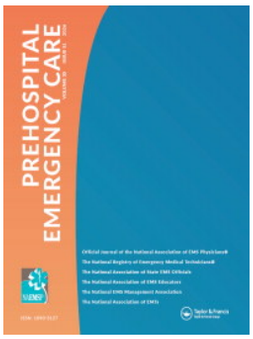

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A Live Human Model Comparison Evaluating ThoraSite® Accuracy for Needle Thoracostomy

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ABSTRACT

Objectives: Needle thoracostomy (NT) is a time-sensitive procedure infrequently performed by EMS clinicians with variable success rates. Our primary objective was to evaluate the accuracy of NT site selection by paramedics using ThoraSite® compared to traditional anatomic landmarks (ALs). Secondarily, we assessed paramedic-rated confidence and ease of ThoraSite® use.

Methods: We conducted a randomized, two-arm crossover study including fire-based paramedics. Emergency physician investigators determined a NT placement zone for live human models in three size groups, confirming with ultrasound and demarcating the zone with "invisible" ultraviolet ink. Following training, paramedics performed NT site selection on the models using ThoraSite® and ALs by placing a sticker at the selected insertion site. Accuracy of placement was confirmed with ultraviolet flashlight. If placement was outside the demarcated zone (DZ), we identified underlying structures with ultrasound. We evaluated the effect of approach on placement accuracy and time-to-NT placement using linear models with covariates of paramedic, approach, and model size. For the outcome of accuracy, we used a log link function. For time-to-NT, we log-transformed the values for the parametric analysis allowing interpretation of the coefficients as percent differences. We compared paramedic confidence in performing the NT procedure and perceived ease of procedure using a 5-point Likert scale.

Results: There were 112 paramedics that performed 223 ThoraSite® and 223 landmark attempts with 383 correct placements within the DZ: 198 attempts using ThoraSite® compared to 185 with ALs, odds ratio (OR) 1.91 (95%CI 1.01–3.62), $p=0.04$. Placement accuracy by model size followed similar trends. Incorrect placement over critical structures occurred in 1 ThoraSite® and 3 AL attempts. The mean time for NT site selection was 14.3s (SD = 7.11) using ThoraSite® and 18.7s (SD = 7.40) using ALs ($p<0.01$). Overall procedural confidence improved with training. However, there was no statistically significant difference in the change in confidence with ThoraSite® as compared to ALs (OR = 1.55 95%CI = 0.89–2.72). Paramedics rated ease of NT placement significantly higher using ThoraSite® (median = 5, IQR = 4–5) compared to ALs (median = 4, IQR = 4–5; $p<0.01$).

Conclusions: ThoraSite® was associated with increased odds of NT site selection in the DZ, reduced time-to-NT site selection, and increased self-rated ease reported by paramedics.

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Introduction

Tension pneumothorax is a time-critical, life-threatening condition that requires immediate recognition and treatment. A recently released position statement from the National Association of Emergency Medical Services Physicians highlights the importance of needle thoracostomy (NT) for pleural decompression in the setting of recognized tension pneumothorax (1). In the position statement, the authors make specific reference regarding the need for quality management to improve safety and effectiveness of the procedure. The frequency of procedural error has been described as significant with varied success rates documented in the literature (2). Published failure rate estimates are mixed, regardless of technique or anatomic location with retrospective studies reporting success rates of NT performed in the field ranging from 6% to 83% across a variety of techniques, including the anatomic approach and needle length used (2–7). Inaccurate placement risks both failure to decompress a tension pneumothorax and potentially patient injury.

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Despite some risks, NT is the primary method for prehospital field management of a tension pneumothorax (1). For this reason, techniques to assist with achieving accurate placement will also have the potential to reduce failure rates and decrease iatrogenic injury. This has led to development of ThoraSite® (SAM® medical), a device intended to help health care practitioners identify an accurate anatomic insertion site *via* a lateral approach for NT decompression using a card template that is placed in the patient's axilla and displays a 'safety zone' for NT placement (8). While a limited study, Shah et al (8) reported high accuracy by trained operators in an initial feasibility study using ThoraSite® for 24 attempts in 12 differing cadaver body types (e.g., short and tall, underweight and obese, and male and female). The potential universality of the device supports the ThoraSite® as a promising tool to be used in prehospital environments. To date, no published studies have evaluated ThoraSite® effectiveness or accuracy of placement in live humans or with prehospital clinicians as device operators.

In this study, we assessed the effect of the ThoraSite® device on the frequency of accurate anatomic site selection by paramedics for lateral NT placement, compared to standard methods using anatomic landmarks (ALs). We hypothesized that use of the ThoraSite® device would result in higher frequency of accurate site selection for NT placement compared to standard AL methods on live human volunteers. We also assessed paramedic impressions of ease of use and perceived confidence with the NT procedure.

Methods

Study Design

This is a prospective, randomized two-arm crossover study comparing use of the ThoraSite® device to standard AL methods for lateral NT site selection. The ThoraSite® device is an FDA registered, Class 1 device, intended for use in adults as an anatomic landmarking tool to help identify the 3rd to 5th intercostal space by identifying a defined "safety zone" for inserting a NT when using a lateral approach. The device uses a card template that is placed on the lateral chest and oriented using directional arrows to align the device with a patient's anterior to mid-axillary line, spine, and hip such that a window will display a "safety zone" to place the needle in the displayed intercostal space (Figure 1). The Lundquist Institutional Review Board (IRB) at Harbor-UCLA Medical Center reviewed this study protocol and determined it was exempt from IRB oversight.

Figure 1. Image of ThoraSite®.
The ThoraSite® is a NT landmark identification device that aligns a patient's axilla, spine, and hip to identify a "safe zone" for NT insertion.

Study Setting and Selection of Participants

This study was conducted with paramedics from three fire-based EMS agencies in Los Angeles County (LAC) over a 2-week period in July 2023. The LAC 9-1-1 responding EMS system is composed of 29 fire-based EMS agencies and one law enforcement agency. Three EMS agencies volunteered for participation in this study on the basis of having expressed interest in the field use of the ThoraSite® device and willingness to participate. The EMS agency characteristics are described in Supplemental File Table 1. All active paramedics at each participating EMS agency were scheduled to complete training but had the option to decline study participation. The LAC EMS treatment protocols included needle thoracostomy using ALs for suspected tension pneumothorax (9). Prior to this study, the ThoraSite® was not in use in LAC by any EMS agencies.

Sample Size Calculation

A previous study estimated the baseline rate of correct NT site identification by EMS clinicians using ALs to be 67% (10). In order to detect a 15% increase over this baseline rate (which we believed to be clinically meaningful) with 80% power, a total of 290 attempts, or 145 paired attempts, in each placement method group were required. Each participating paramedic would have two attempts based on this study's design; therefore, the minimum target sample size without missingness or withdrawal was calculated to be 73 participants.

Study Procedures

Study procedures, outlined in Figure 2, consisted of: 1) pre-intervention survey; 2) participant training that reviewed tension pneumothorax clinical presentation and management; 3) hands-on manikin and live-model training with review of ALs for NT placement and ThoraSite® training; 4) 1:1 randomization to first NT placement approach with either ThoraSite® or AL for site selection (two randomizations were performed for each participant *via* coin toss: once for side of initial site selection and once for technique); 5) post-intervention survey.

Pre-Intervention

The pre-intervention survey captured baseline characteristic data including age, sex, number of years as a paramedic, and previous NT experience. Paramedics were also asked to rate their confidence in NT placement before training on a 5-point Likert scale. The educational review consisted of a 20-minute didactic session incorporating hands-on use of a training manikin to review the indications and placement

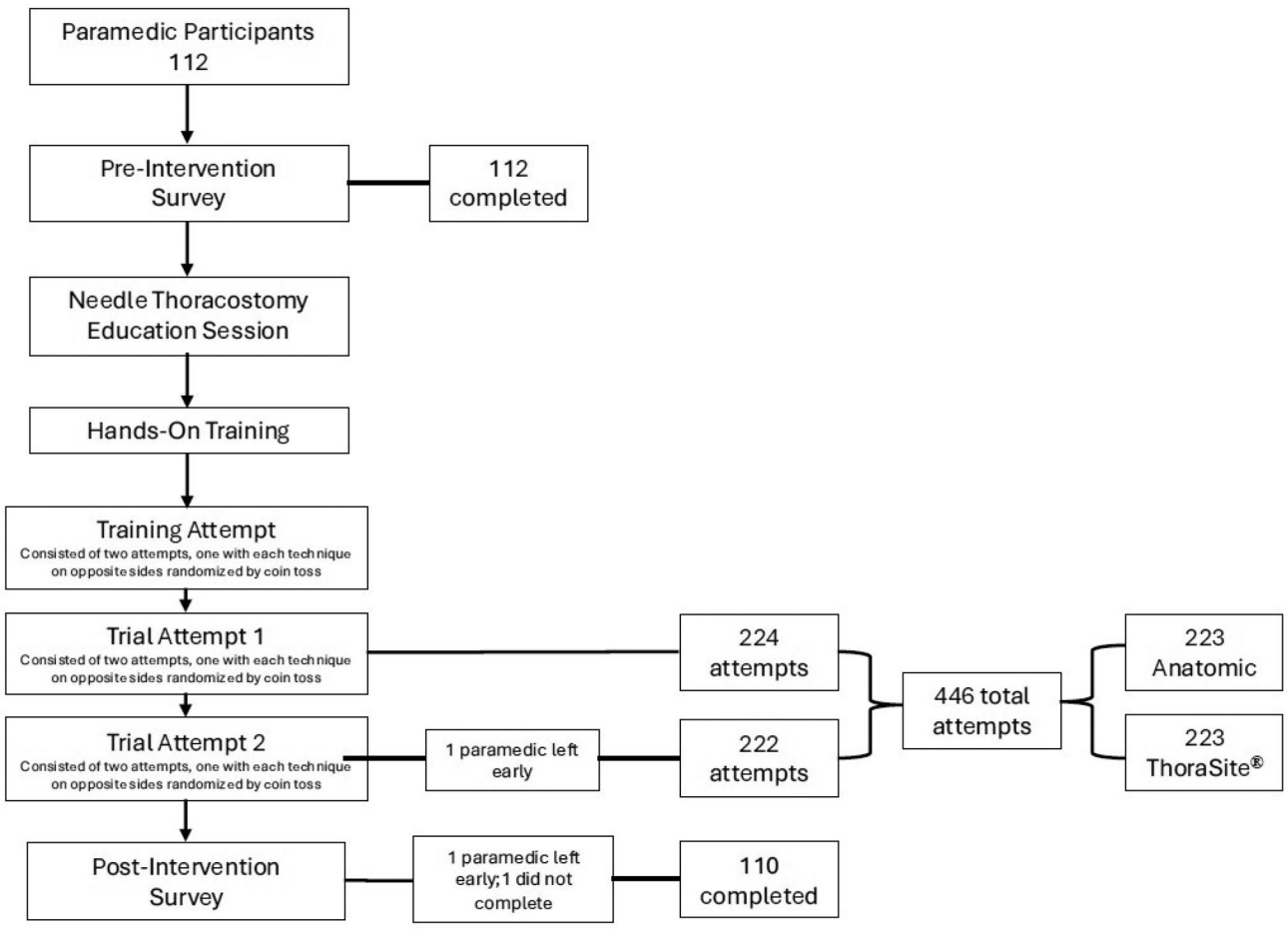

Figure 2. Flowchart of study procedures.

procedure for NT per LAC EMS protocols, the ALs for lateral NT placement, and the manufacturer-recommended use of the ThoraSite® device as demonstrated on a live-model. This training was performed on the same day, just prior to the participant completing their NT attempts.

NT Site Selection with Randomized Technique

A total of thirty-one live human model volunteers were recruited from paramedics participating in each training session and study investigators. Prior to any paramedic attempted NT site selection, models were prepared by having a demarcated zone (DZ) drawn on their torso with "invisible" UV pen by two emergency medicine physicians using anatomic landmarks and ultrasound (U/S), verifying the accuracy of the DZ by mutual agreement. The DZ was bordered by the anterior axillary line, mid-axillary line, 4th and 6th ribs. There were three stations each with different live human models of varying sizes by height, defined as short (< 64 inches), medium (64 to 71 inches), and tall (> 71 inches) and paramedic participants rotated through the stations. Rotation through the stations was not randomized. The stations operated simultaneously and the order in which participants moved through the stations was variable with each participant instructed to visit each station once.

Paramedics each performed three NT attempts on three different live human models (with the exception of one paramedic who left early before the third attempt: see Figure 2). Each NT attempt consisted of two site selections randomized by coin flip, first to side and then to ALs vs ThoraSite®. Both coin flips were performed at the time of paramedic arrival to the station by a study investigator who informed the paramedic of their first side and method. The first model for each paramedic was considered a training session and the two subsequent models were trial attempts (Figure 2). The training attempt was intended to familiarize the paramedic with expectations for the trial attempts. During the training attempt, paramedics were allowed to ask clarifying questions about ALs and/or ThoraSite® device use. The training session and both trial attempts each consisted of two site selections on opposite sides of the model, one using ALs and one *via* ThoraSite®. The method and side of the model that was used first was randomized by coin tosses. Each attempt grouping was performed on a different model. For example, a paramedic performed a NT attempt using one approach (ALs or ThoraSite®) on either the right side or left side of one model (both selected by coin toss) and then a second attempt using the other approach on the opposite side of the same model, before rotating to the next model.

To indicate their NT site selection, participants were instructed to place a 0.25 inch diameter, circular sticker on the volunteer model at the site at which they would insert the needle. Each attempt was timed using a stopwatch by a study investigator. Sticker placement was evaluated as "correct" or "incorrect" by study investigators based on whether it fell within the DZ as revealed by shining a UV flashlight on the model's torso after the attempt (Figure 3). If the placement was outside the DZ, an emergency physician evaluated for underlying critical structures (i.e., stomach, liver, spleen, peritoneum, kidney, heart) using U/S.

Post-Intervention Survey

Following NT site selection attempts, paramedics were instructed to complete a survey developed by the investigators rating their post-training confidence and perceived ease of NT site selection on a 5-point Likert scale for both the AL and ThoraSite® approaches. The survey included an optional free-text question where participants could provide narrative feedback on the ThoraSite® device. We did not allocate a specific time for completion of the survey; the pre- and post-test surveys were designed to be completed within five minutes (Supplemental File Figure 1).

Outcomes

The primary objective for this study was to evaluate the accuracy of NT site selection using ThoraSite® with our primary outcome measure being comparing the frequency of the NT placement site selection falling within the DZ with and without ThoraSite®. Secondary objectives included evaluating time to NT placement and paramedic perceptions using the device. Therefore, secondary outcomes measures included time to site selection, paramedic confidence in NT site selection rated on a 5-point Likert Scale, and paramedic-rated ease of NT site selection on a 5-point Likert scale.

Analysis

We compared the accuracy of site selection and time-to-site selection using linear models, with covariates of paramedic, approach and model size. A generalized linear model with a log link function was used to assess the odds ratio associated with Thorasite® as compared to ALs for the outcome of accuracy whereas a linear mixed effects model was used to analyze log-transformed times for time-to-site-selection; paramedic was included as a fixed effect in the accuracy model and random effect in the time-to-site-selection model. To test whether there was significant interaction between approach and model size on either the outcome of accuracy or time-to-site selection, we introduced an interaction into each model respectively; however, this term is not included in the models used to estimate the primary effect of approach. We compared paramedic confidence in their performance of the NT procedure with Thorasite vs AL using a cumulative logistic regression, including pre-training self-rated confidence as a covariate. We also compared pre- and post-training procedural confidence without accounting for training method using a Wilcoxon Signed-Rank test. "Training" attempts (the first two attempts per participant, one with NT and one with Thorasite) were excluded from the analysis. We compared perceived ease of the NT procedure between methods with a Wilcoxon Signed-Rank test (as no covariate adjustment was included). Analyses were performed using SPSS and R.

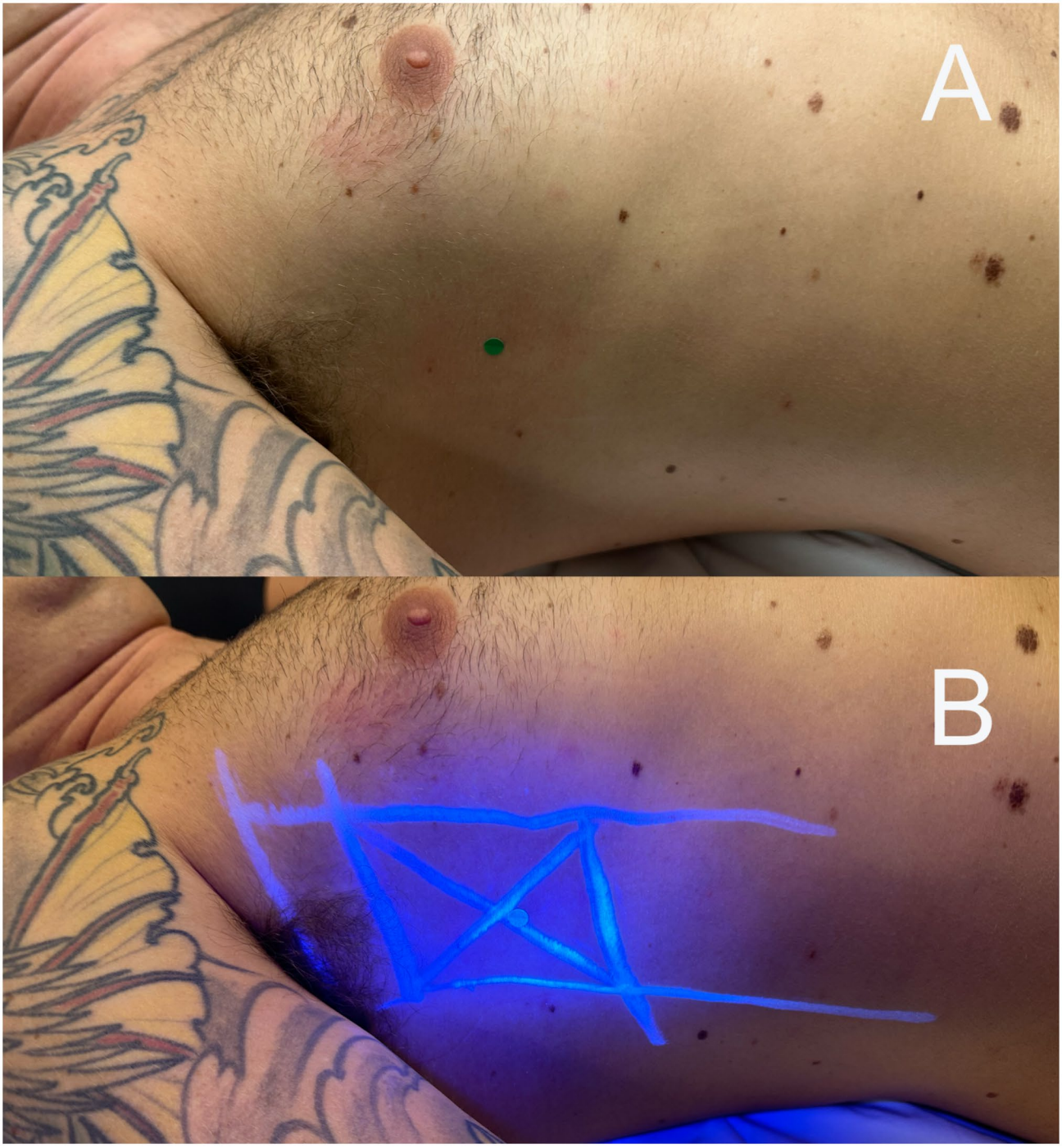

Figure 3. Use of UV Light to reveal DZ. (A) Participant placed sticker indicating selected NT insertion site. (B) Accuracy of NT site selection confirmed by visualizing the DZ with UV light.

Results

Characteristics of Study Participants

We recruited 112 paramedics to participate in this study with characteristics described in Table 1. No paramedics declined participation in the study. One participant left early and did not complete trial attempts on a third model. Two study participants did not complete the post-intervention survey. Notably our paramedic cohort was primarily male ($n = 109$, 97%) with the majority ≤ 45 years old ($n = 83$, 74%). Over one-third of paramedics in the cohort had never placed a NT during patient care ($n = 42$, 38%) with a similar percentage that had only placed 1–2 NTs ($n = 41$, 37%). Only 13 participants had placed more than five NTs during their time as paramedics (11%). There was a wide distribution in years of experience with the largest group endorsing 11–15 years of paramedic experience ($n = 29$, 26%).

NT Placement

The study included 446 NT site selection attempts (223 ThoraSite® and 223 AL) on live human models resulting in

Table 1. Paramedic demographics $N = 112$.

	Frequency	%
Age (years)		
18–25	0	0%
26–35	37	33%
36–45	46	41%
46–55	24	21%
56–65	3	3%
Not Reported	2	2%
Sex		
Female	3	3%
Male	109	97%
Experience: Prior NT Placements		
1–2	41	37%
3–5	15	13%
5–10	6	5%
10–15	5	4%
>15	2	2%
Never	42	38%
Not Reported	1	1%
Experience: Years as a Paramedic		
1–5	23	21%
6–10	24	21%
11–15	29	26%
16–20	17	15%
>20	16	14%
Not reported	3	3%

Table 2. Model characteristics and attempt frequency.

Model type	Height (in)		BMI		Total attempts*	Male (%)
	62		31.1		56	0%
Short (< 64 in) (n = 2)	63		22.1			
	Median	IQR	Median	IQR		
Medium (64–71 in) (n = 18)	68.5	66.3, 70.0	25.8	25.1, 27.1	284	89%
Tall (≥ 72 in) (n = 11)	75.0	74.0, 75.5	26.2	24.5, 28.0	106	100%

*Total attempts per Model Type.

Table 3. Correct attempts by technique.

	Frequency correct	Percentage	OR, 95% CI
Total			
ThoraSite	198/223	89%	1.91, (1.01–3.62)‡
Anatomic	185/223	83%	
By Size			
Short			
ThoraSite	25/28	89%	3.33, (0.68–2.97)†
Anatomic	20/28	71%	
Medium			
ThoraSite	128/142	90%	1.41, (0.68–2.97)†
Anatomic	123/142	87%	
Tall			
ThoraSite	45/53	85%	1.47, (0.53–4.07)†
Anatomic	42/53	79%	

*Short (< 64 in), Medium (64–71 in), and Tall (> 71 in) ‡Adjusted for model size and clustering by paramedic. †No covariate adjustment.

the desired 1:1 randomization by coin toss, also achieving 1:1 randomization for side of first attempt (223 left and 223 right). Of the 31 model volunteers recruited, 2 were short, 18 medium, and 11 tall. Model characteristics are shown in Table 2 and Supplemental Table 2. There were 383 (86%) correct NT placements. Use of the ThoraSite® device resulted in correct placements 198 (89%) times, while the AL approach was correct 185 (83%) times (OR 1.91, 95% CI 1.01–3.62, $p = 0.04$) (Table 3). The interaction term between placement method and model size was not significant, indicating no subgroup effect associated with NT method. Correct placement by model size for ThoraSite® compared to AL occurred 25 (89%) and 20 (71%), OR 3.33 (95%CI 0.74–14.72) times for short, 128 (90%) and 123 (87%), OR 1.41 (95%CI 0.68–2.97) for medium, and 45 (85%) and 42 (79%), OR 1.47 (95%CI 0.53–4.77) for tall, respectively. Mean time for NT site selection using the ThoraSite® device was 14.3 s (SD = 7.11) and 18.7 s (SD = 7.40) for AL with a 29% time reduction in the adjusted model (95% CI −35%, −22%, $p < 0.01$). Of the misplacements (Table 4), one with the ThoraSite® device was over a critical structure (stomach) while three with the AL approach were over critical structures (liver).

Table 4. Location of NT misplacements.

	Frequency	Percentage	Mean displacement (cm)
ThoraSite®, $n = 25$			
Anterior	4	16%	1.1
Posterior	4	15%	1.4
Superior	2	8%	0.7
Inferior[1]	14	54%	1.1
Not Documented	1	4%	0.5
Anatomic, $n = 38$			
Anterior	9	24%	1.0
Posterior[2]	7	18%	1.4
Superior	7	18%	1.3
Inferior[3]	13	34%	1.5
Not Documented	2	5%	2.7*

[1]Critical Structure Stomach (1 attempt); [2]Critical Structure Liver (1 attempt); [3]Critical Structure Liver (2 attempts); *Missing displacement data (only documented in one of two attempts).

Paramedics self-rated confidence in the NT procedure post-training, after adjustment for pre-training confidence, was not significantly higher with the ThoraSite® device (median = 5, IQR = 4–5) vs AL (median = 5, IQR = 4–5) with an estimated OR for ThoraSite® of 1.55 (95%CI 0.89–2.72). Paramedic self-rated confidence post-training (median = 5 IQR = 4–5), regardless of the device used for training, was significantly higher than pre-training (median = 4 IQR = 3–4, p = < 0.01). Paramedic-rated ease of the procedure was significantly higher for the ThoraSite® (median = 4, IQR = 4–5) compared to ALs (median = 4, IQR = 4–5, p = <0.01) (Supplemental Table 3). Qualitatively, paramedics commented that the ThoraSite® device "takes away the unsure feeling of hitting your landmarks", "seems like a great device", and "made placement much easier". Concerns the paramedics shared included that the ThoraSite® device was "slightly cumbersome" and that they were "unsure how well this will work on" patients with larger body habitus.

Discussion

We found that use of the ThoraSite® device was associated with increased odds of correct NT site selection and reduced time to NT site selection by paramedics. To our knowledge, this is the first published study evaluating the performance of EMS clinicians using the Thorasite® device with regards to accurate site identification for NT placement in live human models. Our use of U/S to confirm accurate

landmarks and placement position was novel and allowed evaluation of potential injuries resulting from inaccurate NT site selection. Given the demonstrated accuracy and low frequency of misplacements, this study adds to the current body of literature that the ThoraSite® may be a useful device to improve EMS clinician accuracy of needle placement.

Inaccurate anatomic location selection is one of several factors that contributes to failed NT placement by EMS clinicians. Traditionally, the second intercostal space, midclavicular line (2MCL) has been used, however, studies have found that the chest wall is generally thicker anteriorly compared to lateral areas of the torso which can contribute to placement failure (11–13) even when using accurate anatomic landmarks (6,14). In addition to ensuring adequate needle length (8 cm), some authors have supported lateral NT placement as preferred, where overall chest wall thickness is ostensibly decreased (13). For this reason, landmarking assistance tools that target lateral landmarks, like the ThoraSite® device, may be of benefit to prehospital clinicians when instructed to preferentially use lateral approaches for NT.

In our study we found that use of the ThoraSite® device was associated with improved accuracy and shorter time-to-site selection for NT placement. While our result estimate suggests a near 2-fold improved accuracy of site selection, it should be noted that the lower limit of the confidence interval approached one, which includes the possibility of a very small effect and may not be clinically significant. The shorter time-to-placement was not likely clinically significant with an absolute difference in mean time of approximately four seconds. The device was viewed favorably overall by paramedics who reported higher ratings in ease of use compared to traditional ALs. The NT procedure can be difficult to perform correctly in a stressful field environment that may have limited light or working space. Given the emergent nature of the procedure, a simple tool like the ThoraSite® device may ease the rapid identification of a placement location for NT and for this reason, may provide benefit to EMS clinicians performing this critical procedure and can be considered for use by EMS agencies if deemed affordable. At the time of publication, cost for the ThoraSite® device was approximately $15 per unit.

Overall, attempts using the ThoraSite® device were more accurate than attempts using ALs alone. Although the subgroup analysis by model height did not reveal a difference in site selection accuracy between methods by model size, the power of this analysis to detect a difference in these subgroups was limited by a small sample size in each group. It is notable that the largest difference in accuracy compared to ALs was observed in the short model group. It is possible that ALs may be incorrectly estimated more frequently in shorter patients making it useful to observe the difference in accuracy favoring the ThoraSite® device use in this subset of patients, noting that the ThoraSite® device is intended for use in adult and adolescent patients only.

In our study, we evaluated the marginal difference of accurate placement using the ThoraSite® device compared to traditional ALs after standardized refresher training, which was small. It is likely that the refresher training performed prior to the trial attempts resulted in improved "correct" placements for both approaches during the trial attempts. Paramedic training reinforces skill performance, which is likely to result in improved success, therefore, the accuracy reported using traditional ALs in this study may not be representative of success rates in the field or those found in previous studies given the temporal proximity to receiving training (10). Our results demonstrated that paramedics rated a significantly improved level of confidence after their training and trial attempts for both ALs and ThoraSite® which supports this assertion. Frequent training has been suggested to maintain NT proficiency. One study's evaluation found that only 60% of previously Advanced Trauma Life Support (ATLS) trained emergency physicians successfully identified the correct AL for NT placement when performed without preparatory training (15). If reflective of accuracy in actual patients, this figure is concerning as incorrect NT placement has the potential of injuring vital anatomic structures resulting in increased morbidity and mortality (12,16). Future studies that evaluate the accuracy when using the ThoraSite® device external to a training environment are warranted since such a tool may prevent patient harm resulting from misplacements.

Despite being highly accurate in facilitating NT site selection, use of ThoraSite® resulted in misplacements in 11% of attempts in our study. A previous study by the device creator using cadaver models commented specifically on anterior/posterior misplacement but did not include information regarding inferior misplacement or complications (8). In our study, we found that 56% of incorrect placements with the ThoraSite® device and 34% with ALs were inferiorly misplaced (Table 4) which would be most likely to be complicated by iatrogenic solid organ injury or entry into the peritoneum. By using U/S, we were able to identify that one of these misplacements would have hit a critical structure (stomach) should NT have been performed with the ThoraSite® compared to three using ALs (liver).

Finally, this is the first ThoraSite® study to investigate paramedic perceptions of the device. While paramedics included in the study found the device easy to use, their confidence increased after additional education, but this does not appear to be from using the device alone since no difference was found in paramedic confidence between the two methods post-training. Our study included practicing emergency response field paramedics who work in an urban environment with overall limited experience performing NT in departments with low NT placement volume. Although our findings may not be generalizable to paramedics that work in different environments or have varying experience levels with NT, our results support use for ThoraSite® as a clinical tool that was well received by field paramedics.

Limitations

The primary limitation of our study is that it is unclear how well our findings in a controlled environment would translate to field use. While participating paramedics were timed during this study, that alone does not replicate the stressors of managing a live critical patient, environmental

distractions, or other complicating factors such as the extra time it may take to find the device, that paramedics may deal with in their typical field setting. It is possible that under these circumstances, performance accuracy with the ThoraSite® device may be reduced and future research would benefit from exploring performance in an operational environment. Notably, our study included paramedics from three EMS agencies that volunteered to participate in the study, which could introduce a selection bias. While our study included models of varying size by height, the mean BMI in our healthy models, many of whom were fire-service paramedics, was 25.9 which greatly differs from that of the adult population in the United States, where the prevalence of obesity for adults is >40% (17), thus it is likely that our models were not representative of the general population. Models were limited to those that volunteered and were, as expected, predominantly "medium" height. Despite efforts made to recruit varying sized models, short body type models were of limited availability in our study. It is unclear if similar accuracy for NT site selection would be achieved in typical patients encountered by EMS clinicians. Another limitation is that paramedics made trial attempts back-to-back and could have gained proficiency as the study progressed. We attempted to mitigate this by randomization of the technique used but could not eliminate this possibility completely. In addition, both paramedics and those assessing NT placement were not blinded to the evaluation of correct placement by technique used, which could introduce bias. We attempted to mitigate this through use of two independent evaluators determining the DZ such that placement accuracy could be measured in absolute binary terms. Additionally, our study did not account for paramedic experience or variability, making it difficult to attribute outcomes solely to use of the ThoraSite® device or identify user populations where the device may be best utilized, such as those with minimal previous experience in performing NT. Due to the sample size, we were unable to fit a model adjusting for paramedic experience, number of NT attempts prior to the study, or the order of the attempt (Thorasite® vs AL). In this study, NT performance and ThoraSite® use was assessed immediately after training, so it is unclear what the impact of suboptimal skill retention may be over time.

Conclusions

Use of the ThoraSite® device was associated with increased odds of correct NT site selection and reduced time to NT site selection by paramedics using live models. There was no significant interaction between NT site selection technique and model size, although power to detect a subgroup effect was limited by sample size. Paramedic confidence showed a statistically significant improvement after training, though no significant difference in post-training confidence was found between ALs and ThoraSite® methods. Paramedics rated ease of procedure significantly higher when using the ThoraSite® device. Our results suggest that the ThoraSite® device may be a useful clinical adjunct to optimize NT placement by field paramedics.

Author Contributions

DW, NB, KW and MGH conceived and designed the study. DW oversaw the data collection of the study. KW, JW, MA, JT, MK, EA, MC, JN, AR, and LM assisted in data collection. NB and JT provided statistical consultation on study design and performed statistical calculations. DW, NB and JT analyzed the data. DW, JW, and EA drafted the manuscript, and all authors contributed to its revision and final submission.

Declaration of Generative AI in Scientific Writing

The authors did not use a generative artificial intelligence (AI) tool or service to assist with preparation or editing of this work. The author(s) take full responsibility for the content of this publication.

Disclosure Statement

The authors report there are no competing interests to declare.

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