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ORIGINAL ARTICLE

The sonographic protocol for the emergent evaluation of aortic dissections (SPEED protocol): A multicenter, prospective, observational study

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Abstract

Objectives: An aortic dissection (AoD) is a potentially life-threatening emergency with mortality rates exceeding 50%. While computed tomography angiography remains the diagnostic standard, patients may be too unstable to leave the emergency department. Investigators developed a point-of-care ultrasound (POCUS) protocol combining transthoracic echocardiography (TTE) and the abdominal aorta. The study objective was to determine the test characteristics of this protocol.

Methods: This was an institutional review board–approved, multicenter, prospective, observational, cohort study of a convenience sample of adult patients. Patients suspected of having an AoD received a TTE and abdominal aorta POCUS. Three sonographic signs suggested AoD: a pericardial effusion, an intimal flap, or an aortic outflow track diameter measuring more than 35 mm. Investigators present continuous and categorical data as medians with interquartile ranges or proportions with 95% confidence intervals (CIs) and utilized standard 2×2 tables on MedCalc (Version 19.1.6) to calculate test characteristics with 95% CI.

Results: Investigators performed 1314 POCUS examinations, diagnosing 21 Stanford type A and 23 Stanford type B AoD. Forty-one of the 44 cases had at least one of the aforementioned sonographic findings. The protocol has a sensitivity of 93.2% (95% CI 81.3–98.6), specificity of 90.9 (95% CI 89.2–92.5), positive and negative predictive values of 26.3% (95% CI 19.6–33.9) and 99.7% (95% CI 99.2–100), respectively, and an accuracy of 91% (95% CI 89.3–92.5).

Conclusions: The SPEED protocol has an overall sensitivity of 93.2% for AoD.

KEYWORDS
aortic dissection, point-of-care ultrasound

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INTRODUCTION

An aortic dissection (AoD) results from a disruption in the medial layer of the aorta typically secondary to an intimal tear.[1] Stanford type A dissections (A-AoD) involve the ascending aorta, whereas Stanford type B ones (B-AoD) involve the descending aorta only.[1] Mortalities can exceed 50% based on time to diagnosis and treatment as well as associated complications.[1,2] While abrupt-onset chest and/or abdominal pain is present in 70%–85% of cases, history and physical examination lack adequate sensitivity and specificity given the myriad of nonspecific signs and symptoms associated with AoD, including dyspnea, syncope, neurovascular deficits, and even case reports of asymptomatic presentations.[1–9]

Timely and accurate diagnosis reduces mortality by approximately 30%–60%.[1,2] However, the aforementioned nonspecific signs and symptoms often mimic other pathology causing misdiagnosis and treatment delays 16%–39% of patients.[3–5] In fact, a study by Sullivan et al.[10] found that emergency physicians (EPs) evaluating confirmed cases of AoD only suspected it in 43% of instances. With sensitivities exceeding 95% computed tomography angiography of the chest, abdomen, and pelvis (CTA-CAP) is considered the criterion standard diagnostic imaging modality.[1] However, patients are often too unstable to leave the emergency department (ED). Therefore, numerous studies have assessed various other diagnostic methods, including transesophageal echocardiogram (TEE), D-dimer, and magnetic resonance imaging/angiography (MRI/MRA). While each has a sensitivity exceeding 95% for A-AoD, most are not readily available.[1] Transthoracic echocardiography (TTE) has been well studied in A-AoD with sensitivities between 52% and 90% and specificities of 63%–100%.[1] Data are more limited with respect to B-AoD, but evidence demonstrates sensitivities between 33% and 70%.[1]

Given the diagnostic challenge and high mortality associated with AoD, the American College of Cardiology and the American Heart Association developed an AoD detection risk score system yielding a sensitivity >95% but a limited specificity <40%.[11,12] Additional studies combining TTE and/or D-dimer with the AoD scoring system have demonstrated similar or worse sensitivities.[13–16] Overall, the negative predictive values remain <80% resulting in potentially unnecessary imaging.[11–16] Moreover, the American College of Emergency Physicians (ACEP) does not recommend the routine use of clinical decision rules in suspected cases of AoD.[17]

More recent studies have assessed EP-performed TTE POCUS for AoD. Nazerian et al.[18] demonstrated a sensitivity of 88% for A-AoD. More importantly, Pare et al.[19] demonstrated that the immediate availability of POCUS reduced the time to diagnosis an AoD by 145 min.

The primary objective of this study was to determine the test characteristics of the sonographic protocol for the emergent evaluation of aortic dissections (SPEED), which combines EP-performed TTE and point-of-care ultrasound (POCUS) of the abdominal aorta at diagnosing A-AoD and B-AoD.

METHODS

Study design

This was an institutional review board–approved, prospective, observational, multicenter, cohort study conducted at three clinically diverse EDs of an urban, university health system with >200,000 adult and pediatric visits annually. Investigators followed STROBE and STARD guidelines and checklists for observational studies assessing diagnostic tests. Investigators received no funding.[20,21] All emergency medicine attending physicians are credentialed in the core POCUS applications as defined by the ACEP.[22]

Study setting and population

From January 1, 2010, through December 31, 2019, investigators enrolled a convenience sample of adult patients with clinically suspected Stanford type A or B AoDs prior to performing a POCUS or CTA. Exclusion criteria included patients unable to consent, those with a preexisting or traumatic AoD, and individuals who did not receive a POCUS evaluation prior to advanced imaging, i.e., CTA, MRA, or TEE.

Study protocol

The decision to perform the POCUS protocol was based on the discretion of the attending emergency physician who did not utilize a clinical decision rule or D-dimer.[11–16] Upon enrollment, a unblinded PGY-1 to -3 emergency medicine (EM) resident performed the POCUS examination. The protocol included a parasternal long-axis (PSLA) view using the phased array transducer as well as (2) transverse and sagittal scans of the abdominal aorta, using the curvilinear transducer, from the diaphragmatic hiatus to the bifurcation into the common iliac arteries. The protocol did not include a suprasternal view or mandate the use of color flow or pulsed-wave Doppler. An EM attending reviewed each study concurrently. Three ultrasound fellowship–trained physicians evaluated all sonographic images during weekly quality assurance (QA) to assess the accuracy of each scan. Utilizing one of the following, a GE Loqiq E9 or a SonoSite Edge or M-turbo, EM residents completed all POCUS scans prior to obtaining advanced imaging. Reference diagnostic standards included CTA-CAP, MRI/MRA, or cardiology-performed TEE.

Prior to starting their internship, our EM residents participate in a 4-h introductory POCUS course taught by our emergency ultrasound faculty. Additionally, each resident completes a 3-week emergency ultrasound rotation during their internship in accordance with Accreditation Council for Graduate Medical Education and ACEP guidelines.[22,23] Residents received no additional formal training prior to their study participation aside from bedside teaching throughout their residency training.

Measurements

Prior to study commencement, we defined three sonographic findings consistent with a A-AoD: the presence of either a pericardial effusion or intimal flap or an aortic outflow track (AOFT) diameter greater than 35 mm measured from inner wall to inner wall within 20 mm of the aortic annulus during end-diastole (Figure 1).[24,25] We did not utilize M-mode per current evidence-based guidelines.[24] In the abdominal aorta, the presence of an undulating intimal flap suggested a B-AoD.

The primary objective of this study was to determine the test characteristics of a sonographic protocol at diagnosing Stanford type A and B AoDs. Secondary endpoints included the test characteristics of each individual sonographic findings.

Data analysis

CTA, MRA, and TEE have sensitivities >95% for both types of AoD and cardiology-performed TTE has a sensitivity >95% for A-AoD. POCUS has a sensitivity between 80% and 90% for A-AoD and between 33% and 70% for B-AoD.[1,18,26] Therefore, we hypothesized an estimated difference in sensitivities of 35% between the POCUS protocol (60% sensitivity) and advanced imaging (95% sensitivity) for both types of AoD. Based on a power of 80%, a beta of 0.20, and an alpha of 0.05, investigators calculated a sample size of 42 positive cases. We report continuous and categorical data as means or medians with interquartile ranges (IQRs) or proportions with 95% confidence intervals (CIs) and utilized standard 2×2 tables on MedCalc (Version 19.1.6) to calculate test characteristics with 95% confidence intervals.[27]

RESULTS

During the study period, 103 emergency medicine resident physicians performed 1314 sonographic protocols for suspected AD, supervised by 41 different EM attending physicians. Table 1 reviews patient characteristics. Figure 2 depicts the patient flow chart. EPs diagnosed 21 Stanford type A and 23 Stanford type B. Forty-one of the 44 cases had at least one of the aforementioned sonographic findings. Table 2 summarizes the protocol test characteristics for all AoD types combined and for Stanford type A and B, individually. Table 3 reports the test characteristics of each sonographic finding for A-AoD. Notably, the mean AOFT measurement was 45.1 mm (39.8–50.5) for A-AoD.

EPs missed three B-AoDs when performing the SPEED protocol. Two involved only the descending thoracic aorta and did not extend below the diaphragmatic hiatus. During QA review, ultrasound faculty did not visualize an intimal flap in the descending aorta in the PSLA window. The other missed B-AoD was a 26-mm infrarenal dissection. Images were not available for QA.

DISCUSSION

An undulating intimal flap is a direct sign of AoD.[16] Precursors include intramural hematoma and penetrating ulceration.[1,6,24,26] TTE has limited sensitivity for the latter two, especially without contrast enhancement.[24,26,28] Our results suggest that EPs can accurately detect an undulating intimal flap in the abdominal aorta. In fact, they had a positive predictive value of 100% for this sign. Although only identified in 75% of the patients in this study, once identified, it can hasten the time to specialty consultation and definitive care for the patient.

Assessing for the presence of indirect signs of AoD, including AOFT and pericardial effusion, improves sensitivity. Current evidence-based guidelines regarding AOFT dimensions recommend utilizing the standard leading edge to leading edge technique during end diastole within 20 mm of the aortic valve, typically at the sinuses of Valsalva, which measure between 24 and 40 mm on average.[24,25] Moreover, guidelines discourage M-mode given it underestimates the diameter by 1–2 mm.[24] Additional expert opinion advocates calculating the distance from inner wall to inner wall to improve accuracy.[24,25] The majority of A-AoDs have an AOFT > 40 mm.[16,19,29,30] However, studies have demonstrated that 7%–40% of patients with A-AoD have a diameter of <40 mm but none below 35 mm.[16,19,29,30] Therefore, we chose the inner wall to inner

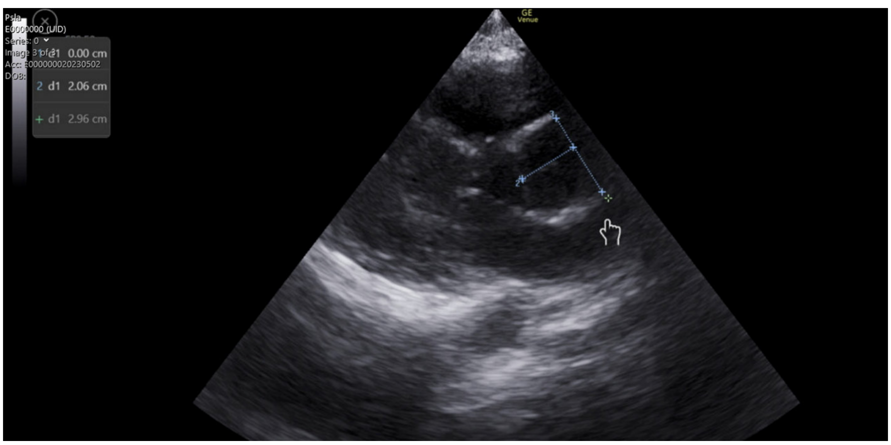

FIGURE 1 Parasternal long axis (PSLA) view with aortic outflow (AOFT) measurements.

TABLE 1 Patient characteristics.

	A-AoD (*n* = 21)	B-AoD (*n* = 23)	Non-AoD (*n* = 1270)
Age (years)	63 (44–87)	57 (44–90)	59 (25–97)
Gender			
Female	7 (33.3)	9 (39.1)	622 (49)
Male	14 (66.7)	14 (60.9)	648 (51)
Symptoms			
Chest pain	13 (61.9)	10 (43.5)	724 (57)
Back pain	7 (33.3)	12 (52.2)	228 (18)
Abdominal pain	4 (19)	10 (43.5)	381 (30)
Sonographic findings			
AOFT > 35 mm	15 (71)	0	103 (8)
Pericardial effusion	13 (62)	0	12 (1)
Intimal flap (visible)	13 (62)	20 (87)	0 (0)

Note: Data are reported as median (IQR) or *n* (%).

Abbreviations: A-AoD, Sanford type A aortic dissection; AoD, aortic dissection; AOFT, aortic outflow track; B-AoD, Sanford type B aortic dissection.

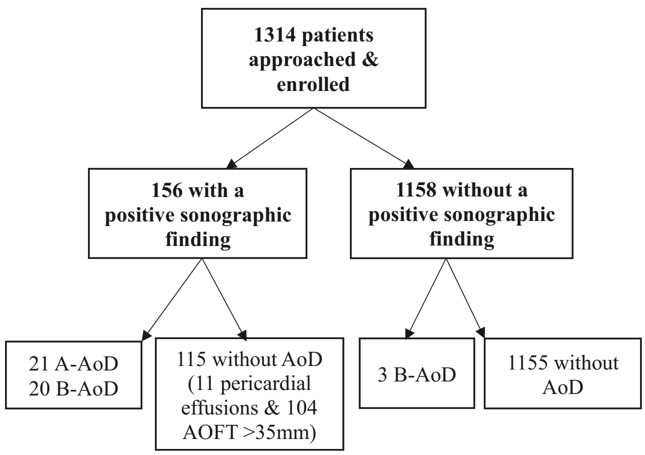

FIGURE 2 Patient flow chart.

wall method and defined 35 mm as abnormal to improve our sensitivity. Studies have shown appropriate correlation between AOFT measurements calculated with TTE POCUS and CTA.[31,32] In fact, Taylor et al.[31] demonstrated that TTE POCUS was within 0.6 mm of CTA. While a study by Nazerian et al.[32] indicated that EPs underestimate AOFT diameters in fewer than 10% of suspected cases of aortic root dilation. Our results show using 35 mm as the cutoff for AOFT resulted in 100% sensitivity for type A-AoD, potentially being a reasonable way to screen out A-AoD in patients if this finding is replicated in future studies.

The SPEED protocol facilitates a timely, accurate, and safe diagnostic means for AoD. Similar to prior studies assessing TTE, our sonographic protocol was 100% sensitive for A-AoD. Atypical presentations account for misdiagnosing 16%–39% of patients with AoD and subsequent increased morbidity and mortality.[1–5] In fact, mortality increases by 1%–2% hourly from symptom onset.[6,26] A review of the International Registry of Acute Aortic Dissection demonstrated that the average time to diagnosis is 4.3 h with an additional 4.3 h before surgical intervention.[33] Although this study did not measure time to diagnosis, Pare et al.[19] demonstrated a reduction of 143 min to diagnosis by implementing a POCUS first approach.

Numerous case reports advocate for additional sonographic images, including the suprasternal window and visualizing the carotid artery.[34,35] However, neither would have improved our outcomes. Nonetheless, we support additional views depending on the clinical presentation, patient risk factors, and the quality of traditional cardiac windows. Likewise, assessing for regional wall motion abnormalities and acute aortic regurgitation is appropriate.[26] POC TEE and CEUS represent emerging options for the EP.[28]

Clinical decision tools and ordering a D-dimer would not have changed our results for A-AoD.[11–16] However, a D-dimer may have been elevated in the three missed B-AoDs, but none of those cases had D-dimers ordered. Given the considerably lower mortality associated with B-AoD and the significantly increased usage of CTA in the preceding decades, an approach combining abdominal aorta POCUS with a D-dimer may reduce ionizing radiation without sacrificing diagnostic accuracy.[2,6,9,36] Numerous studies have validated ultrasound, including POCUS, as the initial diagnostic imaging standard for aneurysms.[37,38] AoDs present an additional pathology warranting a POCUS-first approach and future studies combining the SPEED protocol with a D-dimer test may increase the sensitivity for B-AoD as well.

It is important to recognize that the SPEED protocol cannot exclude an AoD. The authors advocate for its use to expedite the diagnosis and management of AoD. The presence of an intimal flap is diagnostic of AoD. Likewise, the presence of the aforementioned indirect sonographic signs identifies higher risk patients necessitating immediate advanced imaging, surgical evaluation, and medical intervention. Nevertheless, high-risk patients without sonographic findings of AoD warrant immediate evaluation as well. Given the poor PPV, providers may wait for advanced imaging and consultation in low-risk patients with or without the presence of indirect sonographic findings. Given the myriad of signs and symptoms of AoD and corresponding risk factors, providers must utilize clinical gestalt to distinguish between high- and low-risk patients in addition to other diagnostic modalities.

LIMITATIONS

This study suffers from the limitations of an unblinded, observational design with convenience sampling at a single health system resulting in selection and spectrum biases and smaller sample size. Furthermore, we did not account for patients diagnosed with an AoD who did not receive a POCUS. Likewise, we excluded all AoD patient transfers from outside hospitals, and our protocol did not assess for the presence of AoD precursors, including intramural hematoma or penetrating ulcerations.[1,6] Moreover, we did not account for clustering

TABLE 2 SPEED protocol test characteristics for A-AoDs and B-AoDs.

	A-AoD and B-AoD (95% CI)	A-AoD (95% CI)	B-AoD (intimal flap only) (95% CI)
Accuracy	91 (89.3–92.5)	91.1 (89.4–92.6)	99.8 (99.3–100)
Sensitivity	93.2 (81.3–98.6)	100 (83.9–100)	87 (66.4–97.2)
Specificity	90.9 (89.2–92.5)	90.9 (89.2–92.5)	100 (99.7–100)
PPV	26.3 (19.6–33.9)	15.4 (9.8–22.6)	100 (83.2–100)
NPV	99.7 (99.2–100)	100 (99.7–100)	99.8 (99.3–100)
PLR	10.2 (8.5–12.5)	11 (9.3–13.2)	Undefined
NLR	0.1 (0.0–0.2)	Undefined	0.1 (0.1–0.4)

Abbreviations: A-AoD, Sanford type A aortic dissection; B-AoD, Sanford type B aortic dissection; NLR, negative likelihood ratio; NPV, negative predictive value; PLR, positive likelihood ratio; PPV, positive predictive value; SPEED, sonographic protocol for the emergent evaluation of aortic dissections.

TABLE 3 SPEED protocol test characteristics for A-AoDs.

	A-AoD ($n = 21$)		
	AOFT > 35 mm (95% CI)	Pericardial effusion (95% CI)	Intimal flap (95% CI)
Sensitivity	100 (83.9–100)	61.9 (38.4–81.9)	61.9 (38.4–81.9)
Specificity	91.8 (90.2–93.3)	99.1 (98.5–99.6)	100 (99.7–100)
PPV	16.8 (10.7–24.5)	54.2 (32.8–74.5)	100 (75.9–100)
NPV	100 (99.7–100)	99.4 (98.7–99.7)	99.4 (98.8–99.7)
PLR	12.2 (10.2–14.7)	71.5 (36.3–140.7)	Undefined
NLR	Undefined	0.4 (0.2–0.7)	0.4 (0.2–0.6)

Abbreviations: A-AoD, Sanford type A aortic dissection; AOFT, aortic outflow tract; NLR, negative likelihood ratio; NPV, negative predictive value; PLR, positive likelihood ratio; PPV, positive predictive value; SPEED, sonographic protocol for the emergent evaluation of aortic dissections.

occurring at each clinical site or by individual physicians enrolling predominately, although more than 100 residents, supervised by more than 40 attendings participated in the study. Each of these factors limits the generalizability of our protocol.

We recognize that the sample size was small overestimating the PPV. However, the prevalence of AoDs ranges between 5 and 30 per 1 million patients.[6,9] During the 10-year study period, our ED treated nearly 1 million patients. Throughout that time, investigators diagnosed 44 AoDs with our sonographic protocol. Additionally, this omits all the aforementioned excluded patients. Therefore, our patient population has a higher prevalence comparatively, which further restrictions the broader applicability of our results.

Faculty within the division of emergency medicine developed and implemented the protocol. Unblinded physicians performed the POCUS protocol specifically to evaluate for AoD. Furthermore, we did not account for physicians being unblinded to laboratory data (i.e., D-dimer) or plain film findings, if available, prior to POCUS. Each of these factors introduces bias toward overcalling sonographic signs, which impacts the test characteristics, particularly the sensitivity. Moreover, providers enrolled patients clinically suspected of having an AoD. Given the myriad of signs and symptoms of AoD, the authors could not define specific indications to warrant a workup for an AoD. Thus, more than likely low-risk patients were included thereby inflating the protocol's specificity and NPV.

Finally, our ED is not representative of the broader emergency medicine community. We have an active ultrasound division with numerous faculty and fellows. All ED attendings are credentialed in POCUS. In our department, residents are the treating clinicians, who typically have more POCUS experience compared to most practicing EPs, and we did not account for varying experience with POCUS across training years.

CONCLUSIONS

In summary, The sonographic protocol for the emergent evaluation of aortic dissections protocol, combining transthoracic echocardiography with abdominal aorta point-of-care ultrasound, has an overall sensitivity of 93.2% for aortic dissection. Larger, multicenter, studies are required to validate these findings.

AUTHOR CONTRIBUTIONS

Ryan C. Gibbons: data acquisition, analysis and interpretation, manuscript draft. Dylan Smith: data acquisition, analysis and interpretation. Rivka Feig: data acquisition, analysis and interpretation. Molly Mulflur: manuscript revision. Thomas G. Costantino: study concept and design; data acquisition, analysis and interpretation; manuscript revision.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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