Assessment of Human Cadaveric Tissue Penetration Capabilities of A Novel Automated Needle Decompression Device (ANeeD) for Pre-Hospital Treatment of Pneumothorax

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Background/Introduction

- Pneumothorax is a common battlefield injury observed in 51.8% of thoracic trauma cases.
- Prehospital decompression is made particularly difficult by variations in chest wall thickness (CWT) and landmark identification.
- Traumatic changes to thoracic anatomy and increases in CWT due to common comorbidities such as subcutaneous emphysema and rib fractures contribute to a prehospital failure rate ranging between 39% and 76% based on site of insertion.[1,2,3]
- We developed a field-ready ultrasound guided automated needle decompression device (ANeeD) to enable untrained personnel to treat pneumothoraces in combat environments.
- Previous trials conducted utilizing six 45kg porcine models demonstrated the device's ability to identify pertinent landmarks and detect lung sliding in swine.
- Mechanical difficulties were encountered in swine testing with needle strangulation or incomplete epidermis penetration observed in 37% of needle deployments
- These findings necessitated further evaluation of the ANeeD devices penetration efficacy in human tissue.

Methods

Cadaver Model:

6 cadavers, 3 male and 3 female, were utilized as testing subjects in this study. Male donor BMI ranged from 21.6 to 24.3, and female donors BMI ranged from 21.6 to 25.6.

Device Setup & Testing:

The ANeeD device was tested at intercostal spaces along the mid-axillary and mid-clavicular lines in each cadaver. Testing was done in two phases:

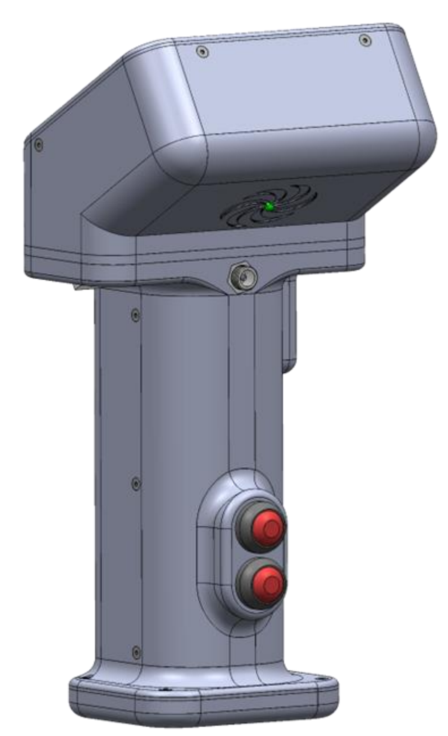
1. Evaluation of algorithmic anatomic landmark and pneumothorax detection
2. Activation and evaluation of needle decompression

Data Recording & Analysis:

For evaluation of the algorithm, the difference between algorithmically detected rib margins and the pleural line and visually identified values for these metrics were recorded for each deployment. The algorithm detection of pneumothorax was also recorded as it was presented on screen at time of needle deployment.

Evaluation of the mechanical device was done by analyzing successful needle penetration of all three layers of donor tissue. This was recorded as "yes" or "no" for each deployment.

Results



Device Evaluation:

The ANeeD device successfully penetrated skin and subcutaneous tissue layers of cadaver tissue in all 53 needle deployments. All three tissue layers were successfully penetrated in 50/53 deployments, with rib strikes preventing proper penetration in the remaining 3 deployments.

Needle depths within 3 mm of chosen depth were seen in 98% of successful deployments. Secondary findings in needle placement due to US sensor offset were able to be corrected manually.

Skin 53 / 53

Subcutaneous Tissue 53 / 53

Parietal Pleura 50 / 53

Algorithm Evaluation

Rib margins and pleural line depth were algorithmically identified via ultrasound imaging within 3 mm of the cephalad rib in 75.5% of cases, and within 3 mm of the caudal rib in 69.8% of cases. Accurate identification of the pleural line within 3 mm was seen in 66.02% of cases.

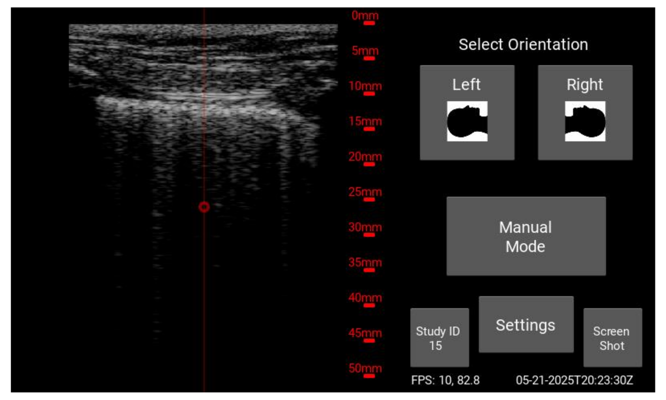


Image 1: ANeeD Device GUI prior to algorithmic analysis / deployment

	Within 1mm	1mm < 3mm	3mm < 5mm	Greater than 5mm
Cephalad Rib	31	9	0	12
Caudal Rib	30	7	1	14
Pleural Line	31	3	1	17
				Total: 52

Table 1: Accuracy of ANeeD Algorithm in Identifying Position of Cadaver Ribs and Pleural Line

Conclusions

- The ANeeD device is capable of penetrating human tissue to specified depths as necessary for field decompression of a pneumothorax.
- Embedded computer algorithms trained and tested on swine models proved to be less accurate on human cadavers.
- Adjustments to placement and deployment can correct for issues caused by US sensor-needle offset.
- Further revisions to cradle design and algorithm windowing can help address secondary findings to further improve device use on human tissue.

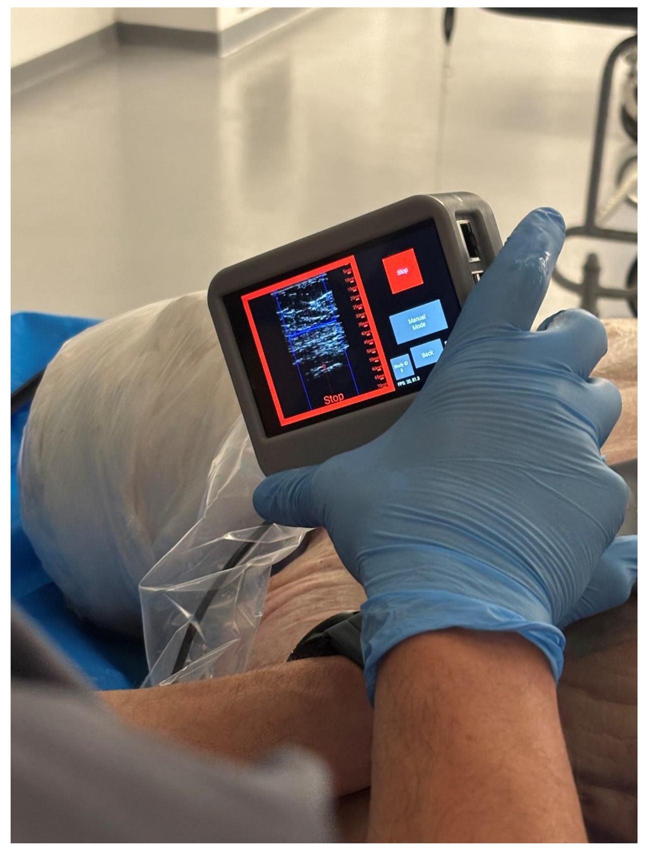
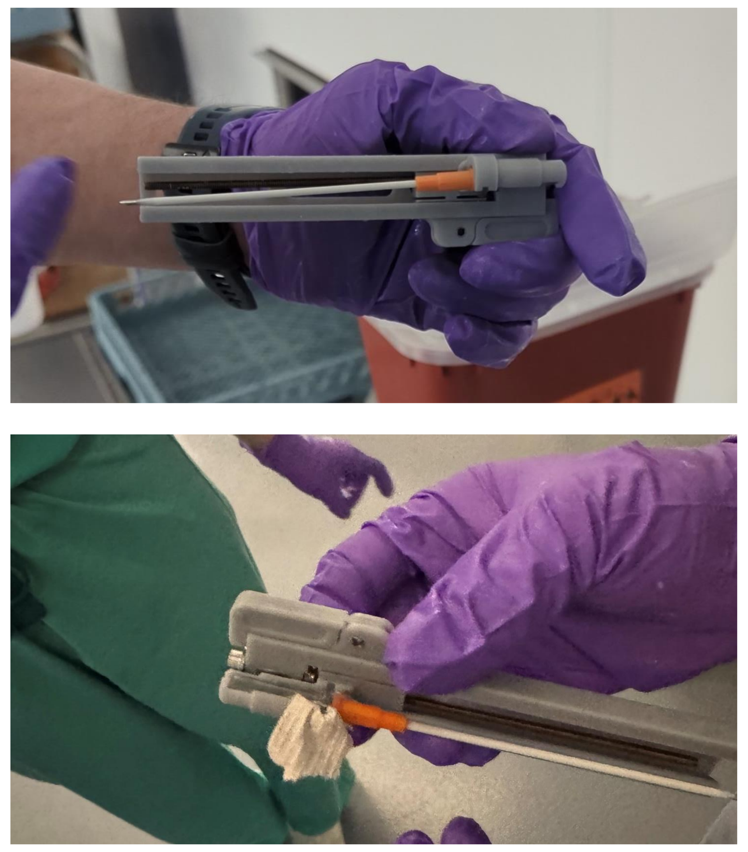
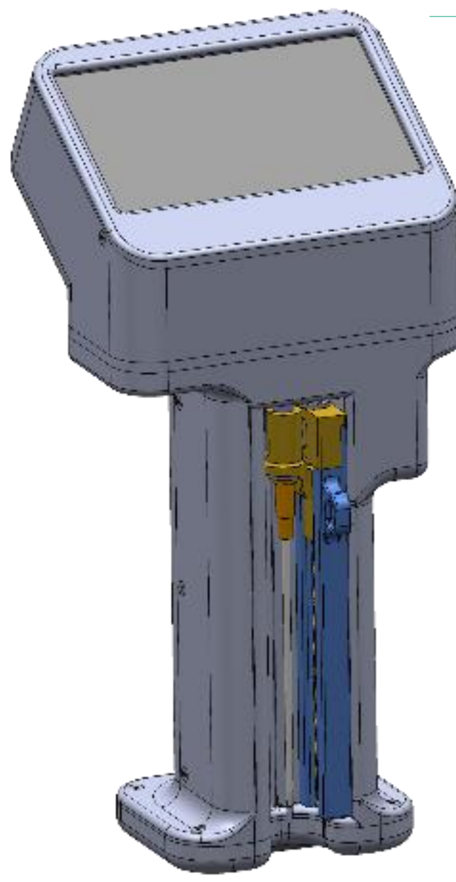


Image 2: The ANeeD Device analyzing presence of pneumothorax during testing



Images 3/4: Corrections made to needle cradle throughout cadaver testing to improve device accuracy



Citations

1. Ahmad SJS, Degiannis JR, Head M, et al. Meta-analysis of the optimal needle length and decompression site for tension pneumothorax and consensus recommendations on current ATLS and ETC guidelines. *World J Emerg Surg*. 2025;20(1):39. Published 2025 May 19. doi:10.1186/s13017-025-00613-7
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3. Kaserer A, Stein P, Simmen HP, Spahn DR, Neuhaus V. Failure rate of prehospital chest decompression after severe thoracic trauma. *Am J Emerg Med*. 2017;35(3):469-474. doi:10.1016/j.ajem.2016.11.057