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REVIEW ARTICLE

Review article: Accuracy of emergency physician performed point-of-care ultrasound of the thoracic aorta: A systematic review and narrative synthesis of the literature

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Abstract

Point-of-care ultrasound (POCUS) is becoming ubiquitous in emergency medicine. POCUS for abdominal aortic aneurysm is well established in practice. The thoracic aorta can also be assessed by POCUS for dissection and aneurysm and transthoracic echocardiography is endorsed by international guidelines as an initial test for thoracic aortic pathologies. A systematic search of Ovid Medline, PubMed, EMBASE, SCOPUS and Web of Science from January 2000 to August 2022 identified four studies evaluating diagnostic accuracy of emergency physician POCUS for thoracic aortic dissection (TAD) and five studies for thoracic aortic aneurysm (TAA). Study designs were heterogeneous including differing diagnostic criteria for aortic pathology. Convenience recruitment was frequent in prospective studies. Sensitivity and specificity ranges for studies of TAD were 41–91% and 94–100%, respectively when an intimal flap was seen. Sensitivity and specificity ranges for studies of thoracic aorta dilation >40 mm were 50–100% and 93–100%, respectively; for >45 mm ranges were 64–65% and 95–99%. Literature review identified that POCUS is specific for TAD and TAA. POCUS reduces the time to diagnosis of thoracic aortic pathology; however, it remains insensitive and cannot be recommended as a stand-alone rule-out test. We suggest that detection of thoracic aorta dilation >40 mm by POCUS at any site increases the suspicion of serious aortic pathology. Studies incorporating algorithmic use of POCUS, Aortic Dissection Detection Risk Score and D-dimer as decision tools are promising and may improve current ED practices. Further research is warranted in this rapidly evolving field.

Key words: *dissecting aneurysm, emergency departments, point-of-care systems, thoracic aorta, ultrasound.*

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Key findings

- POCUS is specific for thoracic aortic aneurysm as well as for thoracic aortic dissection when an intimal flap is seen directly and can reduce the time to diagnosis.
- Indirect signs of thoracic aortic dissection are less specific. In the correct clinical context visualisation of any indirect signs should trigger up-triage of pending advanced imaging requests.
- POCUS cannot be used in isolation to rule-out acute aortic syndromes in the ED. It is possible that combining POCUS with D-dimer and/or ADD-RS will be established as a safe approach in future studies.

Introduction

Point-of-care ultrasound (POCUS) performed by the emergency physician (EP) can be a powerful tool in the ED. Systematic approaches using POCUS for investigation of chest pain in the ED have been established.[1,2] These approaches evaluate pulmonary and cardiac pathologies, along with focused assessment of the proximal aorta. Thoracic aortic dissection (TAD) and thoracic aortic aneurysm (TAA) remain difficult diagnoses to make in the ED. Missed or delayed diagnoses cause harm, are of medicolegal concern and the subject of coronial inquests.[3,4] The role of POCUS in evaluating the thoracic aorta is emerging[5] but not yet routine or familiar to most clinicians. We present a systematic review of the diagnostic accuracy of EP POCUS for TAD and TAA and a synthesis of the associated literature with the aim of establishing the role of thoracic aorta POCUS in the ED.

Background

A minority of ED patients will present with symptoms of TAD or TAA with incidences of 3–4 and 6–10 cases per 100 000 patients per year, respectively.[6,7] Stanford type A TAD has a mortality rate of 1–2% per hour in the early stages of disease[8] and spontaneous TAA rupture is also a life-threatening diagnosis. Timely and accurate diagnosis of thoracic aorta pathologies remains challenging due to reliance on advanced imaging techniques. The International Registry of Acute Aortic Dissection reported a median door to diagnosis time of 4.3 h.[9] Tools such as the Aortic Dissection Detection Risk Score (ADD-RS) and D-dimer have shown high sensitivity,[10] however, are non-specific and patients with positive results must await definitive diagnosis with imaging.

Computed tomography angiography (CTA) is the gold standard for imaging of the thoracic aorta, with a sensitivity and specificity for TAD of 100% and 98%, respectively.[11] The limitations of CTA are that it may not be immediately available in busy or low-resourced EDs, exposes patients to ionising radiation and has a significant intravenous contrast burden. Magnetic resonance angiography (MRA) and transoesophageal echocardiography (TOE) are alternative imaging techniques with high diagnostic accuracy but are also resource intensive. The increasing expertise developing in EDs globally means a POCUS scan may be more readily available than CTA and has potential to reduce time to diagnosis.

The continuum of acute aortic syndromes (AAS) including penetrating atherosclerotic ulcer (PAU), intramural haematoma (IMH) and Stanford type A and B dissections are all diagnosed accurately with CTA. They can also be identified with POCUS, although PAU and IMH findings are subtle and require excellent image quality. Aortic dissection can be diagnosed with POCUS when an intimal flap is seen. POCUS can also increase suspicion by identifying indirect sonographic signs of TAD including pericardial effusion, aortic valve regurgitation and aortic dilation.[12] Example POCUS findings are demonstrated in Figure 1 and corresponding cineloops online in Appendix S1. International guidelines support transthoracic echocardiography (TTE) as an initial test for suspected aortic dissection.[12,13] Current guidelines do not highlight the opportunity for this to be done by POCUS trained EPs.

Proximal TAA can be diagnosed and is routinely monitored with TTE.[14] The aortic arch and distal descending thoracic aorta may also be seen with POCUS. The accuracy of POCUS for abdominal aortic aneurysm is high.[15] Currently the accuracy of POCUS for TAA is not well understood.

Methods

This review was designed to align with the Preferred Reporting Items for Systematic Review and Meta-Analysis of Diagnostic Test Accuracy guidelines.[16] A search to identify studies of accuracy of EP POCUS of the thoracic aorta was performed on Ovid Medline, PubMed, EMBASE, SCOPUS and Web of Science databases, the search strategy is shown in Appendix S2.

Papers were identified from search results and reviewing the reference lists of relevant papers. Papers published from 1 January 2000 to 22 August 2022 were considered. Inclusion criteria were studies of diagnostic accuracy of POCUS TTE for TAD or TAA, with scans performed at bedside in ED or by

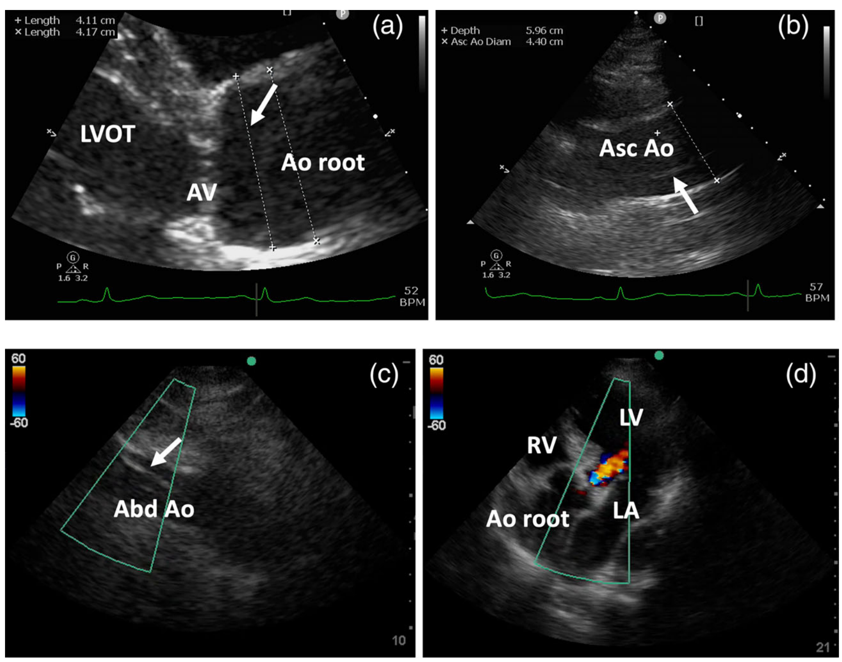

Figure 1. *(a) Parasternal long axis view demonstrating dilated aortic root measuring 4.11 cm correctly measured in diastole with leading edge to leading edge technique as indicated by arrow. (b) Long axis view of dilated ascending aorta measuring 4.40 cm with intimal flap present as indicated by arrow. (c) Long axis view of abdominal aorta demonstrating intimal flap indicated by arrow. (d) Apical five chamber view with colour doppler demonstrating aortic regurgitation in a patient with known Type A aortic dissection. No intimal flap is visible in this still image. Abd Ao, abdominal aorta; Ao root, aortic root; Asc Ao, ascending aorta; AV, aortic valve; LA, left atrium; LV, left ventricle; LVOT, left ventricular outflow tract; RV, right ventricle.*

EPs and diagnosis confirmed by CTA, TOE, MRA, surgical or autopsy findings. Abstracts in conference proceedings were included as full texts. Exclusion criteria were insufficient data for sensitivity and specificity analyses, case report or case series with fewer than 10 patients, review articles, trauma and peri-operative imaging studies, paediatric population, no reference imaging or surgical findings and full text not available in English.

Search results were imported into Covidence[17] (Veritas Health Innovation, Melbourne, Australia) review management software. WT and JEC reviewed papers by title and abstract, JH resolved conflicts. Full text were reviewed by WT and JEC; JH and DLH adjudicated conflicts by consensus. A QUADAS-2[18] assessment was completed for the included papers by consensus between WT and DLH. Where sensitivity, specificity or confidence interval data was not published but able to be imputed this was calculated with Python 3.10.7[19] (Scotts Valley, CA, USA) and indicated with a footnote. As a result of risk of bias assessment and the noted significant heterogeneities between studies including different diagnostic criteria meta-analysis was not appropriate.

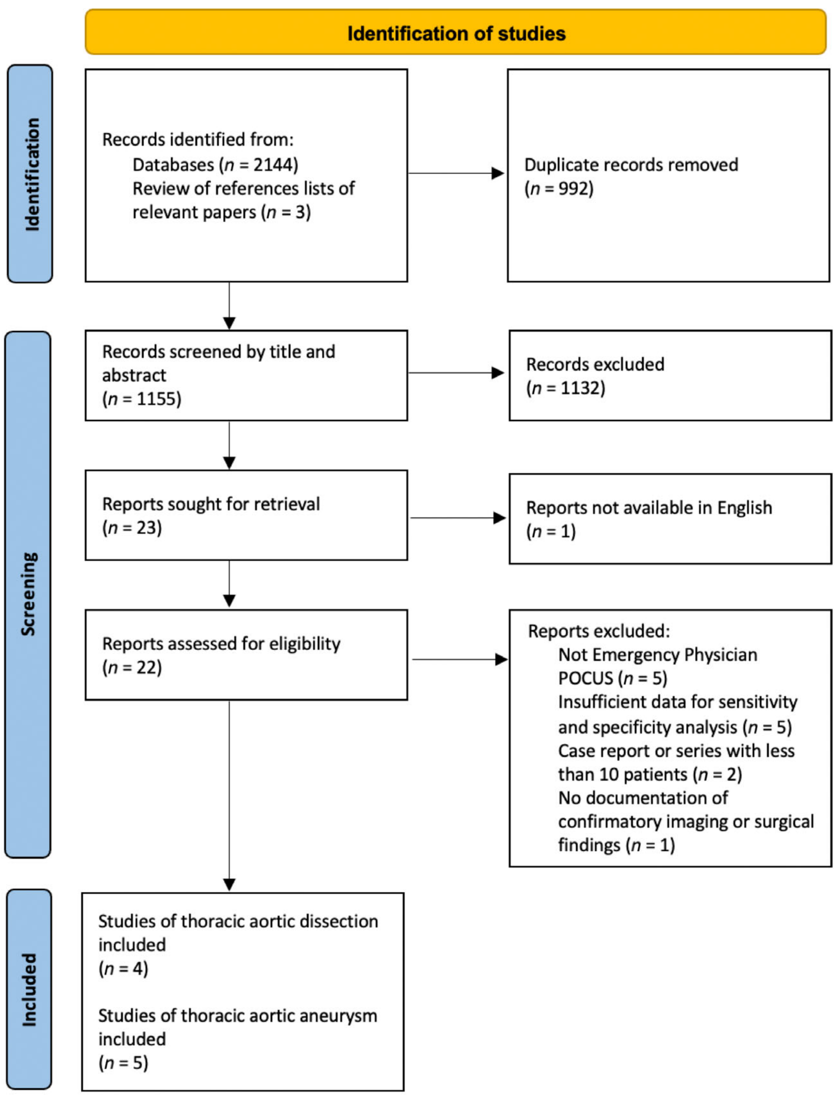

Figure 2. *Preferred Reporting Items for Systematic Review and Meta-Analysis diagram of flow of study selection for systematic review of diagnostic accuracy studies. Adapted from Page* et al.[16]

Results

Figure 2 demonstrates the flow of selection of studies. The search identified 1155 unique papers of which nine were eligible for data extraction. Characteristics of each study are displayed for TAD in Table 1 and TAA in Table 2. Diagnostic accuracy results are presented in Figures 3 and 4. Risk of bias was assessed with the QUADAS-2 tool in Appendix S3 and Appendix S4.

Thoracic aortic dissection

This review identified four papers examining POCUS for diagnosis of TAD.[20–23] Across all studies 1634 patients underwent POCUS, 169 were confirmed to have Type A dissection and 78 were diagnosed with Type B. One study was retrospective,[21] two were prospective single centre[20,23] and one was prospective multicentre.[22] The prospective multicentre study involved 170 cardiologist performed scans that were excluded from this review. The remaining scans performed by EPs or non-cardiologist physicians are included together. The remaining studies included only EP POCUS scans. Diagnostic criteria for TAD differed with two studies only including patients with direct signs of intimal flap[23] and IMH,[20] one diagnosed those with intimal flap, effusion or aortic dilation >35 mm[21] and one included direct signs of PAU, IMH, intimal flap or indirect signs and analysed accuracy for both direct and indirect signs.[22]

The diagnostic accuracy results have been separated into studies utilising direct signs alone and those using both direct and indirect sonographic signs. For studies using direct signs,[20,23] POCUS specificity was high with a range of 94–100%, however showed a wide range of sensitivity between 41–91%. The most recently published study by Wang *et al.*[23] had the highest sensitivity using direct signs, reporting 86% for Type A or Type B and 91% for Type A alone. The three studies using direct and indirect signs demonstrated higher sensitivity for TAD of

TABLE 1. *Characteristics of studies assessing the diagnostic accuracy of emergency physician point-of-care ultrasound of the thoracic aorta for thoracic aortic dissection*

	Study design and site(s)	Recruitment	Size of POCUS population (Type A/Type B dissection)	Exclusions	Investigator experience	Ultrasound machine(s)	Ultrasound view(s)	Sonographic signs	Reference standard(s)	Primary outcome(s)	Secondary finding(s)
Nazerian *et al.* (2014)	Prospective cohort – adult tertiary university hospital	Convenience sample of patients with compatible symptoms, who had CTA or TOE requested and underwent POCUS prior to CTA or TOE	281 (50/13) including IMH in corresponding aortic area for Type A	Nil reported	EPs with at least 2 years' experience	MyLab30 Gold (Esaote, Genova, Italy), Philips HD7 (Philips, Amsterdam, The Netherlands)	Left parasternal, left high parasternal, apical or subcostal	Intimal flap, IMH	CTA or TOE	POCUS detection of Type A or Type B TAD	ADD-RS >0 or any US sign sensitivity 96%, ADD-RS >1 with direct US sign specificity of 98% for Type A TAD
Gibbons *et al.* (2017) (Conference abstract only)	Retrospective cohort – single centre	Patients who underwent CTA and ultrasound post-implementation of ultrasound protocol	442 (12/16)	12 patients diagnosed without ultrasound, transfers, known TAD	Not stated	Not stated	TTE with an evaluation of the abdominal aorta	Intimal flap, pericardial effusion or aortic outflow >35 mm	CTA	POCUS detection of Type A or Type B aortic dissection	Nil
Nazerian *et al.* (2019)†	Prospective cohort – 5 tertiary centres in 4 countries	Patients with acute aortic syndrome considered in the differential who underwent POCUS prior to advanced imaging or surgery	839 (85/27) additional 20 IMH, 11 aortic rupture, 3 PAU	Nil reported, criteria were trauma and refusal	Cardiologists (170 patients) EPs/non-cardiologist physicians (669 patients) with >1 year ultrasound experience	MyLab5, MyLab30 Gold, MyLab Alpha (Esaote, Genova, Italy), Philips HD7 (Philips, Amsterdam, The Netherlands), Vivid S5 or Vivid S6 (GE Healthcare, Wauwatosa, USA)	>1 of left/right parasternal, apical, suprasternal, subcostal, abdominal, and view for carotid arteries	Intimal flap, IMH, PAU, aorta >40 mm, pericardial effusion or aortic regurgitation	CTA, TOE, MRA, surgery or autopsy	POCUS detection of acute aortic syndrome	ADD-RS ≤1, no POCUS signs and D-dimer <500 ng/mL showed 100% sensitivity for rule out of acute aortic syndrome
Wang *et al.* (2020)	Prospective cohort – university hospital	Convenience sample of patients highly suspected of having dissection by medical staff	72 (22/22)	Nil reported, criteria were refusal, trauma, cardiac arrest at arrival	EPs/Residents underwent 1 week training with 20 practice exercises of heart, blood vessel and abdominal POCUS	Philips CX50 (Philips, Amsterdam, The Netherlands)	Short and long axis views from parasternal, inferior xiphoid, suprasternal sites	Intimal flap visible in multiple views	CTA	POCUS detection of Type A or Type B aortic dissection	Reduced door to diagnosis time of 10.5 min *vs* 79 min for non-POCUS, no significant reduction in time to targeted treatment

†Sub-analysis of sensitivity and specificity for 669 EP/non-cardiologist physician performed POCUS was performed. ADD-RS, Aortic Dissection Detection Risk Score; CTA, computed tomography angiography; EP, emergency physician; IMH, intramural haematoma; MRA, magnetic resonance angiography; PAU, penetrating atherosclerotic ulcer; POCUS, point-of-care ultrasound; TAD, thoracic aortic dissection; TOE, trans-oesophageal echocardiography.

TABLE 2. *Characteristics of studies assessing the diagnostic accuracy of emergency physician point-of-care ultrasound of the thoracic aorta for dilation and aneurysm*

	Study design and site(s)	Recruitment	Cohort size (aorta >40 mm/ >45 mm)	Exclusions	Investigator experience	Ultrasound machine(s)	Ultrasound view(s)	Measurement site(s)	Reference standard	Primary outcome(s)	Secondary finding(s)
Taylor *et al.* (2012)	Retrospective cohort study – urban academic hospital	Retrospective chart review of patients who had CTA and POCUS for suspected thoracic aorta pathology	82 (26/14)	10 with inadequate image quality	Recorded images analysed by 3 fellowship trained investigators	Philips HD11XE, Philips Envisor HD (Philips, Amsterdam, The Netherlands) or Zonare One Ultra SP (Zonare, Mountain View, USA)	Parasternal long axis	Sinus of valsalva, sinotubular junction and largest visible part of the proximal ascending aorta	CTA overread by a single radiologist with expertise in cardiothoracic imaging	POCUS detection of thoracic aorta diameter >40 mm or >45 mm	Nil
Arshad *et al.* (2013) (Conference abstract only)	Prospective cohort study – urban academic hospital	Convenience sampling of patients presenting to the ED who underwent POCUS and CTA for suspected aortic pathology	32 (4)	Not stated	EPs with various skill levels	Not stated	Not stated	Proximal thoracic aorta	CTA assessed by single radiologist	POCUS detection of thoracic aorta diameter >40 mm	Nil
Kinnaman *et al.* (2013) (Conference abstract only)	Prospective cohort study – urban academic hospital	Any patient in ED who underwent CTA	21 (2)	Not stated	EPs, experience not stated	Not stated	Parasternal long axis and suprasternal notch view (SSNV)	Sinus of valsalva, sinotubular junction, ascending aorta and aortic arch (from SSNV)	CTA assessed by attending radiologists	POCUS detection of thoracic aorta diameter >40 mm	Obtaining SSNV rated easy in 60% and difficult in 20%
Nazerian *et al.* (2015)	Prospective cohort study – adult tertiary university hospital	Convenience sampling of adult ED patients undergoing CT for suspicion of thoracic aorta pathology	140 (56/27)	12 excluded as ultrasound not feasible and 3 did not consent, trauma patients excluded	3 EPs with more than 5 years POCUS experience and 4 EPs with between 2 and 5 years experience	MyLab Alpha, MyLab30 Gold (Esaote, Genova, Italy) or Philips HD7 (Philips, Amsterdam, The Netherlands)	Parasternal long axis	Aortic root and ascending aorta at widest point	CTA overread by a single radiologist with expertise in cardiothoracic imaging	POCUS detection of thoracic aorta diameter >40 mm or >45 mm	Acute aortic syndrome in 14 of 34 patients with aortic aneurysm on CTA and 5 of 106 without aneurysm

TABLE 2. *Continued*

	Study design and site(s)	Recruitment	Cohort size (aorta >40 mm/ >45 mm)	Exclusions	Investigator experience	Ultrasound machine(s)	Ultrasound view(s)	Measurement site(s)	Reference standard	Primary outcome(s)	Secondary finding(s)
Kinnaman *et al.* (2016)	Prospective cohort study – urban academic hospital	Convenience sampling of adult ED patients undergoing clinically indicated CTA	79 (7)	97 recruited and 18 patients excluded by ultrasound data loss	4 EPs with fellowship training and 1 senior resident, training sessions with chief sonographer or video and 20-min practice	Zonare Z.one Ultra (Zonare, Mountain View, USA), Philips CX30 or Philips CX50 (Philips, Amsterdam, The Netherlands)	POCUS examination with SSNV	Sinus of valsalva, sinotubular junction, ascending aorta and thoracic aortic arch (from SSNV)	CTA assessed by 2 blinded emergency radiologists	POCUS detection of thoracic aorta diameter >40 mm	Obtaining SSNV rated easy in 64.5% and unable to obtain in 2.5%

CT, computed tomography; CTA, computed tomography angiography; EP, emergency physician; POCUS, point-of-care ultrasound; SSNV, suprasternal notch view.

88–96% with a reduction in specificity to 56–91%.[20–22]

Thoracic aortic aneurysm

Five papers were identified evaluating POCUS to diagnosis of TAA[24–28] comprising 354 patients with 95 (26%) having aortic dilation >40 mm. Two studies also analysed dilation >45 mm, present in 41 (18%) of 222 patients.[26,28] Taylor *et al.*[27] recruited retrospectively all patients who had received CTA and POCUS. Kinnaman *et al.*[24] reported prospectively recruiting a modest 21 consecutive patients with the others using convenience sampling requiring availability and notification of investigators. Two of the included studies had significant proportions of their patients excluded due to data loss[25] or poor image quality.[27] All scans were performed by EPs or EP residents, although the ultrasound training and experience is unclear in two studies.[21,24] No studies explicitly reported assessing the descending thoracic aorta for dilation. The aortic root was measured at either the sinuses of Valsalva, the sinotubular junction or both sites. The aortic root was measured in all studies, the ascending aorta and root in two[26,27] and, the ascending aorta, root and arch from the suprasternal notch view in two.[24,25] All studies compared POCUS to a measurement made on CTA by at least one radiologist.

POCUS specificity was high ranging between 93–100% for dilation >40 mm, and 95–99% for the two studies of dilation >45 mm. Sensitivity varied widely from 50–100% between studies and much broader confidence intervals were reported in each study. For the two studies examining >45 mm diameter sensitivities were 64%[27] and 65%,[26] respectively.

Discussion

Thoracic aortic dissection

Our review found a wide range of sensitivity results for TAD. The sensitivity is low when direct signs are used as the diagnostic threshold. Given the rate of positive CTAs for suspected AAS is low[29] a potential role for POCUS could be to risk-stratify and triage urgency of

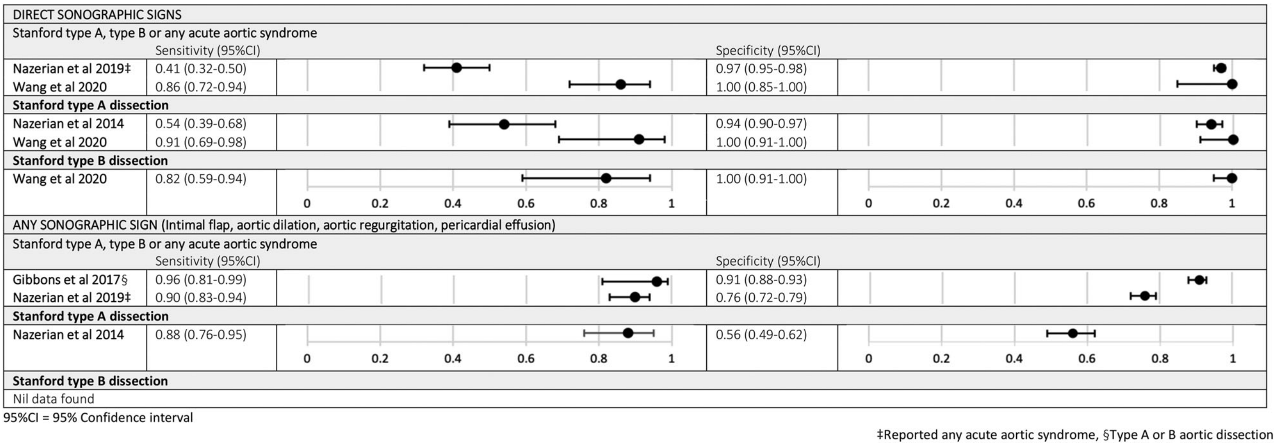

Figure 3. *Forest plot of diagnostic accuracy of emergency physician point-of-care ultrasound studies assessing thoracic aortic dissection with either direct or both direct and indirect sonographic signs.*

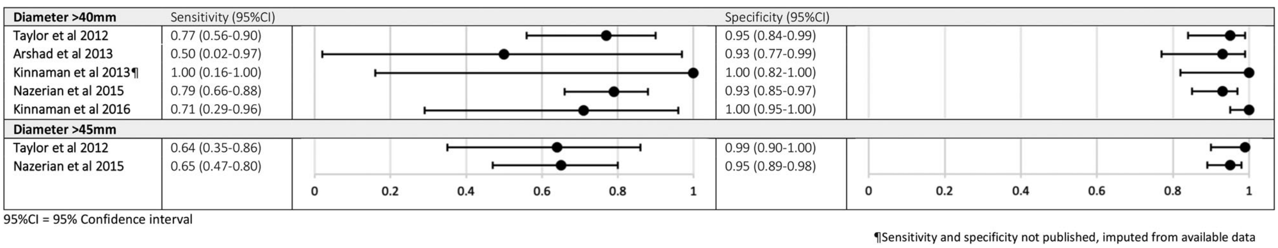

Figure 4. *Forest plot of diagnostic accuracy of emergency physician point-of-care ultrasound studies assessing thoracic aortic dilation >40 mm and >45 mm.*

advanced imaging. If POCUS is used as a risk-stratification tool for patients prior to advanced imaging it may be more appropriate to consider any sonographic sign as a positive scan for TAD. As expected, our results suggest a higher sensitivity of between 88% and 96% in the three studies which include indirect signs.[20–22] This is clearly due to POCUS having exceptionally high sensitivity for pericardial effusion[30] and aortic valve regurgitation, which are present in 46%[31] and 50%[13] of Type A TAD, respectively.

AAS is an overarching term for the acute atherosclerotic aortic pathologies. Nazerian *et al.*[22] included PAU, identified as a crater-like outpouching in the aortic wall, and two studies[20,22] included IMH, seen as crescentic or circumferential aortic wall thickness of >5 mm, as positive POCUS findings. TTE is not recommended as the sole modality to evaluate for these subtle aortic pathologies.[13] When PAU and IMH are suspected, progression to advanced imaging is mandatory.

There is a paucity of data available for diagnosis of Type B aortic dissection with EP POCUS. Type B dissection is less accurately diagnosed on cardiologist performed TTE[32,33] due to difficulty visualising the descending aorta. Wang *et al.*[23] analysed direct signs for Type B dissection, showing a lower sensitivity than for Type A dissection, consistent with findings from studies of cardiologist performed TTE.

Bicuspid aortic valve (BAV) is not examined in the included studies. BAV affects 1–2% of the population,[34] can be diagnosed with POCUS and is a risk factor for both TAD and TAA. Incidence of aortic dilation is reported between 40% and 83% in patients with BAV[35,36] and aneurysm expansion rate is faster. BAV increases relative risk of TAD by 8.4 times; however, the overall risk of aortic dissection remains low in absolute terms at 30 per 100 000 patients per year.[37] In patients with BAV aortic pathology must be suspected, particularly when aorta visualisation is poor.

Thoracic aortic aneurysm

We have found that POCUS is specific for aortic dilation >40 mm and >45 mm. Although, we are unable to meta-analyse sensitivity appears lower and with less consistent results between studies. None of the included studies examined the descending thoracic aorta for aneurysm and only two examined the arch. The descending thoracic aorta is prone to aneurysmal disease and should be comprehensively evaluated where possible.

Previously published POCUS guidelines have endorsed the definition of thoracic aorta diameter >40 mm as borderline and >45 mm as aneurysmal.[1] The typical definition of aneurysm at other sites is a 50% increase in vessel diameter; however, there is little outcome evidence to support use of this definition for the thoracic aorta[13] as dissection or rupture may occur at diameters with <50% dilation. TTE measurement of the thoracic aorta diameter is made perpendicular to the vessel with a leading edge to leading edge measurement[38] and indexed using an aortic diameter to body surface area ratio with a normal limit of <2.1 cm/m^2 in the ascending aorta and <1.6 cm/m^2 in the descending thoracic aorta.[39] The indexing of aortic diameters to BSA is not widely used in POCUS, likely due to time constraints, and studies have consequently defaulted to use of the fixed limits of 40 mm or 45 mm.

This use of a >40 mm measurement for diagnosing dilation is reasonable for patients with a BSA within 1–2 standard deviations of the mean[38] and is a significant POCUS finding. Detection of thoracic aorta dilation >40 mm has a sensitivity of 59% for AAS in symptomatic patients.[22] Aortic dilation is an independently specific finding for TAD with a specificity of approximately 86% on TTE[22,40] and in one study 91% on CTA.[41]

Spontaneous TAA rupture occurs less frequently than TAD; however, the annual TAA rate increases sharply at >60 mm to 3.7% per year.[14] A practical approach for POCUS is: TAD and rupture risk increase with aorta diameter represented by annual rates of 2% for aorta 30–49 mm (with almost no rupture risk), 3% for 50–59 mm and 6.9% for ≥60 mm.[14] The caveat is that Type B dissections have a bimodal distribution and occur more commonly between 40–49 mm and >60 mm.[42] Detection of thoracic aorta dilation >40 mm at any site appears to be a reasonable threshold to increase suspicion of serious aortic pathology in the ED.

Point-of-care ultrasound compared to cardiologist performed TTE

The definition of POCUS differs between professional organisations.[43] The studies we have included were assessing EP performed POCUS. Nazerian *et al*.[22] performed sub-analysis of 170 cardiologist TTEs with 669 non-cardiologist POCUS scans. They found that cardiologists had increased sensitivity for detecting direct sonographic signs of AAS of 70% *versus* 41%. The sensitivity when indirect signs were included was not significantly different between cardiologists and POCUS clinicians with >1 year ultrasound experience. Importantly, POCUS and cardiologist scans were equally specific for AAS. Toksul *et al*.[44] also reported reasonable concordance between cardiologists and EPs assessing aortic root dilation with 92.1% agreement. While further studies are required, this initial data suggests that positive thoracic aorta POCUS findings may be interpreted with comparable confidence to those of cardiologist TTE.

Time to diagnosis, intervention and disposition

Given the high mortality rate of TAD in the early stages outcomes may improve with prompt diagnosis. Wang *et al*.[23] found a time to diagnosis of 10.5 min for patients receiving POCUS compared to 79 min for CTA. There was no difference in time to targeted treatment with medication for heart rate or blood pressure control. Pare *et al*.[45] retrospectively analysed TAD patients and also showed a reduced time to diagnosis of 80 min in the POCUS group *versus* 226 min in non-POCUS. They also showed a reduced misdiagnosis rate of 0% compared to 44%, however were underpowered to prove a mortality benefit or time to disposition benefit with only 32 patients. Možina *et al*.[46] analysed 27 cases of TAD over a 2-year period, again no significant improvement in time to disposition with POCUS was proven.

The above studies confirmed their diagnoses with CTA. Some centres are now proceeding straight to the operating theatre after diagnosis of TAD with cardiologist TTE.[12,32,47,48] As described previously, the specificity of cardiologist and EPs is similar. Proceeding directly to theatre after positive EP POCUS is yet to be studied. This direct to surgery approach is safety-netted by diagnosis confirmation with pre-operative TOE. Pre-operative TOE is current best-practice for TAD diagnosed by any method[13] and is highly accurate with sensitivity and specificity of 98% and 95%.[11]

An approach to thoracic aorta POCUS

A standardised scanning approach describing appropriate views for imaging of the thoracic aorta may be helpful in guiding novice clinicians and future research. One proposed approach is the 'Four S's'.[49] The Four S's are Superior intercostal space (viewing the ascending aorta), Small scale long-axis (descending thoracic aorta), Subxiphoid (inferior descending thoracic and abdominal aorta) and Suprasternal (aortic arch). This evaluates the full extent of the thoracic aorta that is usually visible with ultrasound. It is the upper half of the descending thoracic aorta that is most difficult to assess with ultrasound. This area is visible in just 71% of patients undergoing TTE and due to the oblique nature of the view measurements are less accurate than for other aortic segments.[50]

After assessing the thoracic aorta consideration should be given to scanning the abdominal aorta for pathology. While isolated abdominal aortic dissection is rare, representing just 1.3% of all aortic dissections,[51] dissection flaps from more proximal TAD will frequently extend into the abdominal aorta where they may be visualised. Thus, to maximise sensitivity we recommend that when time permits a comprehensive assessment should include views of the ascending aorta, aortic arch, descending thoracic and abdominal aorta to the level of the common iliac arteries.

It is important that clinicians performing POCUS are cognisant of the potential false positive findings. Reverberation and side lobe artefacts may display linear structures within the aortic lumen on ultrasound.[52] The presence of intimal flap should be confirmed by visualising a flap on two different views.

When assessing for TAD, the detection of pericardial effusion and aortic regurgitation may also represent false positives. Asymptomatic pericardial effusions are a common finding in the elderly and were present in more than 10% of men and 17% of women over 70 years of age in the Framingham study.[53] The majority of effusions will be idiopathic, inflammatory, infective or neoplastic[54] and require careful evaluation when detected even in the absence of TAD. Similarly aortic regurgitation is a common finding with the prevalence of mild, moderate or severe aortic regurgitation being approximately 15% in people over 70 years of age.[55] Most of these cases will represent primary valvulopathy and not secondary dysfunction due to aortic dissection or dilation.

POCUS, Aortic Dissection Detection Risk Score and D-dimer algorithms

An integrated approach with ADD-RS or D-dimer and POCUS may represent an opportunity to improve TAD diagnostic accuracy. D-dimer as an independent test for AAS has a sensitivity of 95–96%.[56,57] Combining ADD-RS ≥1 with D-dimer or ADD-RS ≥2 with D-dimer increases sensitivity above either ADD-RS or D-dimer alone for detecting AAS.[10,58] A successful algorithm incorporating POCUS could improve specificity compared to ADD-RS or D-dimer alone.

We located four papers examining TTE or POCUS and ADD-RS. Chiang *et al.*[59] retrospectively analysed Type A TAD patients who had TTE performed. They found that 81 of their 88 patients were detected by either positive ADD-RS or TTE finding of aortic dilation or effusion. Twenty of these were missed by ADD-RS alone. Another retrospective study of 239 patients with acute chest pain used ADD-RS and ascending aorta diameter >40 mm on TTE to determine risk of ascending TAD.[40] They found that addition of aorta diameter to ADD-RS ≥1 increased specificity from 9% to 88% for ADD-RS ≥1 alone. This corresponded with a reduction in sensitivity to 85% from 95%. ADD-RS ≥2 with aorta >40 mm was highly specific at 98% in their study. In 2014, Nazerian *et al.*[20] found ADD-RS ≥2 with direct sonographic signs was also 98% specific, increased from 81% for ADD-RS alone. Nazerian *et al.*[22] in 2019 showed 100% sensitivity in a low-risk population using ADD-RS ≤1 combined with a negative D-dimer, with POCUS detecting direct sonographic signs in the patients with false-negative D-dimer.

Morello *et al.*[60] recently proposed an algorithm integrating POCUS with ADD-RS and then D-dimer sequentially in the potential rule out of AAS without advanced imaging. Their approach highlights two potential roles for POCUS in improving evaluation of potential AAS patients. The first role of POCUS in the algorithm is in haemodynamically unstable patients where POCUS may be applied rapidly to identify features of AAS potentially reducing time to diagnosis without delaying urgent CTA. The second role is in haemodynamically stable patients where POCUS findings and ADD-RS scoring could be combined to determine patient risk prior to proceeding with CTA or rule-out D-dimer. A foreseeable advantage of this pathway structure is the application of POCUS early in the algorithm may reduce time to diagnosis compared to patients being delayed awaiting positive D-dimer results before initiating further AAS investigation.

Quality of evidence

Aortic pathologies in the ED are rare and this contributes to the limited quantity and quality of available evidence. In studies of diagnostic accuracy POCUS populations were small with fewer than 100 patients scanned in five of nine studies.[23–25,27,28] The use of convenience sampling was frequent.[20,23,25,26,28] Additionally, all prospective studies required EPs to suspect aortic pathology prior to recruitment, potentially failing to identify patients with mild or atypical symptoms. In particular the potential for selection bias is noted in Wang *et al.*[23] reporting 44 aortic dissections from 72 patients, a much higher prevalence than could be expected in a usual ED population.

Two studies by Kinnaman *et al.*[24,25] were noted to have a recruitment period that had a 1-month crossover; however, they had different recruitment techniques. Given meta-analysis was not performed, both papers are still presented in the results. Diagnostic accuracy studies had heterogeneous methods including variations in diagnostic criteria, measurement sites, POCUS clinician experience and ultrasound views. A strength of all the studies was the use of accurate reference standards to confirm diagnoses.

Limitations

We have reviewed POCUS performed on the thoracic aorta via a transthoracic approach in our search as abdominal aorta POCUS is well established in practice. We have not included any papers which solely examined the abdominal aorta. Despite this some papers in our review included subxiphoid or abdominal aorta assessments as a part of their protocol. Multiple studies included in this review contained limited descriptions of the training and experience of clinicians performing the POCUS assessments. This may reduce the generalisability of our findings. Another limitation is that we have not been able to perform meta-analysis of the included studies.

Conclusion

POCUS cannot be used in isolation to rule-out AAS in the ED. Despite this we still suggest that when time permits thoracic aorta POCUS scans should be performed in a comprehensive and systematic manner to examine the full length of the visible aorta and maximise its potential sensitivity. It is possible that combining POCUS with D-dimer or ADD-RS will be established as a safe rule-out approach in future studies.

POCUS is specific for TAA as well as for TAD when an intimal flap is seen. Indirect signs of TAD are less specific but identification of aortic diameter >40 mm at any site should increase suspicion of aortic pathology. In the correct clinical context visualisation of any indirect signs should trigger up-triage of pending advanced imaging requests.

Thoracic aorta POCUS can reduce time to diagnosis although it has not yet been demonstrated to reduce time to treatment or disposition. Hastened diagnosis of these time-critical pathologies would be expected to improve morbidity and mortality if it can reduce time to intervention. Given the increasing expertise available in EDs and improvements in image quality with modern ultrasound technology further prospective research is warranted with larger populations.

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Competing interests

None declared.

Data availability statement

The data that supports the findings of the present study are available in the supplementary material of this article.

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Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Appendix S1. Cineloop example findings in point-of-care ultrasound of the thoracic aorta.
Appendix S2. Search strategy for systematic review.
Appendix S3. QUADAS-2 bias risk assessment of emergency physician point-of-care ultrasound studies for thoracic aorta dissection.
Appendix S4. QUADAS-2 bias risk assessment of EP POCUS studies for thoracic aorta dilation and aneurysm.