Video-Guided Tube Thoracostomy With Use of an Electrical Nonfiberoptic Endoscope

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Purpose. Tube thoracostomy is a common and generally safe procedure. However, potential hazards can occur during placement of the chest tube. Inasmuch as unexpected injuries may arise from tube thoracostomy, we propose a novel video-guided method.

Description. We used an independent complementary metal oxide semiconductor image sensor with a processing chip to obtain a front view image of the chest cavity. The device is connected to an aluminum shaft with four small light-emitting diode crystals in the tip, and a detachable small monitor with a battery inside. The apparatus is small and can be used to direct vision-guided tools in tube thoracostomy.

Evaluation. We performed video-guided tube thoracostomy in 6 patients with pleural adhesions. All patients experienced good tolerance to the procedure and had no immediate adverse events. The thoracostomies were performed by a single surgeon with good acceptability, and each procedure was completed in less than 10 minutes.

Conclusions. In some cases of pleural adhesion, the video-guided thoracostomy may be a safer alternative to non–image guided tube thoracostomy.

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ube thoracostomy is a common and generally safe procedure. However, under certain conditions, the procedure may result in unexpected injury. For example, in patients with a history of chest operations and with a previous infection in the pleural space, adhesions between the lung and chest wall may be very dense. Therefore, placement of a chest tube guided by a rigid stylet through a tiny incision in the chest wall may cause severe lung injury, which in serious cases can have lethal consequences. One cause of lung injury is the inability to determine whether a patient has pleural adhesions before the start of the procedure, especially when the patient’s history is not available. In the case of diffuse adhesions, the resistance may be sufficiently low that the injury is not immediately evident, and it is discovered only when unexpected severe air leaks or bleeding manifest after the procedure. However, if the location and function could be determined at the time of insertion, subsequent adjustments might be avoidable.

Sometimes in a plain chest roentgenogram, pleural adhesions can be identified by certain image features, such as a part of the lung adhering to the lateral chest wall in the setting of tension pneumothorax or hydrothorax, rather than collapsed into the hilar region. Many alternatives have been suggested to minimize potential hazards resulting from tube thoracostomy. A common approach is the so-called open method, in which a large incision is made to allow finer palpation to ensure a safe entry site, followed by placement of the tube. However, the open method is experience dependent and may prove to be difficult and unreliable for most physicians. This method can usually help confirm that the entry site is safe, but determining the distal location of the tip is not possible. Because tube thoracostomy with a rigid stylet is easier, we designed tools to help avoid unexpected injury, with the aim of letting physicians get a front view of the pleural cavity. In the case of partial adhesion, the tube may be moved to a better space with the video-guided tool.

In this study, we selected 6 patients to undergo video-guided thoracostomy. These patients were suspected of having pleural adhesions, on the basis of either surgical history or imaging results.

Technology

To effectively guide the tube, the guiding device must be very small. We designed an independent image-obtaining device, similar to the electrical nonfiberoptic endoscope (ENFE) that we reported in a previous study [1]. The basic component of this device is a
complimentary metal-oxide semiconductor image sensor with a resolution of \(640 \times 480\) pixels and horizontal/vertical viewing angles of 60°. The refresh rate was 30 frames per second, and the focus was adjusted to a range of 3 to 7 cm for clarity. Two to six circumferential light-emitting diodes (LED) were placed in the tip of the device to provide illumination. The current for each LED was 15 to 18 mA. The overall structure is shown in Figure 1. We divided the stylet and monitor into two independent parts, which could be connected. For better flexibility, the shaft of the stylet was made of aluminum. There were only four wires in the aluminum shaft, which allowed it to be bent and deformed to guide the tube in the proper direction. The viewing device was a small monitor with a lithium battery inside. When connected to the monitor, the current from the battery was provided to the image sensor, image processing chip, and LEDs. Then, the signals were conveyed backward so that the operating environment was visible in the small monitor. The monitor was also designed to be hand-held. We used this method to place the chest tube in 6 patients with a known history of lung operation or chronic pleural infection.

**Technique**

The execution of the basic procedure was very straightforward. The patient was placed in a lateral decubitus position for better exposure of the operative field; alternatively, the patient was allowed to choose a comfortable supine or slightly tilted position. We routinely administered intravenous analgesics. The operative field was then prepared, disinfected with 2% chlorhexidine or iodine solution, and subsequently covered. After local anesthetics were given subcutaneously, a small incision of approximately 0.8 to 1.5 cm was made. The device was placed inside the chest tube. Then, under the guidance of the device (Fig 2A), the tube was extended through a safe tract or route into the pleural space (Fig 2B). After confirmation of safety, length, location, and function, the device was immediately removed, and a bottle was then connected to the chest tube. After the procedure, we evaluated the success of the treatment by roentgenology of the chest. There was no evidence of kinking, bending, or extending too far into the mediastinum. In the
After patient evaluation, the presence of pleural adhesion was our main reason for choosing the video-guided tube thoracostomy technique over the conventional blind胸腔穿刺技术. Six highly selected patients underwent the procedure. The clinical data are shown in Table 1. The components of the device were disinfected by ethylene oxide as a standard preparation for medical devices. Here, we briefly describe two cases. The first case was a rare condition of anorexia nervosa with resultant spontaneous pneumothorax. Because the patient did not promptly seek medical attention, her condition had deteriorated to empyema and necrotizing pneumonia. The lung did not heal spontaneously and was found to have air leaks for more than 1 month, even after decortication and wedge resection. Her chest tube was changed to prevent infection, but pleural adhesion was evident in most of the pleural space around the tube. To prevent tube injury to the lung, we used a video-guided method to replace the original tube with a new tube. After drainage for several weeks, the replacement tube was removed, and the patient was discharged.

A more complicated condition was encountered in the second case. The patient was admitted to our branch hospital with a diagnosis of severe septic shock resulting from bilateral pneumonia. Within days of her admission, the infection became overwhelming, and the lung became necrotic. Although tube thoracostomy was performed to drainage the infected lung, the air leaks were so severe that ventilation was unable to maintain a sufficient level of saturation. After aggressive treatment with antibiotics and drainage of a massive pericardial effusion, the sepsis could be controlled. However, the patient’s right lung was still necrotic, and the infection became overwhelming. The lung was transferred to Taipei, where he underwent resection of the gangrenous right upper lobe and right lower lobe. The two lobes were quickly excised because the vascular pedicle and bronchus had become totally gangrenous and necrotic. Initially, the air leaks could be controlled. However, the patient’s right lung was still necrotic. The patient did not promptly seek medical attention, but pleural adhesion was evident in most of the pleural space around the tube. To prevent tube injury to the lung, we used a video-guided method to replace the original tube with a new tube. After drainage for several weeks, the replacement tube was removed, and the patient was discharged.

Table 1. Clinical Demographics and Rationale for 6 Patients Who Underwent VGTT

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>Diagnosis</th>
<th>CoM</th>
<th>Side</th>
<th>Indication for TT</th>
<th>Indication for VGTT</th>
<th>Evaluation Before VGTT</th>
<th>Time for VGTT (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>F</td>
<td>Chronic pneumothorax</td>
<td>Anorexia</td>
<td>R</td>
<td>Chronic pleural infection</td>
<td>Pleural adhesion</td>
<td>CXR</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>M</td>
<td>Recurrent pneumothorax</td>
<td>None</td>
<td>R</td>
<td>Dyspnea</td>
<td>Pleural adhesion</td>
<td>CT scan</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>94</td>
<td>M</td>
<td>Chronic pneumothorax</td>
<td>Ischemic bowel disease</td>
<td>R</td>
<td>Recurrence after chemical pleurodesis</td>
<td>Pleural adhesion</td>
<td>CXR</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>44</td>
<td>M</td>
<td>Chronic BP fistula</td>
<td>Necrotizing pneumonia/empyema</td>
<td>R</td>
<td>Chronic pleural infection</td>
<td>Pleural adhesion</td>
<td>CXR</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>59</td>
<td>M</td>
<td>Chronic BP fistula</td>
<td>Necrotizing pneumonia/empyema</td>
<td>R</td>
<td>Chronic pleural infection</td>
<td>Pleural adhesion</td>
<td>CT scan</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>74</td>
<td>M</td>
<td>Recurrent pneumothorax</td>
<td>COPD</td>
<td>R</td>
<td>Dyspnea</td>
<td>Partial adhesion</td>
<td>CXR</td>
<td>4</td>
</tr>
</tbody>
</table>

BP = bronchopleural; CoM = comorbidity; COPD = chronic obstructive pulmonary disease; CT = computed tomography; CXR = chest radiograph; F = female; M = male; R = right side; TT = tube thoracostomy; VGTT = video-guided tube thoracostomy.
the condition of the pleural space to be observed. After safety was confirmed, the tube was then placed in its proper location (Fig 4). The follow-up chest roentgenogram is shown in Figure 3B. The patient did not report any major discomfort during the procedure. The time required for the procedure was short, as described in Table 1.

**Comment**

Adverse events arising from tube thoracostomy are not uncommon. They include a malpositioned and kinked tube and direct injury to the diaphragm (Fig 5A) and lung, resulting in bronchopleural fistula (Fig 5B). One reason for these adverse events is that the physician is unable to properly obtain a front image view of the chest cavity. Therefore, when the tube is improperly and forcefully inserted into the tissues, the procedure can be extremely dangerous. Although uncommon, cases of massive hemothorax and hemoptysis with lethal outcome occur every year. In a retrospective study, the success rate of tube thoracostomy was only 78%. In 22% of the cases, the tubes were bent, were twisted, or extended too far into the pleural space; half of these cases required adjustment [2]. Although various modifications have been proposed [3], direct visual guidance may very well be the most promising method.

The ENFE has many potential benefits. First, the complimentary metal oxide semiconductor module is quite inexpensive. Owing to its detachable design, the cost of the monitor can basically be ignored, inasmuch as it is considered a disposable tool. The second benefit is its semirigid aluminum body. The bendable rod-shaped body provides maximal flexibility and rigidity to guide the tube. Currently, the smallest size of the video device is a 640 × 480 pixel sensor 3.5 mm in diameter. It can be readily used in any tube that is larger, and it is universally applicable in the treatment of most adults. The third benefit is that illumination is provided. The device has white-light LED with a color temperature of 6400 K and provides clear visibility. In terms of resolution and illumination, the ENFE is better than flexible fiberoscopy. The minimal requirement for lighting the pleural space is 500 Lux at a distance of 5 cm. A major advantage of video-guided thoracostomy is that it allows the physician to determine when it is necessary to stop the procedure because of diffuse adhesion.

The current limitations of this device include its inability to take pictures or save images, and the anterior lens should be more hydrophobic. The light from LEDs...
can be designed to be adjustable based on the environment. The clinical conditions for which video-guided tube thoracostomy will be most effective remain to be determined, given that the cases included in this preliminary study are quite limited.

**Conclusion**

This study is not intended to replace the standard procedure. However, under certain difficult conditions, video-guided tube thoracostomy may afford a critical advantage and result in a better outcome.

**Disclosures and Freedom of Investigation**

The authors received no external funding and bought the complimentary metal oxide semiconductor modules and chips from NewKen Technology Inc. Design and assembly were performed by the authors and by UniMax Ltd. All authors had full control of the design of the study, methods used, outcome parameters, analysis of data and production of the written report.

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**References**


**Disclaimer**

The Society of Thoracic Surgeons, the Southern Thoracic Surgical Association, and *The Annals of Thoracic Surgery* neither endorse nor discourage use of the new technology described in this article.

**INVITED COMMENTARY**

After reading the article by Chen and colleagues [1], I had the typical reaction when introduced to a superbly practical and elegant innovation—a “why didn’t I think of that” moment. Given that many patients require drainage of their pleural spaces, it follows that inspecting the organs requiring such therapies could help many patients.

Identifying blebs causing spontaneous pneumothoraces, evaluating associated injuries in trauma, and viewing effusion loculations or pleural metastases are just a few examples for which this technology could be useful. Besides optimizing tube placements and preventing lung injury, it follows that direct simple endoscopic procedures like pleural biopsy could be performed by the use of small instruments passed beside the drainage catheter.

Greater imaging accessibility brought about by miniaturization and cost reduction is transforming much of what we do. For instance, the similarly constructed Glidescope device improves endotracheal intubation safety. Laparoscopic ports are advanced more carefully through the abdominal wall with camera-tipped trocars. Capsule endoscopy (http://www.givenimaging.com) embodies not only miniaturization and affordability but also the capture of images by wireless transmission.

We can expect that this trend will continue for other imaging techniques. Pocket ultrasound probes are now available as smartphone attachments (http://www.mobisante.com/product-overview/) at a fraction of the cost of large systems. Why teach auscultation skills to trainees when they can carry an echocardiography probe in their stethoscope pocket instead? The cost has become so reasonable that disposable transesophageal echocardiography probes for perioperative cardiac monitoring are now available (http://imacorinc.com/). Thus, it is logical to expect that others will build on the work of these authors by using chest tubes as portals for enhanced imaging or monitoring of thoracic organs.

Tempering my enthusiasm for the authors’ invention is the current trend to reduce the size of pleural drainage tubes. Smaller, more comfortable catheters work well.