major trauma
Index tests	**Index test:** FAST, CEUS **US protocol:** 73 participants with a history of minor trauma, haemodynamic stability, and at least 1 positive finding at baseline US such as abdominal free fluid, perirenal fluid collection, signs of hepatic, splenic, or renal injury were subjected to both CEUS and CE-MDCT. CEUS was performed immediately after baseline US.

Menichini 2015 *(Continued)*

	Hardware used: Acuson Sequoia 512 Ultrasound System (Siemens, Germany), equipped with both curved- and linear-array probes **Description of imaging technique:** the study was conducted to detect the presence of free intraperitoneal fluid in the perihepatic area, Morison pouch, epigastric region, perisplenic region, paracolic gutters, and Douglas pouch, and the presence of perirenal fluid collection. Intra-abdominal organs were evaluated specifically for evidence of injury. Adequate US technology consisting of contrast-specific software that operates in real time at a low mechanical index (pulse inversion technology) was applied. 2 x 1.2 mL boluses of second-generation blood pool contrast agent (SonoVue, Bracco, Italy) were administered through a 20-gauge catheter in the antecubital vein, followed by saline (0.9%). An abdominal scan of 3 minutes folllowed each bolus, starting with the right and left kidney, liver and pancreas, and finally the spleen. A traumatic lesion was identified as the presence of a hypoechoic area that persisted unchanged during all the acquisition phases, with a subcapsular distribution in the case of haematoma, or a parenchymal localisation in the case of lacerations. The presence of intralesional hyperechoic spots was interpreted as a sign of active bleeding.
Target condition and reference standard(s)	**Target condition:** free fluid and air, organ injury **Reference standard:** CE-MDCT, MDCT 16 scanner (LightSpeed 16, GE Healthcare, USA) **Description of technique:** the scanning parameters were as follows: 100 to 250 mAs (applied with the care-dose technique and with a medium value of 115 mAs), 100 to 120 kV (according to physical build), 2.5-mm collimation, 13.5 mm/s table, and 1-mm reconstruction interval. A dose of 2.5 mL/kg of non-ionic contrast agent (Xenetix 350, Guerbet, France) was injected at a rate of 1.5 mL/s to 2 mL/s. Arterial phase is performed with an acquisition delay of 40 s; a venous phase is routinely performed with 70-second delay; late phase (5 minutes) was performed only in case of suspected urinary tract lesion. The presence of a parenchymal bleeding was defined as the presence of hyperechoic/hyperdense postcontrast intralesional spots.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**High**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		

Menichini 2015 *(Continued)*

If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Low	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		

Menichini 2015 *(Continued)*

Did all participants receive a reference standard? (Risk of partial verification bias)	No
	High

Nandipati 2011

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Queens, USA **Study period:** June 2007 to May 2008 **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 204: 152 men and 52 women **Participants included in analysis:** 159 **Age:** mean age 43.01 ± 19.5 years (range not reported) **Type of injury:** polytrauma, blunt and penetrating trauma **Injury severity:** ISS 12.5 ± 5.3 **Haemodynamic stability:** not reported **Inclusion criteria:** patients with polytrauma, blunt and penetrating trauma to the chest or thoraco-abdominal area **Exclusion criteria:** patients who had chest tube placement without sonogram or CXR, or penetrating abdominal and extremity injuries
Index tests	**Index test:** EFAST **US protocol:** EFAST was performed in all participants having a FAST examination as a part of their secondary survey. Chest radiography and CT scan were performed after the initial primary and secondary survey. Senior resident (level V) or attending on the trauma team familiar with the principles of the FAST examination who had attended a formal US course performed the EFAST examination. **Hardware used:** 7.5-MHz linear probe, no further technique specifications reported **Description of imaging technique:** participants were kept in a supine position, and the anterior thorax was examined with the probe placed in the second intercostal space in the midclavicular line. Bilateral ultrasonographic images were obtained and compared. Pneumothorax was considered when the absence of both lung-sliding and comet-tail artefacts was noted.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technique specification not reported), CXR

Nandipati 2011 *(Continued)*

	Description of technique: not reported		
Flow and timing	**Time between US and reference standard:** not reported		
Comparative			
Notes			
Methodological quality			
Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, au-	No		

Nandipati 2011 *(Continued)*

topsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?			
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Ojaghi 2014

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Iran **Study period:** winter of 2013 **Care setting:** emergency department of a hospital **Mass casualty:** no **Participants enrolled:** 163 **Participants included in analysis:** 150: 124 men and 26 women **Age:** not reported **Type of injury:** multiple trauma, chest trauma **Injury severity:** ESI1 and ESI2 **Haemodynamic stability:** not reported **Inclusion criteria:** patients with severe multiple trauma based on the mechanism of injury, or their history and examination findings of suspected chest injuries, and chest CT scan according to an ATLS algorithm. The mechanisms of injury included: car rollover, being thrown out of the vehicle, frontal impact, compression of the chest with the steering wheel or dashboard, severe side impact, fall, or acceleration/deceleration injury. **Exclusion criteria:** those who underwent a tube thoracostomy before US due to their unstable clinical situation or for any other reason, such as a lack of access to US at the time of admission
Index tests	**Index test:** FAST

Ojaghi 2014 *(Continued)*

	US protocol: participants were evaluated according to the ATLS algorithm, and examination findings were recorded following initial evaluations, an emergency medicine specialist performed chest US to detect pneumothorax and haemothorax. **Hardware used:** General Electric E200 US with 2 types of probes, namely: a curve probe of 5-MHz frequency for haemothorax assessment and a linear probe of 6.5- to 9-MHz frequency for pneumothorax assessment **Description of imaging technique:** US images of the lung are built with air artefacts as the air stops the beam, however this artefact varies when it is in the pleural space. In a normal lung view, pleural movement along the parietal and visceral sides is called lung sliding, which can easily be seen with US. This characteristic is also known as the gliding sign. Moreover, sharp resonance appears during ventilation at the border of the pleura and lung, known as a comet-tail artefact. Trapped air in the pleural space prevents visualisation of lung sliding signs and comet-tail artefacts, therefore, based on these findings, pneumothorax can be detected with US. US permits the detection of amounts of loculated pleural fluid as small as 20 mL, which cannot be identified by X-rays, which are only capable of detecting volumes > 50 mL.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technique specification not reported), CXR **Description of technique:** assigned radiologists reported both CT scan and portable CXR results, while a specialist performed US. These 2 groups of examiners were unaware of each other's results. No further specifications of technique were reported.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	No		
		High	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		

Ojaghi 2014 *(Continued)*

Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Smith 2010

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Africa **Study period:** January to December 2008 **Care setting:** hospital emergency department **Mass casualty:** no **Participants enrolled:** 91 (gender not reported) **Participants included in analysis:** 52 **Age:** not reported **Type of injury:** thoracal or abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** all patients presenting to the emergency department who had sustained abdominal or thoracic trauma **Exclusion criteria:** not reported
Index tests	**Index test:** FAST **US protocol:** FAST scan findings were subsequently supported by either CT scanning or laparotomy. Where this was not indicated, findings were verified by a second qualified emergency department ultrasonographer repeating the FAST scan. All cases were documented with indication for scan, result, and final method of confirmation with any discrepancies in findings. Scans were recorded as positive or negative for free intra-abdominal or pericardial fluid. **Hardware used:** Aloka SSD 500 B-scan US machine (Aloka, Japan) with a 3.5-MHz abdominal probe **Description of imaging technique:** scans were performed on the supine participant. Right upper quadrant, left upper quadrant, pericardial and pelvic views were obtained according to FAST scanning principles.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (technique specification not reported), laparotomy, second US examination **Description of technique:** scans were confirmed by CT in 31 cases (43.1%) and laparotomy in 17 cases (23.6%). The remaining 24 cases (33.3%) were rescanned by a second qualified ultrasonographer and observed clinically.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Smith 2010 *(Continued)*

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			

Smith 2010 *(Continued)*

Was there an appropriate interval between index test and reference standard?	Yes	
Did all patients receive the same reference standard?	No	
Were all patients included in the analysis?	Yes	
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes	
		Low

Soudack 2004

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** Israel **Study period:** May 1998 to January 2000 **Care setting:** hospital emergency department **Mass casualty:** no **Participants enrolled:** 313: 204 boys and 109 girls **Participants included in analysis:** 109 **Age:** mean age 7.1 years (range 0 to 17 years) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** all children included in the analysis were listed consecutively in the trialists' database. Data pertaining to the mechanism of injury, clinical findings, diagnostic imaging, and management were analysed. **Exclusion criteria:** not reported
Index tests	**Index test:** FAST **US protocol:** during daytime working hours, FAST examination was performed by a staff radiologist trained in sonography; at other times, it was performed by a radiology resident who had received at least 6 months' theoretical and clinical training in sonography in emergency settings **Hardware used:** Tosbee scanner (Toshiba, Tokyo, Japan) equipped with a convex phased–array transducer with a frequency of 3.5 MHz or 7 MHz, depending on size of participant **Description of imaging technique:** sonographic examination consisted of evaluation of 4 anatomic areas for the presence or absence of free fluid: the midline infrasternal or second left intercostal space (to detect haemopericardium), Morison's pouch or the hepatorenal space, the splenorenal space, and the pelvis. Visualisation of the retrovesical space required distension of the bladder before the FAST exami-

Soudack 2004 *(Continued)*

	nation. When the bladder was empty, retrograde filling with saline was done using a Foley catheter. A positive FAST result was defined as a study with evidence of free peritoneal fluid plus a report of parenchymal injury or retroperitoneal fluid.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CECT, using a Helical Twin Flash scanner (Elscint, Haifa, Israel) until 1999 and a multislice Mx8000 scanner (Marconi, Cleveland, OH) thereafter, ELAP **Description of technique:** CT examination performed when, despite a negative FAST result, clinical signs of abdominal injury, such as abrasions of the torso skin, distension of the abdomen, signs of peritoneal injury, or haematuria were present. CT examination of the abdomen performed if requested by the trauma surgeon. Participants who had CT examination of the chest were more likely to undergo abdominal CT examination, depending on the discretion of the trauma surgeon. A contrast medium was administered orally or through a nasogastric tube. An IV non-ionic iodinised contrast medium (2 mL/kg) was administered. The CT scanning protocol consisted of a 5.5-mm slice thickness at a 5-mm interval, a voltage of 120 kV, and a current of 200 mA. The CT examinations were interpreted by the radiology resident and the senior radiologist on call.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		

Soudack 2004 *(Continued)*

Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Low	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Talari 2015

Study characteristics	
Patient sampling	Cross-sectional study
Patient characteristics and setting	**Study location:** Iran

Talari 2015 *(Continued)*

	Study period: not reported **Care setting:** hospital emergency department **Mass casualty:** no **Participants enrolled:** 200: 133 men and 67 women **Participants included in analysis:** 200 **Age:** mean age 29.6 ± 18.3 years (range not reported) **Type of injury:** blunt abdominal trauma **Injury severity:** GCS 12.9 ± 3.4 **Haemodynamic stability:** stable conditions **Inclusion criteria:** haemodynamically stable patients with severe blunt trauma referred to the emergency department of Shahid Beheshti hospital in Kashan, Iran. Severe trauma was assumed if the mechanism of trauma was high energy (falls more than 3 m, motor vehicle accident with a speed more than 50 km/h, crush injuries, rollover, and pedestrian accidents), or if severe injuries such as vertebral or pelvic fractures were detected. **Exclusion criteria:** haemodynamically unstable patients (systolic blood pressure < 90 mmHg), penetrating trauma, pregnant women, and those with underlying diseases associated with intra-abdominal fluid (cirrhosis, congestive heart failure)
Index tests	**Index test:** FAST **US protocol:** evaluation by FAST in the supine position **Hardware used:** Medison ultrasound (V20) curvilinear 3.5- to 5-microhertz transducer **Description of imaging technique:** the Huang classification was used for measurement of the intra-abdominal fluid. 1 point was given for each intra-abdominal region (Douglas pouch, hepatorenal recess, perisplenic and paracolic gutters) if free intra-abdominal fluid was present; 2 points were given if > 2 mL free fluid was seen in the hepatorenal recess and Douglas pouch, or floating bowel loops were observed.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CECT, Toshiba-Astion (no further specification of technique reported) **Description of technique:** US followed by abdominopelvic CT for all participants from the diaphragm dome to pubis symphysis with IV contrast (Visipaque 270 mg vial, 1 mL/kg). The CT scan was reported by a second radiologist who was blinded to the results of the US.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	
Methodological quality	

Talari 2015 *(Continued)*

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	No		
		High	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			

Talari 2015 *(Continued)*

Was there an appropriate interval between index test and reference standard?	Yes	
Did all patients receive the same reference standard?	Yes	
Were all patients included in the analysis?	Yes	
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes	
		Low

Todd Miller 2003

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** USA **Study period:** October 2001 to June 2002 **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 372: gender not reported **Participants included in analysis:** 359 **Age:** mean age 38 years (range 2 to 93 years) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable conditions **Inclusion criteria:** all haemodynamically stable patients with suspected blunt abdominal injury (i.e. abdominal pain or mechanism of injury consistent with the production of an intra-abdominal injury) **Exclusion criteria:** inadequate FAST examination attributable to physical build
Index tests	**Index test:** FAST **US protocol:** all participants with abdominal pain or mechanism of injury consistent with the production of an intra-abdominal injury underwent a 4-view FAST examination at the completion of the secondary survey during initial trauma evaluation. The presence of intra-abdominal injury without free abdominal fluid (true-negative FAST examination), retroperitoneal injury, bony injury (lower thoracic, lumbar, or pelvic fractures), and clinically significant "incidentalomas" were also recorded. **Hardware used:** 3.5 MHz, SonoSite, Bothell, WA **Description of imaging technique:** FAST examinations were recorded as positive or negative for 3 abdominal views and considered inadequate if any 1 of the 3 abdominal views could not be obtained. A true-positive FAST examination was defined as free fluid detected in any 1 of the 3 abdominal views confirmed

Todd Miller 2003 *(Continued)*

	by CT scan, whereas a true-negative FAST examination was defined as no free abdominal fluid by FAST examination or CT scan. A false-negative FAST examination was defined as any negative US examination with a subsequent CT scan that showed the presence of intra-abdominal fluid. A false-positive FAST examination was defined as one in which the FAST examination was felt to demonstrate free abdominal fluid, but the CT scan was negative for free fluid.
Target condition and reference standard(s)	**Target condition:** free fluid and air, organ injury **Reference standard:** CT (technique specification not reported) **Description of technique:** CT scan of the abdomen and pelvis was obtained and interpreted by an in-house radiologist within 1 hour of the FAST examination being completed. Participants underwent CT scanning of the abdomen and pelvis as a confirmatory test for the presence of intra-abdominal fluid and intra-abdominal injury.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		

Todd Miller 2003 *(Continued)*

		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MD-CT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Tso 1992

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** USA **Study period:** 8 consecutive months in the 1990 academic year **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 163: gender ratio male:female 3:1

Tso 1992 *(Continued)*

	Participants included in analysis: 163 **Age:** mean age 34 years (range 2 to 93 years) **Type of injury:** blunt abdominal trauma **Injury severity:** ISS 13, GCS 14 **Haemodynamic stability:** stable conditions **Inclusion criteria:** patients admitted to trauma centre through the admitting area and judged to require DPL or CT for evaluation of intra-abdominal injury **Exclusion criteria:** hypotension, suspected severe head injury, indications for immediate laparotomy, and the discretion of the attending traumatologist
Index tests	**Index test:** FAST **US protocol:** participants evaluated by real-time sector scanning sonography, within 1 hour of admission, by surgical trauma fellows **Hardware used:** Siemens Sonoline SL-2 using either 3- or 5-MHz transducers **Description of imaging technique:** the pelvis, the paracolic gutters, and the subhepatic space were studied for evidence of free intraperitoneal fluid. Positive sonography studies showed free peritoneal or extraperitoneal fluid or organ disruption.
Target condition and reference standard(s)	**Target condition:** free fluid and air, organ injury **Reference standard:** CT (technique specification not reported), DPL, laparotomy **Description of technique:** positive CT scans showed free peritoneal or extraperitoneal fluid or organ disruption
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**Low**
DOMAIN 2: Index Test All tests			

Tso 1992 *(Continued)*

Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	No		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Valentino 2010

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** Bologna, Italy **Study period:** 2004 to 2008 **Care setting:** hospital emergency department **Mass casualty:** no **Participants enrolled:** 1584 **Participants included in analysis:** 133: 99 men and 34 women **Age:** mean age 40.2 years (range not reported) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable conditions **Inclusion criteria:** the causes of blunt abdominal trauma were road accident, sports injury, accidental fall, or accident at work. Patients had suspected abdominal injuries with pain at palpation, bruises of the abdomen, probable fracture of the lower ribs, or presence of abdominal free fluid at FAST. **Exclusion criteria:** not reported
Index tests	**Index test:** US, CEUS **US protocol:** US and CEUS performed consecutively by 1 radiologist, after which CECT was performed by another radiologist. The latter was informed of the US/CEUS diagnosis but was blinded to the images. **Hardware used:** ATL 5000 HDI and Philips iU22 using 2e5- and 1e5-MHz convex probes **Description of imaging technique:** in addition to FAST assessment, a complete study of the solid organs of the abdomen was performed in all participants to search for possible alterations. US outcome was considered positive when peritoneal free fluid or alterations in the parenchymal echo pattern consistent with traumatic injury were found. CEUS was performed after baseline US. A standard protocol was followed, and contrast agent was injected in 2 separate doses of 2.4 mL to permit an adequate study of the solid organs of the right upper and left quadrant. CEUS outcome was considered positive when a perfusion defect of the studied organ was found, characterised by hypoechogenicity with or without interruption of the organ profile. Where there was non-perfusion of part of or the whole organ, the finding was interpreted as a sign of vascular injury, and the passage of microbubbles outside the damaged organ was interpreted as active bleeding.
Target condition and reference standard(s)	**Target condition:** free fluid and air, organ injury **Reference standard:** CECT **Description of technique:** after CEUS, CECT was performed in the venous phase before and after administration of non-ionic contrast agent. In the presence of free fluid collection, late-phase evaluation was carried out at 3 to 15 minutes to identify active bleeding or urine collection.

Valentino 2010 *(Continued)*

Flow and timing	**Time between US and reference standard:** < 1h		
Comparative			
Notes			

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Unclear		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	Unclear		
		Unclear	**Unclear**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	No		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		

Valentino 2010 *(Continued)*

Was the reference imaging standard (i.e. MD-CT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Verbeek 2014

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** Amsterdam, the Netherlands **Study period:** January 2004 to December 2009 **Care setting:** level I trauma centre **Mass casualty:** no **Participants enrolled:** 131: 90 men and 41 women **Participants included in analysis:** 120 **Age:** mean age 37 years (range not reported) **Type of injury:** high-energy pelvic fracture **Injury severity:** ISS 26 ± 14 **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** all adults with a high-energy major pelvic fracture admitted to the trauma resuscitation room. A major pelvic fracture was defined as a disruption of the pelvic ring in at least 2 places.

Verbeek 2014 *(Continued)*

	Exclusion criteria: isolated pelvic fracture patients, transfer patients, and patients declared dead on arrival
Index tests	**Index test:** FAST **US protocol:** initial participant assessment followed the institutional protocol and ATLS principles. According to the local imaging protocol, all high-energy trauma participants underwent chest and pelvic radiography as well as FAST within 5 minutes of arrival. FAST was performed by the trauma team radiologist (a senior radiology resident, or junior resident under supervision of an attending radiologist). **Hardware used:** Aloka ProSound SSD 3500Plus (Biomedic, Almere, the Netherlands) **Description of imaging technique:** a FAST result was considered positive if haemoperitoneum was detected in any of the 3 abdominal regions (left and right upper quadrant and pelvis)
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT (multislice CT scanner Somatom Sensation 4, Siemens Medical Systems, Erlangen, Germany) **Description of technique:** a CT scan was considered positive if any haemoperitoneum (more than a physiological amount in the pelvis) was detected. The amount of haemoperitoneum was quantified as small (1 region), moderate (2 regions), or large (3 regions). For the purposes of this study, 2 senior radiology residents who were blinded to the FAST result reviewed all CT scans for the presence of haemoperitoneum.
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Did the study avoid inappropriate exclusions?	Yes		
		Low	**High**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		

Verbeek 2014 *(Continued)*

Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Wong 2014

Study characteristics	
Patient sampling	Retrospective cross-sectional study

Wong 2014 *(Continued)*

Patient characteristics and setting	**Study location:** Singapore, Asia **Study period:** January 2009 to December 2010 **Care setting:** emergency department of a tertiary hospital **Mass casualty:** no **Participants enrolled:** 476: 389 men and 87 women **Participants included in analysis:** 221 **Age:** mean age 38.9 years (range not reported) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** not reported **Inclusion criteria:** the identities of trauma patients who presented to the emergency department resuscitation room were acquired from the file and verified with the hospital's trauma registry. The performance of US was a mandated field in the trauma registry. **Exclusion criteria:** penetrating trauma and burns
Index tests	**Index test:** FAST **US protocol:** FAST, no further details reported **Hardware used:** not reported **Description of imaging technique:** not reported
Target condition and reference standard(s)	**Target condition:** free fluid and air, organ injury **Reference standard:** CT, no further details reported **Description of technique:** not reported
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**

Wong 2014 *(Continued)*

DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	No		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Unclear		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Unclear		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	Unclear		
		Unclear	**Unclear**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Zhang 2006

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Study location:** China **Study period:** September 2004 to October 2005 **Care setting:** hospital emergency department **Mass casualty:** no **Participants enrolled:** 163 **Participants included in analysis:** 135: 114 men and 21 women **Age:** mean age 45 ± 15 years (range not reported) **Type of injury:** multiple trauma **Injury severity:** ISS 29.1 ± 12.4 **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** patients with multiple trauma in either the resuscitation room or the emergency intensive care unit were enrolled. All patients suffered from blunt trauma, including traffic accident, falls, crush injuries, and other causes. **Exclusion criteria:** subcutaneous emphysema and/or cardiac arrest following probable tension pneumothorax
Index tests	**Index test:** EFAST, CXR **US protocol:** US was performed after initial rapid assessment by physical examination and essential resuscitation for participants in the resuscitation room. US was conducted in all participants admitted to the emergency intensive care unit and in hospitalised participants with impairment of lung function requiring a chest CT scan. **Hardware used:** SSD-900, Aloka Co, Tokyo, Japan; 3.5-MHz convex probe and occasionally a 7.5-MHz linear probe **Description of imaging technique:** participants were kept in a supine position and an examination of the anterior, lateral, and posterior thoraces was performed. Bilateral US images were compared, and characteristic signs (i.e. pleural line, lung sliding, comet-tail artefacts) were identified in either real-time or time-movement mode.
Target condition and reference standard(s)	**Target condition:** free fluid and air **Reference standard:** CT, 16-slice spiral CT scanning unit (Volume Zoom, Siemens Co, Forchheim, Germany), CXR **Description of technique:** portable chest radiography and CT scans were performed before or after US with participants in the supine position. The results of chest CT and radiography were interpreted by independent radiologists who were unaware of participants' conditions and the findings of US.
Flow and timing	**Time between US and reference standard:** < 3 hours

Zhang 2006 *(Continued)*

Comparative
Notes

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Did the study avoid inappropriate exclusions?	Yes		
		Unclear	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Yes		
Was the US protocol (i.e. 'classic' FAST) appropriate?	Yes		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	No		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Yes		
Was the reference imaging standard (i.e. MDCT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Yes		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accept-	No		

Zhang 2006 *(Continued)*

ed, established, or practiced rules or recommendations?			
		Low	**Low**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	Yes		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Zhou 2012

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Study location:** China **Study period:** 12 to 31 May 2008 **Care setting:** various hospitals **Mass casualty:** yes (earthquake) **Participants enrolled:** 2204: 1045 men and 1149 women, 19 gender unknown **Participants included in analysis:** 96 **Age:** mean age 44.82 years (range 7 months to 103 years) **Type of injury:** blunt abdominal trauma **Injury severity:** not reported **Haemodynamic stability:** stable and unstable conditions **Inclusion criteria:** patients damaged directly and indirectly by the Wenchuan earthquake, initially examined by US within 24 hours to evaluate suspected blunt abdominal trauma at different hospitals in Sichuan province **Exclusion criteria:** non-injury diseases such as stress disorder, delivery, and internal diseases
Index tests	**Index test:** FAST **US protocol:** the initial US findings were compared with the results of subsequent CT, DPL, repeated US, cystography, operation and/or autopsy, and/or the clinical course **Hardware used:** not reported

Zhou 2012 *(Continued)*

	Description of imaging technique: US findings were considered positive if evidence of free fluid or a parenchymal injury was identified. All indeterminate parenchymal lesions were considered positive US findings. A parenchymal lesion was defined as a hyperechoic or hypoechoic area in a solid organ or a distortion of the normal echo structure of a solid organ. For the objectives of the present study, pleural and pericardial effusions were considered negative findings for abdominal injury. Positive US findings were considered true positives if initial US finding was positive, and the injury was identified by the best available reference. Positive US findings were considered false positives if injury was not confirmed at subsequent studies. In cases of medical ascites or physiologic pelvic fluid in female participants, US findings were considered as false positives because injury could not be excluded with US alone, and further investigation was required to rule out injuries. Negative US findings were considered as true negatives if findings of subsequent studies were negative or if the participant had an uneventful clinical course, or both. Negative US findings were considered as false negatives if a subsequent study revealed free fluid, haemoperitoneum, or any visceral abdominal injury.
Target condition and reference standard(s)	**Target condition:** free fluid and air, organ injury **Reference standard:** CT (no further details reported) (DPL, repeated US, cystography, operation and/or autopsy) **Description of technique:** not reported
Flow and timing	**Time between US and reference standard:** not reported
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Did the study avoid inappropriate exclusions?	No		
		High	**Low**
DOMAIN 2: Index Test All tests			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
If a threshold was used, was it pre-specified?	Yes		
Was the qualification of the US operator appropriate?	Yes		
Was the US hardware (i.e. generation, manufacturer, probe, etc.) up to date?	Unclear		

Zhou 2012 *(Continued)*

Was the US protocol (i.e. 'classic' FAST) appropriate?	Unclear		
Are there concerns that the definition or performance of the index test (i.e. POC US of trauma) do not match generally accepted, established, or practiced rules or recommendations?	Unclear		
		Unclear	**Unclear**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Unclear		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Was the qualification of the doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	Unclear		
Was the reference imaging standard (i.e. MD-CT-rows (4 to ≥ 256 slices), contrast-imaging, etc.) up to date?	Unclear		
Are there concerns that the definition or performance of the reference tests (e.g. CT, MRI, laparatomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	Yes		
		Unclear	**High**
DOMAIN 4: Flow and Timing			
Was there an appropriate interval between index test and reference standard?	Yes		
Did all patients receive the same reference standard?	No		
Were all patients included in the analysis?	Yes		
Did all participants receive a reference standard? (Risk of partial verification bias)	Yes		
		Low	

Abbreviations
AP: anteroposterior
ATLS: Advanced Trauma Life Support
CECT: contrast-enhanced computed tomography
CE-MDCT: contrast-enhanced multidetector spiral computed tomography
CEUS: contrast-enhanced ultrasound
CT: computed tomography

CXR: chest radiography
DPL: diagnostic peritoneal lavage
EFAST: extended FAST
ELAP: exploratory laparotomy
ESI: Emergency Severity Index
FAST: focused assessment with sonography in trauma
GCS: Glasgow Coma Scale
ICD-10: 10th revision of the International Statistical Classification of Diseases and Related Health Problems
IQR: interquartile range
ISS: Injury Severity Score
IV: intravenous
MSCT: multislice CT
PTS: Pediatric Trauma Score
WHO: World Health Organization
US: ultrasound/ultrasonography

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Abdulrahman 2015	Insufficient information to calculate diagnostic accuracy
Ala 2016	Inadequate reference standard
Arrillaga 1999	Inadequate reference standard
Beck-Razi 2007	Penetrating trauma
Behboodi 2016	Inadequate diagnostic values
Brooks 2004a	Penetrating trauma
Brooks 2004b	Inadequate reference standard
Brown 2001	Inadequate reference standard
Byars 2013	Inadequate index test
Cook 2015	Insufficient information to calculate diagnostic accuracy
Coskun 2011	Inadequate reference standard
Dan 2010	Inadequate reference standard
Deunk 2010	Inadequate index test
Donmez 2011	Insufficient information to calculate diagnostic accuracy
Faruque 2013	Inadequate reference standard
Hamada 2016	Insufficient information to calculate diagnostic accuracy
Helling 2007	Insufficient information to calculate diagnostic accuracy
Heyn 2008	Inadequate reference standard
Holmes 2012	Penetrating trauma

Study	Reason for exclusion
Hyacinthe 2012	Penetrating trauma
Ianniello 2014	Insufficient information to calculate diagnostic accuracy
Ingeman 1996	Insufficient information to calculate diagnostic accuracy
Jalli 2009	Inadequate index test
Kaya 2015	Inadequate reference standard
Kern 1997	Penetrating trauma
Kirkpatrick 2002	Inadequate reference standard
Kirkpatrick 2004	Insufficient information to calculate diagnostic accuracy
Kirkpatrick 2005	Inadequate reference standard
Krupnick 1997	Case-control study
Ku 2013	Penetrating trauma
Kumar 2014	Insufficient information to calculate diagnostic accuracy
Lichtenstein 2005	Insufficient information to calculate diagnostic accuracy
Matsumoto 2016	Insufficient information to calculate diagnostic accuracy
Mihalik 2012	Insufficient information to calculate diagnostic accuracy
Moylan 2007	Inadequate reference standard
Mumtaz 2016	Penetrating trauma
Nagarsheth 2011	Penetrating trauma
Natarajan 2010	Insufficient information to calculate diagnostic accuracy
Pak-art 2003	Inadequate reference standard
Richards 2004	Inadequate reference standard
Richardson 1997	Case-report
Schleder 2013	Penetrating trauma
Sheng 2013	Penetrating trauma
Smith 2009	Insufficient information to calculate diagnostic accuracy
Smith 2013	Inadequate reference standard
Smith 2015	Battlefield scenario
Soldati 2007	Insufficient information to calculate diagnostic accuracy

Study	Reason for exclusion
Soult 2015	Penetrating trauma
Tajoddini 2013	Insufficient information to calculate diagnostic accuracy
Tam 2005	PenetratIng trauma
Tas 2004	Insufficient information to calculate diagnostic accuracy
Tayal 2006	Inadequate reference standard
Tummers 2016	Inadequate reference standard
Tunuka 2014	Inadequate reference standard
Valentino 2008	Insufficient information to calculate diagnostic accuracy
Van Diepen 2013	Insufficient information to calculate diagnostic accuracy
Vassiliadis 2003	Penetrating trauma

Characteristics of studies awaiting classification *[ordered by study ID]*

Armstrong 2018

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Type of injury:** blunt abdominal solid organ injury **Participants included in analysis:** 18 **Age:** 7 to 18 years **Care setting:** level 2 trauma centre
Index tests	**Index tests:** conventional US and CEUS
Target condition and reference standard(s)	**Reference standard:** CT
Flow and timing	**Time between index test and reference standard:** 48 hours
Comparative	
Notes	May be incorporated into the review at the next update

Elbaih 2017

Study characteristics	
Patient sampling	Prospective cross-sectional study

Elbaih 2017 *(Continued)*

Patient characteristics and setting	**Type of injury:** polytraumatised patients with a blunt mechanism **Participants included in analysis:** 150 **Age:** mean age 27.98 ± 20.39 years **Haemodynamic stability:** unstable
Index tests	**Index test:** FAST US
Target condition and reference standard(s)	**Reference standard:** exploratory laparotomy
Flow and timing	
Comparative	
Notes	May be incorporated into the review at the next update

Hsu 2017

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Type of injury:** blunt abdominal trauma **Participants included in analysis:** 438 **Inclusion criteria:** patients who had a FAST examination performed by qualified residents and had received subsequent formal radiographic or surgical evaluations
Index tests	**Index test:** FAST US
Target condition and reference standard(s)	**Reference standard:** subsequent surgical findings or formal Department of Radiology reference standards
Flow and timing	
Comparative	
Notes	May be incorporated into the review at the next update

Kozaci 2018

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Type of injury:** multiple trauma with thoracic injuries **Participants included in analysis:** 81 **Age:** > 18 years

Kozaci 2018 *(Continued)*

Index tests	**Index test:** bedside thoracic US
Target condition and reference standard(s)	**Reference standard:** thoracic CT
Flow and timing	
Comparative	
Notes	May be incorporated into the review at the next update

Maximus 2018

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Type of injury:** pneumothorax **Participants included in analysis:** 300 **Care setting:** level 1 urban trauma centre
Index tests	**Index tests:** EFAST and chest X-ray
Target condition and reference standard(s)	**Reference standard:** CT
Flow and timing	
Comparative	
Notes	May be incorporated into the review at the next update

Mumtaz 2017

Study characteristics	
Patient sampling	Prospective study
Patient characteristics and setting	**Type of injury:** blunt or penetrating trauma **Participants included in analysis:** 80 **Haemodynamic stability:** stable **Age:** 57 males with mean age 27.30 ± 9.69 years and 23 females with mean age 30.91 ± 11.58 years
Index tests	**Index tests:** Portable bed side US and supine chest radiograph
Target condition and reference standard(s)	**Reference standard:** CT
Flow and timing	

Mumtaz 2017 *(Continued)*

Comparative	
Notes	May be incorporated into the review at the next update

Sauter 2017

Study characteristics	
Patient sampling	Retrospective cross-sectional study
Patient characteristics and setting	**Type of injury:** multiple blunt trauma with pneumothorax **Participants included in analysis:** 106 **Care Setting:** level 1 trauma centre **Age:** mean age 48.6 ± 19.3 years
Index tests	**Index tests:** EFAST
Target condition and reference standard(s)	**Reference standard:** CT
Flow and timing	
Comparative	
Notes	May be incorporated into the review at the next update

Waheed 2018

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Type of injury:** blunt abdominal injury caused by motor vehicle accident **Participants included in analysis:** 105 **Age:** mean age 32.3 ± 19.3 years (range 15 to 56 years) **Haemodynamic stability:** stable
Index tests	**Index tests:** FAST
Target condition and reference standard(s)	**Reference standard:** CT
Flow and timing	
Comparative	
Notes	May be incorporated into the review at the next update

Zieleskiewicz 2018

Study characteristics	
Patient sampling	Retrospective study
Patient characteristics and setting	**Type of injury:** severe trauma **Participants included in analysis:** 756 **Care Setting:** level 1 trauma centre
Index tests	**Index tests:** EFAST, chest X-ray, pelvic X-ray
Target condition and reference standard(s)	**Reference standard:** total body CT
Flow and timing	
Comparative	
Notes	May be incorporated into the review at the next update

Abbreviations
CEUS: contrast-enhanced ultrasound
CT: computed tomography
EFAST: extended FAST
FAST: focused assessment with sonography in trauma
US: ultrasound

D A T A

Presented below are all the data for all of the tests entered into the review.

Table Tests. Data tables by test

Test	No. of studies	No. of participants
1 Main analysis set	34	8635
2 Sensitivity analysis set with lower sensitivity/specificity values in two original studies	34	8635

Test 1. Main analysis set.

Test 2. Sensitivity analysis set with lower sensitivity/specificity values in two original studies.

APPENDICES

Appendix 1. Search strategies

Ovid MEDLINE Databases

Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) <1946 to Present>

The MEDLINE search strategy is based on the following structure:

Search1. *Target Condition + Index Test (POC Ultrasonography)*

OR

Search 2. *Target Condition + Index Test (Ultrasonography) + Reference Standard + DTA Filter + Setting)*

[Target Condition]

1 exp Abdominal Injuries/

2 exp Thoracic Injuries/

3 ((chest or torso) adj3 (injur* or trauma*)).ti,ab,kf.

4 ((injur* or ruptur* or bleed* or trauma*) adj3 (abdom* or thorax or thoracic or thoracoabdom* or thoraco-abdom* or stomach or gastric*)).ti,ab,kf.

5 (free fluid adj3 (abdom* or thorax or thoracic or thoracoabdom* or thoraco-abdom*)).ti,ab,kf.

6 pneumothorax/

7 hemopneumothorax/

8 hemothorax/

9 (pneumothor* or h?emopneumothor* or h?emothor*).ti,ab,kf.

10 (retroperitoneal or retro-peritoneal or intraperitoneal or intra-peritoneal or mediastinum or pericardium).ti,ab,kf,hw.

11 *"Wounds and Injuries"/

12 "Wounds and Injuries"/dg [Diagnostic Imaging]

13 Wounds, Nonpenetrating/

14 rupture/ or exp splenic rupture/ or stomach rupture/

15 ((injur* or ruptur* or bleed* or trauma* or lacerat* or tear? or contusion*) adj3 (spleen* or splenic or hepatic or visceral or liver* or kidney* or pancrea* or renal* or lungs or heart)).ti,ab,kf.

16 ((blunt* or non-penetrat* or nonpenetrat*) adj trauma*).ti,ab,kf.

17 (polytrauma* or poly trauma* or multiple trauma* or mass casualt*).ti,ab,kf,hw.

18 or/1-17

[Index Test]

19 exp Ultrasonography/

20 Diagnostic Imaging/

21 (ultraso* or sonogra*).ti,ab,kf.

22 (diagnos* adj2 (screen* or scan* or imag*)).ti,ab,kf.

23 diagnostic imaging.fs.

24 (advanced trauma life support or atls).ti,ab,kf.

25 or/19-24

26 point of care.ti,ab,kf.

27 Point-of-Care Systems/

28 (POCUS or POC US or POC USG).ti,ab,kf.

29 ((focused adj2 assessment adj2 sonogra* adj2 trauma) or extended-FAST or (FAST adj (ultrasonography or ultrasound))).ti,ab,kf.

30 ((portable or hand-held or handheld or mobile or emergency) adj (sonogra* or ultraso*)).ti,ab,kf.

31 bedside.ti,ab,kf.

32 or/26-31

[Search1: Target Condition + Index Test (POC Ultrasonography)]

33 (18 and 25 and 32)

[*Reference Standard*]

34 exp Tomography, X-Ray Computed/

35 (CT scan or cat scan or (xray* adj1 ct) or xrayct or (compute* adj2 tomograph*)).ti,ab,kf.

36 (MDCT or pan scan or panscan).ti,ab,kf.

37 (laparotom* or laparoscop* or thoracotom* or sternotom* or thoracoscop* or autops*).ti,ab,kf,hw.

38 or/34-37

[DTA Filter]

39 "sensitivity and specificity"/ or "limit of detection"/ or roc curve/ or signal-to-noise ratio/ or "predictive value of tests"/

40 "reproducibility of results"/

41 likelihood ratio*.ti,ab,kf.
42 ((re-test or retest or test-retest or test-re-test) adj reliability).ti,ab,kf.
43 receiver operating characteristic*.ti,ab,kf.
44 (ROC adj5 (analy* or curve or curves)).ti,ab,kf.
45 or/39-44
[Search2: Target Condition + Index Test (Ultrasonography/Diagnostic Imaging (MeSH)) + Reference Standard + DTA Filter]
46 18 and (19 or 21) and 38 and 45
[Limited to Setting]
47 (trauma* or emergenc* or bedside?).ti,ab,kf,hw.
48 (46 and 47)
[Search 1 or Search 2]
49 (33 or 48)
50 remove duplicates from 49

****

Ovid Embase <1974 to date>
As Embase records are more highly indexed (compared to MEDLINE and other database records), there will be one search strand, based on the following structure: *Target Condition + Index Test (POC Ultrasonography) + (Setting OR Reference Standard OR DTA Filter)*

[Target Condition]
1 exp *abdominal injury/ or exp abdominal injury/di
2 exp *thorax injury/ or exp *thorax injury/di
3 ((chest or torso) adj3 (injur* or trauma*)).ti,ab,kw.
4 ((injur* or ruptur* or bleed* or trauma*) adj3 (abdom* or thorax or thoracic or thoracoabdom* or thoraco-abdom* or stomach or gastric*)).ti,ab,kw.
5 (free fluid and (abdom* or thorax or thoracic or thoracoabdom* or thoraco-abdom*)).ti,ab,kw.
6 pneumothorax/ or hematopneumothorax/ or spontaneous pneumothorax/ or tension pneumothorax/
7 hematothorax/
8 (pneumothor* or h?emopneumothor* or h?emothor*).ti,ab,kw.
9 ((fluid*1 or blood or bleed*) and (retroperitoneal or retro-peritoneal or intraperitoneal or intra-peritoneal or mediastinum or pericardium)).ti,ab,kw,hw.
10 blunt trauma/ or crush trauma/
11 *rupture/ or exp *digestive system rupture/ or *spleen rupture/ or exp *thorax organ rupture/
12 rupture/di or exp digestive system rupture/di or spleen rupture/di or exp thorax organ rupture/di
13 ((injur* or ruptur* or bleed* or trauma* or lacerat* or tear? or contusion*) adj3 (spleen* or splenic or hepatic or visceral or liver* or kidney* or pancrea* or renal* or lungs or heart)).ti,ab,kw.
14 ((blunt* or non-penetrat* or nonpenetrat*) adj trauma*).ti,ab,kw.
15 (polytrauma* or poly trauma* or (multiple adj2 trauma*) or mass casualt*).ti,ab,kw,hw.
16 or/1-15
[Index Test]
17 exp echography/
18 diagnostic imaging/
19 (ultraso* or sonogra*).ti,ab,kw.
20 (diagnos* adj2 (screen* or scan* or imag*)).ti,ab,kw.
21 (advanced trauma life support or atls).ti,ab,kw.
22 or/17-21
23 point of care.ti,ab,kw.
24 "point of care testing"/
25 (POCUS or POC US or POC USG).ti,ab,kw.
26 ((focused adj2 assessment adj2 sonogra* adj2 trauma) or extended-FAST or (FAST adj (ultrasonography or ultrasound))).ti,ab,kw.
27 ((portable or hand-held or handheld or mobile or emergency) adj (sonogra* or ultraso*)).ti,ab,kw.
28 bedside?.ti,ab,kw.
29 or/23-28
[Target Condition + Index Test (POC Ultrasonography)]
30 (16 and 22 and 29)
[Setting]
31 (trauma* or emergenc* or ((acute or critical or intensive) adj2 (care or medicine))).ti,ab,kw,hw.
[Reference Standard]
32 exp computer assisted tomography/
33 (CT scan or cat scan or (xray* adj1 ct) or xrayct or (compute* adj2 tomograph*)).ti,ab,kw.
34 (MDCT or pan scan or panscan).ti,ab,kw.

35 thorax radiography/
36 (laparotom* or laparoscop* or thoracotom* or sternotom* or thoracoscop* or autops*).ti,ab,kw,hw.
37 or/32-36
[DTA Filter]
38 diagnostic accuracy/
39 "sensitivity and specificity"/
40 receiver operating characteristic/
41 predictive value/
42 intermethod comparison/ or comparative study/
43 ((re-test or retest or test-retest or test-re-test) adj reliability).ti,ab,kw.
44 likelihood ratio*.ti,ab,kw.
45 receiver operating characteristic*.ti,ab,kw.
46 (ROC adj5 (analy* or curve or curves)).ti,ab,kw.
47 (detect* or diagnos*).ti,ab,kw.
48 or/38-47
[Target Condition + Index Test (POC Ultrasonography) + (Setting OR Reference Standard OR DTA Filter)]
49 (30 and (31 or 37 or 48))
50 Animal experiment/ not (human experiment/ or human/)
51 (exp animal/ or nonhuman/) not ((exp animal/ or nonhuman/) and (human/ or human experiment/))
52 (rat or rats or mouse or mice or swine or porcine or murine or sheep or lambs or pigs or piglets or rabbit or rabbits or cat or cats or feline or dog or dogs or canine or cattle or bovine or monkey or monkeys or trout or marmoset*).ti.
53 case report/
54 or/50-53
55 (49 not 54)
56 limit 55 to (article in press status or conference abstract status or embase status or inprocess status)
57 remove duplicates from 56

****

PubMed (NOT MEDLINE) <1947 to date**>**

#18 (#1 AND #17)
#17 (#5 AND #16)
#16 (#6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15)
#15 (“free fluid” OR “free fluids”)
#14 ((pneumothorax OR pneumothoracic OR pneumothoraces OR hemopneumothorax OR hemopneumothoracic OR hemopneumothoraces OR haemopneumothorax OR haemopneumothoracic OR haemopneumothoraces OR hemothorax OR hemothoracic OR hemothoraces OR haemothorax OR haemothoracic OR haemothoraces))
#13 (“Pneumothorax”[Mesh] OR “Hemopneumothorax"[Mesh])
#12 ((polytrauma OR “poly trauma” OR “multiple trauma” OR “multiple traumas” OR “mass casualties” OR “mass casualty”))
#11 ”Mass Casualty Incidents”[Mesh]
#10 ((blunt OR non-penetrating OR nonpenetrating) AND (trauma OR traumatic))
#9 ((retroperitoneal OR retro-peritoneal OR intraperitoneal OR intra-peritoneal OR mediastinum OR pericardium))
#8 ((spleen OR splenic OR hepatic OR liver OR renal OR kidney OR kidneys OR pancreas OR pancreatic OR lung OR lungs OR heart OR visceral) AND (injury OR injuries OR trauma OR traumatic OR rupture OR ruptured OR bleed OR bleeding OR lacerate OR laceration OR tear OR teared OR contusion OR wound OR wounds))
#7 ((abdomen OR abdominal OR chest OR thorax OR thoracic OR torso OR thoracoabdomen OR thoracoabdominal OR thoraco-abdomen OR thoraco-abdominal OR stomach OR gastric) AND (injury OR injuries OR trauma OR traumatic OR rupture OR ruptured OR bleed OR bleeding OR wound OR wounds))
#6 (“Abdominal Injuries”[Mesh] OR "Thoracic Injuries”[Mesh] OR "Wounds, Nonpenetrating"[Mesh])
#5 (#2 OR #3 OR #4)
#4 (POCUS OR POC-US OR POC-USG OR “POC US” OR “POC USG”)
#3 (((point-of-care OR “point of care” OR “focused assessment” OR "focussed assessment" OR EFAST OR bedside OR bedsides OR portable OR hand-held OR handheld OR mobile OR emergency) AND (sonograph OR sonography OR sonographic OR sonographer OR sonographers OR ultrasonography OR ultrasonographic OR ultrasound)))
#2 ”Point-of-Care Systems"[Mesh]
#1 (pubmednotmedline[sb] OR publisher[sb] OR in process[sb])

****

BIOSIS Previews (Web of Science) <1926 to date>

Topic = (thorax injur* OR thoracic injur* OR chest injur* OR torso injur* OR thoracoabdominal injur* OR thoraco-abdominal injur* OR abdominal injur* OR abdomen injur* thorax injur* OR stomach injur* OR gastric injur* OR thoracic trauma OR chest trauma OR torso trauma OR thoracoabdominal trauma OR thoraco-abdominal trauma OR abdominal trauma OR abdomen trauma OR stomach trauma OR gastric trauma OR pneumothorax OR hemopneumothorax OR haemopneumothorax OR hemothorax OR haemothorax OR pneumothor* OR retroperitoneal OR retro-peritoneal OR intraperitoneal OR intra-peritoneal OR mediastinum OR spleen trauma OR spleen injur* OR splenic trauma OR splenic injur* OR hepatic trauma OR hepatic injur* OR visceral trauma OR visceral injur* OR liver trauma OR liver injur* OR kidney trauma OR kidney injur* OR pancrea* trauma OR pancrea* injur* OR renal trauma OR renal injur* OR lung trauma OR lung injur* OR free fluid OR free air OR organ injur* OR organ lesion* OR vascular lesion* OR blunt trauma OR polytrauma* OR multiple trauma*) AND Topic = (ultraso* OR US OR sonogra* OR diagnos* screen* OR diagnos* scan* OR diagnos* imag* OR point of care OR point-of-care OR POCS OR POCUS OR POC US OR POC USG OR FAST OR focused assessment OR EFAST OR extended-FAST OR ALTS OR advanced trauma life support)

Appendix 2. Review-specific QUADAS-2 coding manual

Domain 1: Participant selection		
Risk of bias	Q1. Was a consecutive or random sample of participants enrolled?	– '**Yes**' if a consecutive or random sample of participants was enrolled – '**No**' if a non-random (or non-consecutive) selection method was used – '**Unclear**' if the procedures are only partially reported and you feel that both 'yes' or 'no' are inadequate
	Q2. Did the study avoid inappropriate exclusions (e.g. exclusion of patients with underlying diseases associated with intra-abdominal fluid)	- '**Yes**' if there were no inappropriate exclusions - '**No**' if there were inappropriate exclusions - '**Unclear**' if it is not clearly stated if there are any inappropriate exclusions
	Summary judgement of risk of bias	– **Low risk: both** answers are 'yes' – **High risk:** ≥ 1 answers are 'no' – **Unclear risk:** all other cases
Concerns regarding applicability	Q3. Are there concerns that the included patients and setting do not match the review question?	– '**Low**' if all patients with blunt thoracoabdominal and/or multiple trauma are the unit of investigation, and if the population characteristics are representative of those who will receive the test in practice – '**High**' if patients with any type of acute abdomen are enrolled, or when there are other covariates that are reason for concern – '**Unclear**' if answering 'low' or 'high' is inappropriate
Domain 2: Index test		
Risk of bias	Q1. Were the index test results interpreted without knowledge of the results of the reference standard?	– '**Yes**' if there is a statement that the index test results were interpreted blind to the results of the reference test – '**No**' if this does not appear to be the case – '**Unclear**' if this information was not reported
	Q2. If a threshold (e.g. the quantity of free intra-abdominal fluid, the number of areas with detectable fluid, etc.) was used, was it prespecified?	- '**Yes**' if the threshold values were prespecified before the start of the study - '**No**' if the threshold values were selected on the basis of the collected data - '**Unclear**' if there is insufficient information to make a judgement

(Continued)

	Q3. Was the qualification of the ultrasound operator appropriate?	– '**Yes**' if his/her background, training, and experience were sufficient according to clinical expert rating (e.g. the operator was a board-certified/qualified trauma or emergency surgeon, radiologist, sonographer, etc.) – '**No**' if the qualification was rated as not appropriate by clinical experts – '**Unclear**' if this information was not reported
	Q4. Was the ultrasound hardware (i.e. generation, manufacturer, probe, etc.) up-to-date?	– '**Yes**' if the technical features were up-to-date according to clinical expert rating (e.g. by mentioning the ultrasound hardware and probes (frequency) used) – '**No**' if the ultrasound hardware was rated as outdated – '**Unclear**' if this information was not reported
	Q5. Was the ultrasound protocol (i.e. 'classic' focused assessment with sonography in trauma (FAST)) appropriate?	– '**Yes**' if the ultrasound protocol (e.g. screening for free fluid and/or air, organ lacerations, etc.) was appropriate according to clinical expert rating – '**No**' if this was not the case – '**Unclear**' if this information was not reported
	Summary judgement of risk of bias	– **Low risk:** ≥ 4 answers are 'yes' – **High risk:** ≥ 3 answers are 'no' – **Unclear risk:** all other cases
Concerns regarding applicability	Q6: Are there concerns that the definition or performance of the index test (i.e. point-of-care ultrasonography (POCS) for trauma) do not match generally accepted, established, or practiced rules or recommendations?	– '**Low concern**' all patients with blunt thoracoabdominal and/or multiple trauma are screened with POCS in an established or recommended manner – '**High concern**' ultrasound protocols deviate significantly from established protocols; patients with any type of acute abdomen were enrolled; or other covariates were a reason for concern – '**Unclear concern**' if answering 'low' or 'high' is inappropriate
Domain 3: Reference test		
Risk of bias	Q1. Is this the type of test that is likely to correctly classify the target condition?	– '**Yes**' when computed tomography (CT) and/or magnetic resonance imaging (MRI), or any invasive procedure like laparotomy/laparoscopy, thoracotomy/thoracoscopy, or autopsy was used as a reference standard – '**No**' if no reference test was specified, or only positive POCS findings were confirmed by an imaging and/or invasive reference test – '**Unclear**' if answering 'yes' or 'no' is inappropriate
	Q2. Were the reference standard results interpreted without knowledge of the results of the index tests?	– '**Yes**' if there is a statement that the reference standard results were interpreted blind to the results of the index test – '**No**' if this does not appear to be the case – '**Unclear**' if this information was not reported
	Q3. Was the qualification of doctors (i.e. radiologists, surgeons, etc.) determining the reference standard appropriate?	– '**Yes**' if his/her background, training, and experience were sufficient according to clinical expert rating (e.g. the operator was a board-certified/qualified trauma or emergency surgeon, radiologist, sonographer, etc.)

(Continued)

		– '**No**' if the qualification was rated as not appropriate by clinical experts – '**Unclear**' if this information was not reported
	Q4. Was the reference imaging standard (i.e. multidetector-row computed tomography (MDCT) rows (4 to ≥ 256 slices), contrast imaging, etc.) up-to-date?	– '**Yes**' if the technical features were up-to-date according to clinical expert rating (e.g. by mentioning the hardware and imaging protocols used) – '**No**' if the CT hardware or imaging protocols were rated as outdated – '**Unclear**' if this information was not reported
	Summary judgement of risk of bias	– **Low risk:** ≥ 3 answers are 'yes' – **High risk:** ≥ 2 answers are 'no' – **Unclear risk:** all other cases
Concerns regarding applicability	Q5: Are there concerns the definition or performance of the reference tests (e.g. CT, MRI, laparotomy, thoracotomy, autopsy, etc.) do not match generally accepted, established, or practiced rules or recommendations?	– '**Low concern**' all patients with blunt thoracoabdominal or multiple trauma, or both undergo a thoracoabdominal or whole-body CT scan irrespective of clinical or ultrasound findings – '**High concern**' reference tests are ordered selectively or conditional on clinical or ultrasound results – '**Unclear concern**' if answering 'low' or 'high' concern is inappropriate
Domain 4: Flow and timing		
Risk of bias	Q1. Was there an appropriate interval between index test and reference standard?	– '**Yes**' if the POCS scan was followed by any reference test within 30 minutes – '**No**' if the reference test was executed after 30 minutes, if the reference test was employed before POCS, or in case of any other conditions – '**Unclear**' if this information was not reported
	Q2. Did all participants receive a reference standard? (Risk of partial verification bias)	– '**Yes**' if it is clear that all (or a random selection of) participants who received the index test also received the reference test – '**No**' if participants did or did not receive a reference test based on the outcome of the index test, or the selection of participants to receive the reference test was not random – '**Unclear**' if this information was not reported
	Q3. Did all participants receive the same (or any equivalent) reference standard?	– '**Yes**' if all participants had the same (or an equivalent) reference standard – '**No**' if this was not the case – '**Unclear**' if this information was not reported
	Q4. Were all participants included in the analysis?	– '**Yes**' if all participants entered into the study were included in the analysis – '**No**' if it appears that some of the participants were excluded from the analysis for whatever reason (e.g. did not complete the study, dubious test results) – '**Unclear**' if neither of the options above are appropriate
	Summary judgement of risk of bias	- **Low risk:** ≥ 3 answers are 'yes'

(Continued)

- **High risk:** ≥ 2 answers are 'no'

- **Unclear risk:** all other cases

CONTRIBUTIONS OF AUTHORS

DS conceived the review and wrote the first draft of the protocol.

JL provided clinical guidance and contributed to the revision of the protocol.

AH provided statistical guidance and contributed to the revision of the protocol.

AH and JL screened the search results, selected studies, and extracted data.

AH performed the statistical analysis.

AE, SM, and PF provided distinct clinical expertise.

PF also evaluated this review with regard to its relevance for the USA healthcare system.

All authors contributed to the writing of the review, which was supervised by DS.

DECLARATIONS OF INTEREST

D Stengel: none known

J Leisterer: none known

P Ferrada: none known

A Ekkernkamp: none known

S Mutze: none known

A Hoenning: none known

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DIFFERENCES BETWEEN PROTOCOL AND REVIEW

In Investigations of heterogeneity, we modified the categorisation of two potential sources of heterogeneity (i.e. reference standard and participant age) since the original classification did not result in sufficiently large subgroups. We were not able to compare single reference standards because each study used computed tomography (CT) as the diagnostic reference instrument, either alone or in combination with additional tests. With respect to participant age, we only compared studies that included patients under 18 years of age versus studies that included adults and mixed-age populations, due to the lack of adult-only studies. We made this decision before analysing the data. We could not explore various secondary sources of heterogeneity (i.e. environment, operator's expertise and background, hardware, test thresholds) due to missing information.

We intended to conduct Sensitivity analyses to investigate the influence of study quality based on the risk-of-bias assessment. We performed two additional analyses which were not prespecified in the protocol: evaluating the effect of two independent reviewers and diagnostic accuracy in a children-only cohort.

In the Assessment of methodological quality section, we removed one redundant item relating to case-control studies from the QUADAS-2 tool because these studies were already omitted from the review according to our predefined exclusion criteria.

We did not contact authors of individual studies as originally planned, since we required no further information or raw data.

The clinical experts Axel Ekkernkamp, Sven Mutze, and Paula Ferrada contributed to the full review and were added as authors.

INDEX TERMS

Medical Subject Headings (MeSH)

*Point-of-Care Systems; Abdominal Injuries [*diagnostic imaging]; Age Factors; Focused Assessment with Sonography for Trauma [*methods]; Reference Standards; Sensitivity and Specificity; Thoracic Injuries [*diagnostic imaging]; Wounds, Nonpenetrating [*diagnostic imaging]

MeSH check words

Adult; Child; Female; Humans; Male