# Incorporating Real-Time Audiovisual and Haptic Feedback in a Novel Thoracostomy Tube Training Model

UTSouthwestern Medical Center

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Alex Najjar BS[1] , Shruti Hegde MD[1], Emily Hofman BS[2], Sruthi Dubagunta BS[2], Daniel Awad BS[2], Omar Khan BS[2], Kraigen Eisaman BS[2], Ifti Hossain BS[2], James Walker, Bradley Sherman, Yash Kadakia BS[1], Caroline Park MD MPH[1]

1: University of Texas Southwestern Medical Center, Department of Surgery. 5323 Harry Hines Blvd. Dallas, TX USA 75390-9159
2: Department of Engineering, University of Texas at Dallas, Dallas, TX

## Introduction

- Chest tube insertion, or tube thoracostomy, prevents lung collapse due to excessive air or fluid in the pleural cavity such as in conditions like traumatic pneumothorax or hemothorax.
- The procedure starts by making an incision at the fourth or fifth intercostal space, mid-axillary line, above the ribs to avoid the neurovascular bundle. It includes finger sweeps for proper pleural entry, guided drainage tube insertion using a Kelly clamp at the apex, and securing the tube to the chest wall.
- Common pitfalls include risks like injury to the intercostal neurovascular bundle and uncontrolled pleural entry, leading to complications such as injury to the chest wall, lung parenchyma, diaphragm, or liver. The overall complication rate can be up to 40%.[1]
- Mastery of this procedure is important yet complicated by infrequent hands-on practical training and the use of minimally invasive techniques. This study aimed to design an affordable and functional model with real-time force-sensing with force and time feedback during thoracostomy.

## Methods and Materials

- Training model consisted of a modified Kelly clamp device with three force sensors (sensor 1 in the index finger position and sensors 2 and 3 in the finger loops) and a manikin with a replaceable chest wall pad.
- Standard values and time range were established using expert-derived data for force values (Newtons "N") and acceptable time to completion of 3-5 seconds.
- Trainee participant levels ranged from PGY-1 to PGY-6 surgery residents, and an introduction to the procedure and training device was provided prior to their attempt to use the device.
- During use of the device by trainees, force and time was measured from entry through the dermis to pleural space puncture, and a significant pressure/force drop indicated puncturing through the chest wall, marking the completion of the procedure.

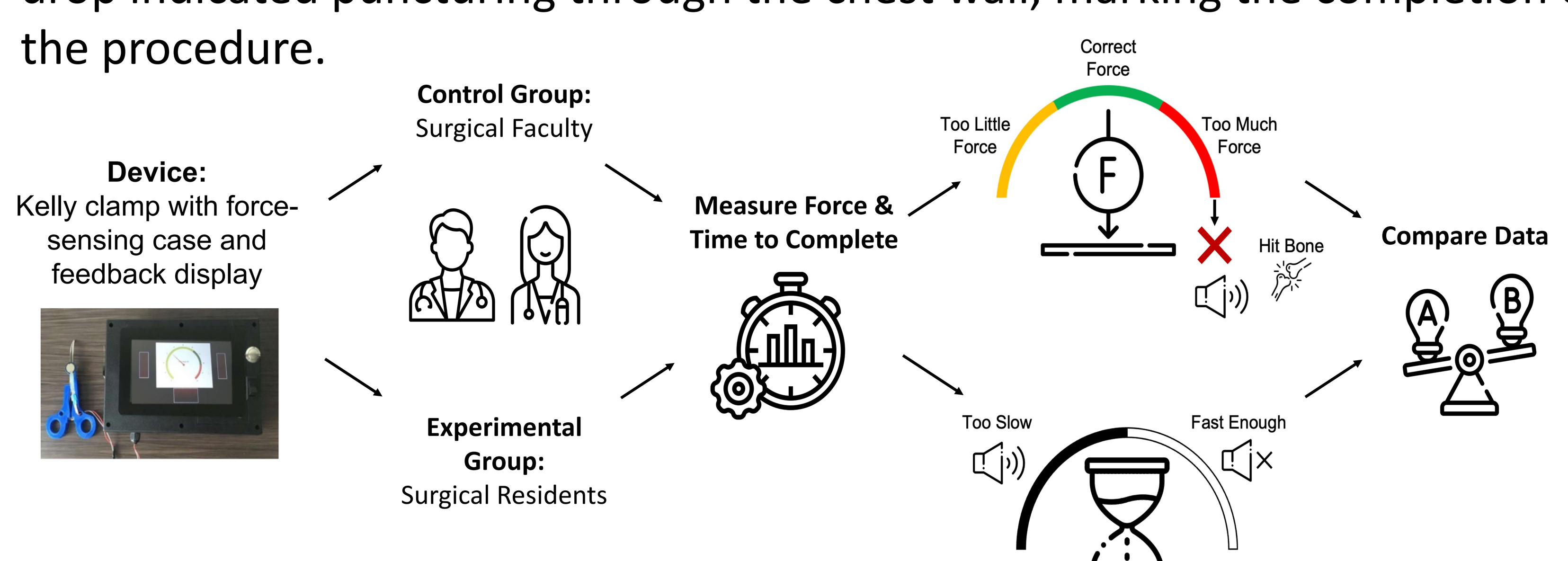


**Figure 1.** Study design

## Results

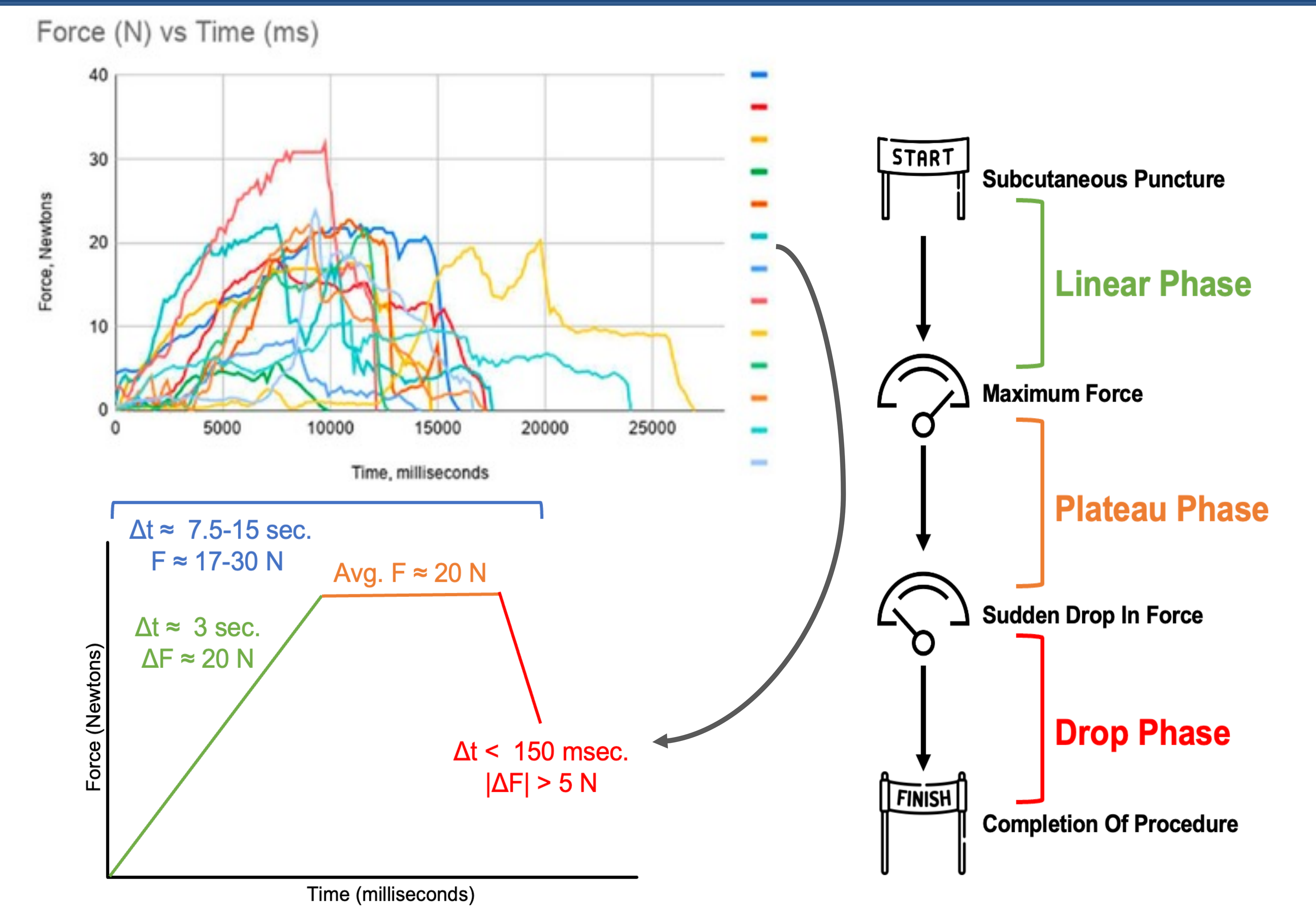


**Figure 2.** Baseline expert force broken down into steps of chest tube insertion

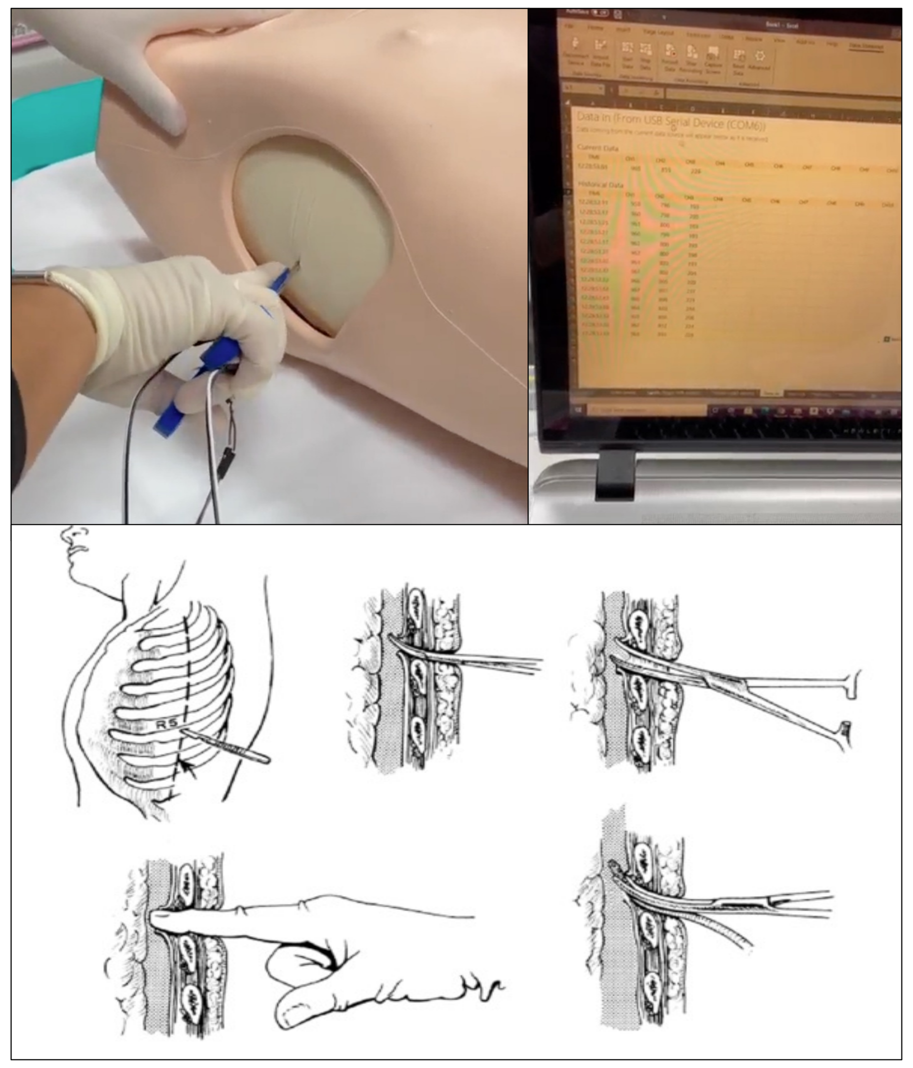

**Figure 3.** Steps in chest tube insertion with demonstration on training model[4]

**Device Feedback by Phase:**

- Linear Phase: Auditory feedback if $F < 10$ N after 3 sec to indicate user should work faster
- Plateau Phase: Audiovisual feedback if $F > 30$ N to indicate presumed contact to bone
- Drop Phase: Audiovisual feedback if $\Delta F > 5$ N in $< 0.6$ sec to indicate completion of procedure/pleural space entry

- All participants used sensor 1, but left-handed users also relied on sensor 3 and right-handed users also relied on sensor 2. Thus, only the measurements from sensor 1 were used.
- Overall cost was about $750 with non-reusable items costing less than $200 and as low as $15.
- Audiovisual feedback was provided appropriately by the device.
- Per users, functionality was not hindered by the device.

## Discussion

- This novel force-sensing chest tube trainer device features continuous force monitoring and provides portability, accuracy, ease of use, and low cost.
- We characterized distinct stages of the thoracostomy process with force and time parameters that allowed us to develop feedback signals for trainees.
- Laparoscopic simulation studies have demonstrated a correlation between several force parameters and participants' experience.[3] At least one study used a similar model using an instrument with an integrated sensor.[4]
- We used a combination of continuous feedback, band-with feedback, and fade-in feedback which may be beneficial for guiding users in both a simulated and a clinical setting.

## Next Steps

- Assessing inter-user reliability in forces across multiple expert surgeons
- Establishing evidence-based ranges for acceptable force and discriminating between expert and novice force patterns
- Determining whether implementation of force-sensing reduces the incidence of complications in the clinical setting

## Contact

Alex Najjar
UT Southwestern Medical Center
Email: Alex.Najjar@UTSouthwestern.edu

## References

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## Disclosures

A provisional patent has been filed for this chest tube training device UTSD 3905 (106546 691748)