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Visually guided tube thoracostomy insertion comparison to standard of care in a large animal model

Matthew C. Hernandez[a], David Vogelsang[d], Jeff R. Anderson[c], Cornelius A. Thiels[a], Gregory Beilman[e], Martin D. Zielinski[a], Johnathon M. Aho[a,b,*]

[a] Department of Surgery, Division of Trauma, Critical Care, and General Surgery, Mayo Clinic, Rochester, MN, United States
[b] Department of Physiology and Biomedical Engineering, Mayo Clinic, Rochester, MN, United States
[c] Office of Translation to Practice, Mayo Clinic, Rochester, MN, United States
[d] Mayo Medical School, Mayo Clinic, Rochester, MN, United States
[e] Department of Surgery, University of Minnesota, Minneapolis, MN, United States

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ABSTRACT

Introduction: Tube thoracostomy (TT) is a lifesaving procedure for a variety of thoracic pathologies. The most commonly utilized method for placement involves open dissection and blind insertion. Image guided placement is commonly utilized but is limited by an inability to see distal placement location. Unfortunately, TT is not without complications. We aim to demonstrate the feasibility of a disposable device to allow for visually directed TT placement compared to the standard of care in a large animal model.

Methods: Three swine were sequentially orotracheally intubated and anesthetized. TT was conducted utilizing a novel visualization device, tube thoracostomy visual trocar (TTVT) and standard of care (open technique). Position of the TT in the chest cavity were recorded using direct thoracoscopic inspection and radiographic imaging with the operator blinded to results. Complications were evaluated using a validated complication grading system. Standard descriptive statistical analyses were performed.

Results: Thirty TT were placed, 15 using TTVT technique, 15 using standard of care open technique. All of the TT placed using TTVT were without complication and in optimal position. Conversely, 27% of TT placed using standard of care open technique resulted in complications. Necropsy revealed no injury to intrathoracic organs.

Conclusion: Visual directed TT placement using TTVT is feasible and non-inferior to the standard of care in a large animal model. This improvement in instrumentation has the potential to greatly improve the safety of TT. Further study in humans is required.

Level of evidence: Therapeutic Level II.

Introduction

Tube thoracostomy (TT) is a potentially life-saving procedure performed by providers in multiple disciplines. Despite TT placement being considered a relatively minor procedure, the placement technique remains largely unchanged over time and is associated with high complication rates (20–40%) in contemporary series [1–6]. A suboptimal placed TT prevents proper drainage of the pleural cavity and often requires replacement. Moreover, TT insertion outside the thoracic cavity or into organ tissues can be a devastating complication.

Several key maneuvers must be completed during standard of care insertion of a bedside TT. First, the correct location for placement, most commonly the "triangle of safety" as described by the British Thoracic Society, must be identified [7]. Second is sharp and blunt dissection of the thoracic wall. Third, a digit or instrument is inserted and the pleural space assessed for access to the cavity. Fourth, blind TT insertion is performed into the pleural space. Complications can occur during all four steps [8–11], but are most common during the insertion maneuver [6] as the TT is significantly longer than the operator's digit. Our efforts have

* Corresponding author at: Mayo Clinic, 200 First Street SW, Rochester, MN, 55905, United States.
E-mail addresses: hernandez.matthew@mayo.edu (M.C. Hernandez), vogelsang.david@mayo.edu (D. Vogelsang), Anderson.Jeff1@mayo.edu (J.R. Anderson), thiels.cornelius@mayo.edu (C.A. Thiels), Zielinski.martin@mayo.edu (M.D. Zielinski), aho.johnathon@mayo.edu, jaho@mtu.edu (J.M. Aho).

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thus been focused on determination of visualization of TT placement location.

Currently, providers are unable to directly visualize the chest wall, lung parenchyma, and other key structures while inserting TT. The inability to see these critical structures creates a potential for development of a TT related complication or placement in an incorrect location. This potential may be increased in the emergent or urgent setting as well as by the habitus of the patient [12,13].

Our previous work has demonstrated the feasibility of a visually directed technique for the direct visualization of TT insertion in a cadaver [14]. In this present study, further refinement of both technique and device are presented to suggest that new technology may facilitate the safe placement of TT in a large animal model. The Tube Thoracostomy Visual Trocar (TTVT, Fig. 1, and Supplemental Video) accommodates 22–40F chest tubes with a camera within the TT to provide direct visualization during placement. We aim to demonstrate the feasibility of direct visualization for TT insertion compared to the standard of care using a large animal model. We hypothesize that direct visual TT placement will have a reduced complication rate and improved positioning success as compared to the standard open technique.

Methods

After obtaining approval from the institutional animal research review board, three domestic cross bred pigs (approximately 45 +–5 kg) were used for experimentation. Multiple straight thoracostomy tubes were utilized (36, 32, 28 French). Decreasing TT sizes were used to demonstrate the generalizability of the tube thoracostomy visual trocar (TTVT) for insertion. Ten chest tubes were placed (5 using standard of care, 5 with visual device) in each animal using the different sized tubes. Laterality for standard of care vs visual placement was assigned randomly and the procedure was repeated a total of five times on each side. For both the experimental and standard of care group a thoracoscope without insufflation was used to assess [1] intrathoracic TT placement [2], location of TT position [3], development complications based on a defined list of complication types [15]. The TT operator was blinded to the thoracoscopic view during placement and was only allowed to utilize the TTVT for visually placed TT or open technique for standard of care.

The TTVT device is based upon the design of a disposable bronchoscope. Modifications included adjustments to the camera length, handle and clamping mechanisms to permit the user to rapidly assemble the device and provide visual guidance during TT insertion. Tube thoracostomy visual trocar placement TTVT was performed as follows [1]. The chest tube is fitted over the TTVT [2]: A thumb operated, clamping mechanism is actuated to position the tip of the camera at or near the distal end of the tube thoracostomy according to operator preference [3]: The tube thoracostomy is inserted through using an open technique and directed via visual guidance using the TTVT camera, to the apex of the lung (Fig. 2A, B) [4]: The clamping mechanism is released by trigger actuation and the TTVT withdrawn from the TT. The procedure is completed by securing the TT according to the standard of care.

For this experiment, all of the procedures were performed by a second year general surgery resident with endoscopic and tube thoracostomy insertion experience. The operator's relationship to the device was as a novice user, and prior *in vivo* visual trocar training was nil. Analysis comparing complications of standard of care compared to TTVT placement was performed using GraphPad Prism 7 (GraphPad Software, Inc. La Jolla CA).

Results

Thirty TT were placed, 15 using TTVT, 15 using standard of care open technique. All of the TT placed using TTVT were without complication and in optimal position. Conversely, 27% of TT placed using standard of care open technique resulted in TT malposition (p value = 0.0996 by Mann Whitney Exact Test). Of the complicated TT insertions (n = 4), 100% were classified as insertional subtype (Table 2). In order to demonstrate important differences in anatomy using the TTVT, Fig. 2C and D outlines differences the TTVT can visualize between the thoracic and peritoneal cavities.

Detailed results by individual animal experiment are shown below and summarized in Table 1.

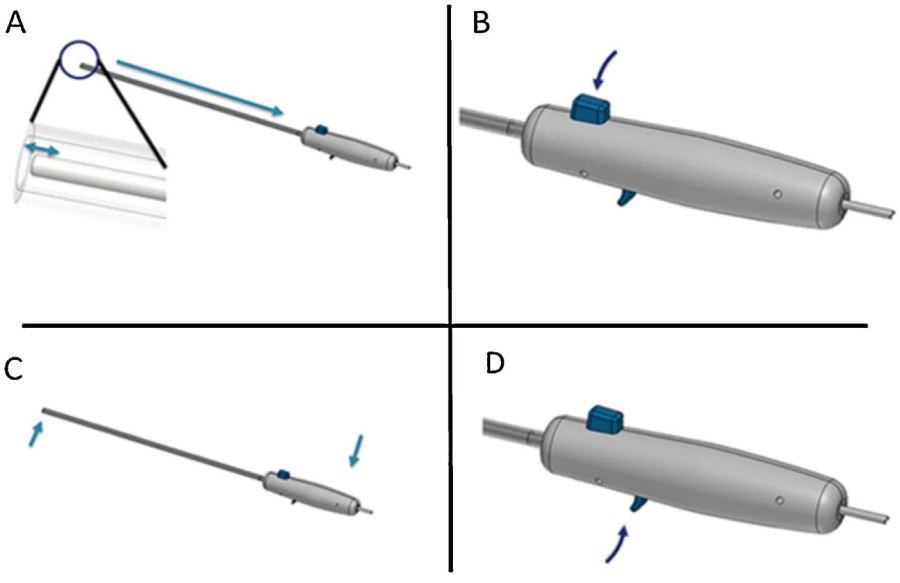

Fig. 1. User Sequence of Visually Guided TT Device: (**A**) Insertion of optical portion of scope into the thoracostomy tube which goes over the camera. (**B**) At the desired position, the thumb actuator clamps the scope and tube together. (**C**) Manipulation of the scope and tube can be performed using a single hand or two hands as desired by the operator. (**D**) Once the tube is visually confirmed in the optimal position, the forefinger trigger actuator releases the clamped scope from the tube and the device may be withdrawn.

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