Original Article

Ultrasound Investigation of the Fifth Intercostal Space Landmark for Chest Tube Thoracostomy Site Selection in Pediatric Patients

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Objectives: Chest tube thoracostomy site selection is typically chosen through landmark identification of the fifth intercostal space (ICS). Using point-of-care ultrasound (POCUS), studies have shown this site to be potentially unsafe in many adults; however, no study has evaluated this in children. The primary aim of this study was to evaluate the safety of the fifth ICS for pediatric chest tube placement, with the secondary aim to identify patient factors that correlate with an unsafe fifth ICS.

Methods: This was an observational study using POCUS to evaluate the safety of the fifth ICS for chest tube thoracostomy placement using a convenience sample of pediatric emergency department patients. Safety was defined as the absence of the diaphragm appearing within or above the fifth ICS during either tidal or maximal respiration. Univariate and multivariable analyses were used to identify patient factors that correlated with an unsafe fifth ICS.

Results: Among all patients, 10.3% (95% confidence interval [CI] 6.45–16.1) of diaphragm measurements crossed into or above the fifth ICS during tidal respiration and 27.2% (95% CI 19.0–37.3) during maximal respiration. The diaphragm crossed the fifth ICS more frequently on the right when compared with the left, with an overall rate of 45.0% (95% CI 36.1–54.3) of right diaphragms crossing during maximal respiration. In both univariate and multivariate analyses, a 1-kg/m^2 increase in body mass index was associated with an increase of 10% or more in the odds of crossing during both tidal and maximal respiration (P = 0.003 or less).

Conclusions: A significant number of pediatric patients have diaphragms that cross into or above the fifth ICS, suggesting that placement of a chest tube thoracostomy at this site would pose a significant complication risk. POCUS can quickly and accurately identify these unsafe sites, and we recommend it be used before pediatric chest tube thoracostomy.

Key Words: point-of-care ultrasound, diaphragm, chest tube thoracostomy, procedural safety

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Placement of a chest tube thoracostomy is an uncommon procedure performed in the pediatric emergency department (PED). The most common indications for placement include pneumothorax, hemothorax, pleural effusion, and penetrating chest trauma.[1] Previous studies have shown the incidence in pediatric trauma resuscitations to be ~20% and medical resuscitations to be ~5%.[2,3] A 2013 single-center study showed that only 39% of pediatric emergency medicine (PEM) providers had performed or supervised a chest tube in the previous year, and a recent survey of PEM physicians across 96 centers reported that less than 20% of providers had performed one in the previous year, with 30% never having performed one.[3,4]

Multiple complications secondary to chest tube thoracostomy have been reported including damage to the chest wall and underlying diaphragm, liver, spleen, and bowel; recurrence of pneumothorax; subcutaneous placement; and infection of the pleural cavity.[5] Complication rates have been described between 5% and 10%.[6] Many complications result from choosing an insertion site that is too caudal, indicating that providers have difficulty selecting an appropriate insertion site using landmarks alone. There have been multiple attempts at locating a "safe space" for chest thoracostomy, the most common being the "triangle of safety," which is defined by the base of the axilla cephalad, the edge of the pectoralis major muscle anteriorly, the edge of the latissimus dorsi muscle posteriorly, and the nipple/fifth intercostal space (ICS) caudally.[5,7–9] Another method of landmark identification known as the midarm point (MAP or MAPPAED) utilizes the ipsilateral arm measuring down to the midpoint of the arm to locate a safe zone between the fourth and sixth ICS in adults and pediatrics, respectively.[10,11]

Ultrasound guidance has been shown to improve success and decrease complications for multiple procedures including thoracentesis, paracentesis, vascular access, and regional anesthesia.[12–19] Gray et al used ultrasound to investigate the safety of landmark-based chest tube thoracostomy at either the fifth ICS or inframammary crease in the midaxillary line in 50 adult emergency department (ED) patients. In their study, 20% of right and 18% of left hemidiaphragms crossed the landmark fifth ICS, suggesting the potential for subdiaphragmatic insertion or diaphragmatic injury if a chest tube was placed using landmarks alone.[20] In a similar study by Lieurance et al, 17% of landmark-identified chest tube sites in adult ED patients were identified as being potentially unsafe because of the presence of the diaphragm and underlying solid organs.[21] In another observational study of adult ED trauma patients undergoing computed tomography, ultrasound identified potential thoracostomy sites above the diaphragm in 97.2% of patients compared with only 88.4% using a landmark-based approach.[22] Ultrasound has the ability to not only identify potentially dangerously low chest tube insertion sites but has also been used to identify vulnerable intercostal arteries and subcutaneous placements.[23]

No previous study has utilized ultrasound to evaluate the safety of the fifth ICS in pediatric patients. The primary goal of this study was to use ultrasound to determine the safety of the fifth ICS for chest tube thoracostomy placement in pediatric patients. Our secondary aim was to identify any patient factors that correlate with a potentially unsafe fifth ICS.

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METHODS

Study Design

This was an observational study using a convenience sample of PED patients presenting to an urban academic medical center with a level 1 trauma designation. The institutional review board approved this study. Subjects were enrolled between December 17, 2022, and May 4, 2023.

Study Population

Patients <18 years of age presenting to the PED when the primary investigator (PI) (M.R.R.) was available were eligible for inclusion. Exclusion criteria included pregnancy, lack of English proficiency, inability to raise arm overhead, previous history of cardiothoracic surgery including previous chest tube, previous history of diaphragmatic dysfunction or surgery including Nissen fundoplication, gastrostomy tube/gastrostomy-jejunum feeding tube, patients deemed too ill by the primary team, patients receiving sedative medication, allergy to ultrasound gel, inability to contact legal guardian, or unwillingness of patient/guardian to participate. Potential participants were identified by the treatment team who notified the PI of their interest in the study. Written consent was obtained from all legal guardians, and written assent was obtained from all subjects 13 years and older before any study activities.

Study Protocol

All point-of-care ultrasound (POCUS) studies were performed by the PI (M.R.R.), a third-year PEM fellow who had completed a general PEM POCUS curriculum and additionally performed 25 practice study scans with 2 POCUS faculty (M.M.M. and A.S.) before patient enrollment. Patients were positioned lying supine with the ipsilateral arm raised above the head. Ultrasound images were acquired with a Sonosite X-Porte (FUJIFILM Sonosite Inc, Bothell, Wash) using either a high-frequency linear (13-6 MHz) or curvilinear (5-2 MHz) transducer based on patient habitus. The fifth ICS was identified in the midaxillary line using the anterior approach described by Hurdle et al.[24] The transducer was placed in the sagittal orientation over the midclavicle and slid medially and laterally to identify the first rib emerging from underneath the clavicle. Once the first rib was identified, the transducer was moved caudally and laterally, transitioning from the sagittal to coronal plane, until the transducer was centered over the fifth ICS in the midaxillary line (Fig. 1; Supplemental Video 1, http://links.lww.com/PEC/B230). Images were recorded over a 60-second window to assess if the diaphragm crossed into the fifth ICS during tidal respiration. An ICS was considered to be "unsafe" if at any point during the recorded video the diaphragm was seen to cross above the superior margin of the sixth rib. If the diaphragm crossed into the fifth ICS (Fig. 2 and Supplemental Figure, http://links.lww.com/PEC/B231), this process was repeated moving cephalad until the recorded ICS remained above the diaphragm. After assessment during tidal respiration, patients able to follow directions were asked to breathe using deep inspiration and complete exhalation to simulate the extremes of breathing. Images were recorded over a 15-second window during these "maximal" breathing periods starting at the first safe tidal ICS and repeated cephalad as needed until no diaphragm crossing was seen. Patients in whom the ICS was unsafe during tidal respiration were assumed to also be unsafe with maximal respiration. This process was repeated bilaterally.

All ultrasound images were saved and stored on the Health Insurance Portability and Accountability Act-compliant QPathE software (Telexy Inc, British Columbia, Canada). Two POCUS-trained faculty (M.M.M. and A.S.) independently reviewed all study images (50% each) to confirm intercostal level and diaphragm location. Any discrepancies in interpretation were reviewed by all 3 investigators to reach consensus.

Patient data including current respiratory symptoms, height, weight, body mass index (BMI), vital signs, medical history, history of prematurity, surgical history, age, sex, and race were collected from the guardian and the electronic medical record. All data were entered into REDCap (Vanderbilt University, Nashville, Tenn).

Statistical Analysis

Based on the study by Gray et al,[20] we estimated that 20% of patients would have a diaphragm that crossed into the fifth ICS. At a 20% population frequency, enrollment of 50 patients per age group provided a 95% confidence interval (CI) between 11% and 33%, which we felt was appropriate. As pediatric patients are not a uniform population, we further divided our planned enrollment into 4 separate age groups (<1, 1–5, 6–12, 13–17 years) and thus targeted a total enrollment of 200 patients.

Descriptive statistics for demographic and clinical variables overall and by age group were calculated. Differences in categorical characteristics between age groups were evaluated using χ^2 tests or Fisher exact tests where appropriate, and differences in continuous characteristics were examined using Kruskal-Wallis tests.

The primary goal of the study was to evaluate the safety of the fifth ICS for chest tube placement. The study included 50

FIGURE 1. Identification of the fifth intercostal space (ICS). The patient is positioned supine with the ipsilateral arm above the head. (Left) The transducer is placed in the sagittal plane along the midclavicle and slid medially and laterally to identify the first rib emerging from underneath the clavicle. (Right) Once the first rib is identified, the transducer is slid laterally and caudally while counting the ribs until reaching the fifth ICS in the midaxillary line in the coronal orientation.

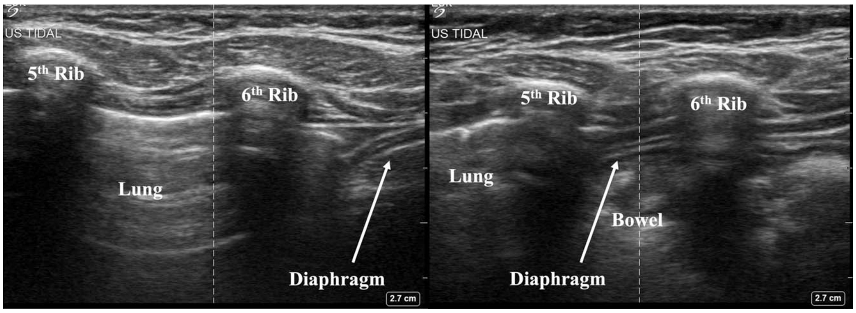

FIGURE 2. Evaluation of the fifth intercostal space (ICS) using the linear transducer. After identification of the fifth ICS within the midaxillary line, the center line is positioned at the superior margin of the sixth rib within the fifth ICS. (Left) A "safe" fifth ICS. The hyperechoic double layer of the diaphragm can be seen below (caudal) the sixth rib within the sixth ICS. The hyperechoic pleural line of the lung with its corresponding A-lines can be seen within the fifth ICS and extending into the cephalad aspect of the sixth ICS. (Right) An "unsafe" fifth ICS. The diaphragm extends above the sixth rib into the fifth ICS. Hyperechoic bowel with its "dirty shadow" can be seen deep to the diaphragm within the fifth ICS. The hyperechoic pleural line of the lung can be seen within the fourth ICS and extending into the cephalad aspect of the fifth ICS.

children per age group each with 2 measures (left and right sides). Safety was assessed by examining the proportion of times the diaphragm crossed into or above the fifth ICS assessed overall, by side of the body, within age group, and within each age group by side. These proportions with tidal and maximal respiration were estimated using a generalized estimating equation approach assuming a binomial distribution and a logit link. Fixed effects included side of the body, age group, and the side by age group interaction with a random effect for subject to account for correlation between measures collected on the same subject. The proportion of patients in whom the diaphragm crossed the fifth ICS with 95% confidence interval overall, by side of the body, within age group, and within each age group by side was estimated from the model to determine the safety of the fifth ICS.

Our secondary aim was to identify any patient factors that correlated with a potentially unsafe fifth ICS. We utilized the same generalized estimating equation approach and performed univariate and multivariable analysis evaluating additional patient variables including sex, BMI, race, and occurrence of respiratory symptoms to account for further sources of variation in the likelihood of diaphragm crossing.

Lastly, we evaluated the accuracy of ultrasound interpretation of both the correct identification of the fifth ICS and the interpretation of the diaphragm location in relation to the fifth ICS by assessing interrater agreement between the PI (M.R.R.) and secondary image reviewer (M.M.M. or A.S.) using the κ statistic. All analyses were conducted in SAS v9.4 (SAS Institute, Cary, NC).

RESULTS

A total of 170 patients were approached for enrollment, with 17 excluded because of a history of a gastrostomy tube or parent/patient refusal, leaving 153 patients enrolled. Fifty patients in 3 separate age groups, 1–5 years, 6–12 years, and 13–17 years, were ultimately used for the study. The <1-year age group proved difficult for recruitment, with only 3 patients enrolled, and thus we abandoned this age group and removed them from the analysis.

The final study population included 150 children, of whom a majority were male (74.0%) and self-reported as White (58.7%). A larger percentage of the 13- to 17-year age group were male relative to the younger groups. Age groups had similar race distribution. A smaller percentage of older children presented with respiratory symptoms. As expected, height, weight, and BMI increased with increasing age group, and respiratory rate decreased. Patient characteristics overall and by age group are provided in Table 1.

Across all measurements, the estimated rate of the diaphragm crossing the fifth ICS was 10.3% during tidal respiration and 27.2% during maximal respiration. Children between the ages of 6 and 12 years had lower rates for crossing the fifth ICS relative to children aged 1–5 years and 13–17 years for both tidal and maximal respiration. Crossing of the fifth ICS occurred more frequently on the right side of the body during both tidal (left: 5.9% vs right: 17.3%; $P = 0.002$) and maximal respiration (left: 14.6% vs right: 45.0%; $P < 0.001$). This difference between sides held for all age groups with both tidal and maximal respiration. The estimated proportion of times the diaphragm crossed the fifth ICS overall, by side of the body, within age group, and within each age group by side is shown in Table 2.

We also examined factors in addition to side of the body and age group that affected whether the diaphragm crossed the fifth ICS using both univariate and multivariable models, which included type of respiration, side of the body, age group, respiratory symptoms, and BMI. In univariate models, the likelihood of the diaphragm crossing the fifth ICS was associated with side of the body and BMI during both tidal and maximal respiration. Specifically, the odds of the diaphragm crossing the fifth ICS were 62% lower during tidal respiration and 70% lower during maximal respiration on the left side versus the right side of the body ($P = 0.001$ and $P < 0.001$, respectively). In addition, a 1-kg/m^2 increase in BMI was associated with an 11% increase in the odds of the diaphragm crossing during tidal respiration and a 10% increase during maximal respiration ($P = 0.003$ and $P = 0.001$, respectively). Crossing the fifth ICS during tidal respiration was not significantly associated with exhibiting respiratory symptoms; however, the odds of crossing the fifth ICS during maximal respiration were 2.6 times higher in those without respiratory symptoms compared with those with symptoms ($P = 0.005$). These findings all held with similar magnitude of effect in the multivariable model. Univariate and multivariable odds ratios for the different factors considered are shown in Table 3.

For evaluation of POCUS image interpretation accuracy, correct identification of the fifth ICS occurred in 298 of the 300 interspaces measured, with the 2 incorrect sites being in the sixth ICS, giving an interrater agreement of $\kappa = 0.968$ (95% CI 0.925–1.00), indicating excellent agreement. When looking at accuracy of interpretation of the diaphragm in relation to the fifth ICS, across all 514 measurements taken during tidal and maximal respiration,

TABLE 1. Patient Characteristics Overall and by Age Group

	All (n = 150)	Age 1–5 y (n = 50)	Age 6–12 y (n = 50)	Age 13–17 y (n = 50)	*P*
Age, y, median (IQR)	9.5 (8.0)	4.0 (2.0)	9.5 (4.0)	14.5 (3.0)	<0.001
Sex, n (%)					<0.001
Female	39 (26.0)	19 (38.9)	16 (32.0)	4 (8.00)	
Male	111 (74.0)	31 (62.0)	34 (68.0)	46 (92.0)	
Race, n (%)					0.705
Asian	3 (2.00)	2 (4.00)	1 (2.00)	0 (0.00)	
Black	53 (35.3)	18 (36.0)	15 (30.0)	20 (40.0)	
White	88 (58.7)	29 (58.0)	30 (60.0)	29 (59.2)	
Hispanic	5 (3.33)	1 (2.00)	3 (6.00)	1 (2.00)	
Other	1 (0.67)	0 (0.00)	1 (2.00)	0 (0.00)	
Weight, kg, median (IQR)	33.3 (37.7)	16.9 (4.90)	33.3 (15.5)	66.0 (18.9)	<0.001
Height, cm, median (IQR)	141.8 (59.0)	106.5 (12.0)	142.8 (20.0)	175.0 (8.0)	<0.001
BMI, kg/m^2, median (IQR)	17.3 (5.30)	15.5 (2.70)	16.5 (4.90)	20.4 (6.80)	<0.001
Respiratory symptoms, n (%)					0.050
Yes	62 (41.3)	27 (54.0)	20 (40.0)	15 (30.0)	
No	88 (58.7)	23 (46.0)	30 (60.0)	35 (70.0)	
Respiratory rate, median (IQR)	19.5 (5.0)	22.5 (4.0)	19.0 (2.0)	17.0 (2.0)	<0.001
SPO$_2$, median (IQR)	99.0 (3.0)	99.0 (3.0)	98.5 (1.0)	99.0 (3.0)	0.757

Continuous values are reported as median (interquartile range [IQR]), and categorical variables are reported as n (%). *P* values for continuous variables are from the Kruskal-Wallis test and for continuous variables are from Fisher exact test.

the 2 raters agreed on 498 of 514, with an interrater agreement of κ = 0.889 (95% CI 0.836–0.934), indicating strong agreement.

DISCUSSION

This is to our knowledge the first study using POCUS to investigate the diaphragm in relation to the fifth ICS in pediatric patients. When comparing our results to previous adult studies, the overall right-sided tidal respiration crossing rate of 17.3% in this study is similar to the 20% reported by both Gray et al and Lieurance et al,[20,21] and our all-measures tidal respiration crossing rate of 10.3% is similar to the 11.6% reported by Taylor et al.[22] Interestingly, our left-sided tidal respiration crossing rate of 5.94% is lower than the 18% and 13.9% reported by Gray et al and Lieurance et al, respectively.[20,21] The reasons for this are unclear, but likely reflect differences in pediatric versus adult abdominal anatomic proportions, particularly liver and spleen sizes, which also likely explain the differences seen between the right and left sides across the above studies.

TABLE 2. Raw Counts Per Measure and Estimated Proportion (95% CI) of Times the Diaphragm Crossed the Fifth Intercostal Space Overall, by Side of the Body, Within Age Group, and Within Each Age Group by Side for Both Tidal and Maximal Respiration

		Tidal Respiration		Maximal Respiration	
Age Group	Side	No. Above or Crossing/ No. Assessed	% Above or Crossing (95% CI)	No. Above or Crossing/ No. Assessed	% Above or Crossing (95% CI)
All	Total	37/300	10.3 (6.45, 16.1)	78/247	27.2 (19.0, 37.3)
	Left	11/150	5.94 (2.79, 12.2)	23/122	14.6 (7.54, 26.5)
	Right	26/150	17.3 (12.1, 24.3)	55/125	45.0 (36.1, 54.3)
1–5 y	Total	14/100	13.5 (7.05, 24.4)	22/49	45.8 (29.5, 63.0)
	Left	5/50	10.0 (4.22, 21.9)	9/23	40.8 (23.6, 60.6)
	Right	9/50	18.0 (9.64, 31.1)	13/26	50.9 (32.6, 69.1)
6–12 y	Total	9/100	5.87 (1.90, 16.7)	17/98	9.13 (3.26, 23.1)
	Left	1/50	2.00 (0.03, 12.9)	1/49	2.04 (0.29, 13.1)
	Right	8/50	16.0 (8.21, 28.9)	16/49	32.7 (21.7, 48.9)
13–17 y	Total	14/100	13.5 (7.32, 23.6)	39/100	38.2 (27.0, 50.7)
	Left	5/50	10.0 (4.22, 21.9)	13/50	26.0 (15.7, 39.8)
	Right	9/50	18.0 (9.64, 31.1)	26/50	52.0 (38.4, 65.4)

The proportions and 95% confidence intervals are estimated from linear contrasts based on a generalized estimating equations model including side, age group, and the side × age group interaction with a random subject effect to account for correlation between measures collected on the same subject.

TABLE 3. Univariate and Multivariable Odds Ratios for Crossing the Fifth Intercostal Space During Tidal and Maximal Respiration

	Univariate		Multivariable	
	OR (95% CI)	***P***	**OR (95% CI)**	***P***
Tidal respiration				
Side of body, left vs right	0.38 (0.21, 0.68)	0.001	0.35 (0.18, 0.66)	0.001
Age group				
1–5 vs 6–12 y	1.65 (0.60, 4.51)	0.333	2.10 (0.69, 6.39)	0.192
1–5 vs 13–17 y	1.00 (0.39, 2.59)	1.000	4.05 (1.27, 13.0)	0.018
6–12 vs 13–17 y	0.61 (0.23, 1.62)	0.320	1.93 (0.74, 5.04)	0.179
Respiratory symptoms, no vs yes	1.55 (0.67, 3.56)	0.295	1.54 (0.65, 3.66)	0.326
BMI, 1-kg/m^2 increase	1.11 (1.04, 1.19)	0.003	1.17 (1.07, 1.28)	<0.001
Maximal respiration				
Side of body, left vs right	0.30 (0.19, 0.46)	<0.001	0.23 (0.14, 0.37)	<0.001
Age group				
1–5 vs 6–12 y	2.25 (1.70, 9.50)	0.002	4.26 (1.65, 11.0)	0.003
1–5 vs 13–17 y	1.12 (0.57, 3.06)	0.519	2.80 (1.04, 7.54)	0.042
6–12 vs 13–17 y	0.33 (0.16, 0.65)	0.002	0.66 (0.29, 1.49)	0.316
Respiratory symptoms, no vs yes	2.62 (1.35, 5.09)	0.005	2.99 (1.40, 6.37)	0.005
BMI, 1-kg/m^2 increase	1.10 (1.04, 1.16)	0.001	1.14 (1.05, 1.23)	0.002

Odds ratios (ORs) are estimated from a generalized estimating equations model assuming a binomial distribution and logit link and accounting for correlation between repeated measurements taken on the same patient.

Importantly, although our tidal respiratory findings are on par with previous adult studies, none of these studies evaluated the diaphragm during maximal respiration. When evaluated during maximal respiration, we demonstrate a near tripling in the number of diaphragms crossing into or above the fifth ICS, increasing from 10.3% to 27.2% for all measurements across all ages, with nearly 50% of all right diaphragms crossing. This is an important finding, as the clinical situations requiring chest tube placement are highly stressful for children, and their respiratory patterns in those situations are likely different from their tidal respiratory patterns.

Within our secondary analysis, we identified that an increase in BMI by 1 kg/m^2 increased the odds of the fifth ICS crossing by 10%–17%. The previous study by Taylor et al demonstrated that the accuracy of identifying the fifth ICS by landmark palpation in adult patient was 10% lower in patients with a BMI over 30 kg/m^2 compared with those with a BMI under 30 kg/m^2.[22] This finding is intuitive as increasing BMI would generally result in increasing soft tissue that obscures palpable landmarks. Our finding that increasing BMI also increases the likelihood of the diaphragm crossing into the fifth ICS is less intuitive but suggests an impact of increasing BMI on respiratory mechanics. These findings together suggest that patients with elevated BMI are at higher risk for negative outcomes if relying solely on landmark identification. Interestingly, children without respiratory symptoms were 2.5–3 times more likely to have fifth ICS crossing during maximal respiration than children with respiratory symptom. The cause for this is unclear, but it suggests that children with respiratory symptoms have less diaphragmatic respiratory variability, perhaps caused by decreased lung compliance resulting in reduced diaphragmatic excursion.

Overall, the findings in this study indicate that a significant number of children have diaphragms that cross above the fifth ICS, suggesting that placement of a chest tube at this site would pose a significant complication risk. Landmark identification of the fifth ICS using the "triangle of safety" or alternatively the MAP/MAPPAED techniques cannot discriminate these at-risk patients as they lack direct and dynamic lung and diaphragm visualization and thus would not identify many of the potentially unsafe sites identified within our study.[5,7–11] Given our findings and the limitations of described anatomic approaches, we would recommend that POCUS be used to identify a safe ICS before any chest tube placement. Ultrasound equipment is now readily available in almost all ED trauma bays where a large proportion of chest tubes are placed. The high degree of interrater reliability for interpreting diaphragm location reported herein and that reported by Lieurance et al ($\kappa = 0.95$) suggests that this method of evaluation should be easily reproducible, and although we did not directly measure the time to obtain these images, Lieurance et al reported a mean of only 43 seconds to obtain their "Quick Look," suggesting that such an evaluation should not cause a clinically significant delay in management.[21]

This study has several limitations. First, we utilized a convenience sample of pediatric patients with a male predominance and ultimately aborted enrollment of our planned under 1 year age group. Thus, our results are swayed toward males and do not address children under 1 year, although importantly our subgroup analysis did not show any effect by gender. Second, no child in this study required a chest tube, and it is possible that the underlying pathology necessitating a chest tube could alter the location of the diaphragm in relation to the fifth ICS. Along these lines, all children in this study were spontaneously breathing and awake. Children who are sedated or mechanically ventilated likely have different diaphragm mechanics. Third, a single investigator performed all ultrasound studies, and his ultrasound skillset may not be reflective of the larger PEM community. The ultrasound approach used herein is not an advanced technique, however, and basic lung POCUS is now considered a core component of both EM and PEM POCUS training.[25–28] Fourth, this study was conducted in a controlled, nonemergent setting. This is contrary to many clinical situations in which a chest tube is required, and the high reliability of the ultrasound evaluation in our study may be reduced in such settings. Finally, we performed our evaluation only in the midaxillary line, and there may be utility in further evaluation of the anterior and posterior axillary lines as these may be preferred sites for chest tube placement depending on the underlying pathology. Future studies should look to address these limitations, incorporating multiple providers, sedated and ventilated patients, and patients requiring chest tube placement.

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