Ultrasound and Medical Thoracoscopy

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Abstract

Ultrasound is a very useful adjunct to medical thoracoscopy. It allows a real-time assessment of the complexity of the pleural space at the bedside. This in turn minimizes complications and maximizes safety. Traditionally, the induction of a pneumothorax was necessary prior to beginning the medical thoracoscopy in order to minimize the risk of injury to the lung or adjacent solid organs at the time of insertion of the trocar. Unfortunately, this also required a chest radiograph to confirm that the lung did indeed fall away from the chest wall. The induction and documentation of the pneumothorax incurred unnecessary risk, expense and delays. Ultrasound is useful prior to medical thoracoscopy as it allows the physician to evaluate the pleural space at the time of the procedure in the thoracoscopy position. This facilitates the identification of a safe entry site into the thorax even in more complex cases such as those with multiloculated effusions.

Medical thoracoscopy (MT) is a diagnostic/therapeutic procedure performed to visualize the structures of the pleural space, and perform biopsies and pleurodesis when necessary. It is generally performed by pulmonologists under moderate sedation and does not require endotracheal intubation and single lung ventilation. MT is a sterile procedure; however, it is performed safely by many thoracoscopists in a pulmonary procedure room. Traditionally, this procedure was performed using rigid instruments through a trocar; however, a semirigid thoracoscope has recently been developed using technology similar to flexible bronchoscopy [1].

One of the main indications for MT is the evaluation of patients with undiagnosed exudative effusions despite routine relatively noninvasive testing including diagnostic thoracentesis with cytology specimens. Approximately 25% of patients will have an undiagnosed exudative effusion following thoracentesis and blind pleural biopsy [2]. Worldwide, the most common causes for exudative effusions include malignancy and infection, most particularly tuberculosis. The probability of malignancy versus tuberculosis is strongly dependent on the population studied. Overall, malignancy is thought to account for approximately 45% of all exudative effusions; however, this may not hold true in TB endemic countries [3]. In a large series of patients from TB endemic countries, a diagnosis was possible by MT in 99% compared to 51% with needle biopsy and 61% with pleural fluid analysis plus blind pleural biopsy [4]. With respect to the yield for malignancy, Boutin et al. [5] performed MT in patients with previously negative pleural fluid cytology and blind biopsy. They repeated both the thoracentesis and biopsy the day prior to the MT with a combined yield of only 41%, whereas a diagnosis was made in 97% following MT. MT is clearly superior to either thoracentesis or blind pleural biopsy in the diagnosis of undiagnosed exudative effusions. The improved yield is likely related to the size of specimens that can be obtained using this technique coupled with the ability to biopsy abnormal areas under direct visualization.

Many centers, particularly in Europe, also perform thoracoscopy as part of the management of complicated parapneumonic effusion and empyema [6]. MT is used to breakdown locules of infected fluid and lavage the pleural space under direct vision.

Description of MT and Ultrasound Procedures

Online supplementary video 1 reviews the technique of MT including the preprocedure ultrasound. Patients referred for MT should undergo a comprehensive history and physical examination to ensure there exist no contraindications.
to the procedure including uncorrectable bleeding dyscrasias, unstable cardiac or pulmonary disease or inability to tolerate a pneumothorax. Frontal and lateral chest radiographs and thoracic ultrasound to evaluate the pleural space are performed during the initial visit. The patient is placed on respiratory and hemodynamic monitoring throughout the procedure and is positioned in the lateral decubitus position with the healthy lung in the down position. The ipsilateral arm is elevated and abducted while preventing postprocedure plexopathies by supporting and cushioning the elbow and shoulder. A pillow can also be placed under the dependent side to open the intercostal spaces.

Once the patient is positioned, an appropriate entry site is localized using the transthoracic ultrasound (fig. 1). Traditionally, a site in the midaxillary line is selected as there is minimal muscle and adipose tissue. Many physicians use a convex probe with a frequency of 3.5 MHz as this allows an adequate visualization of deeper structures. There is a marker on the probe which corresponds with that on the ultrasound screen to indicate the direction of imaging. By convention the marked probe is oriented in the cephalad direction. The probe is moved along the interspace horizontally and then moved superiorly and inferiorly in adjacent interspaces in order to identify the layers of the chest wall, visceral and parietal pleura, diaphragm, lung and subdiaphragmatic structures (fig. 2). Air within the lung parenchyma causes a scatter of the sound waves and therefore produces a heterogeneous gray artifact. Key structures for orientation include the diaphragm and liver. The liver is considered an echo reference as it is considered isoechoic and structures seen as brighter are considered hyperechoic and those less echogenic are hypoechoic. The liver is readily identified as it is isoechoic and the ducts can often be seen as low echogenicity structures within the organ. The hemidiaphragm is a hyperechoic dome-shaped structure that moves with respiration. The visceral and parietal pleura appear hyperechoic, whereas simple pleural fluid appears anechoic. More viscous fluid such as what might be seen in empyema, blood or more complex or organized pleural fluid will be hypoechoic rather than anechoic. In a healthy pleural space there is only a small amount of fluid separating the thin pleural membranes; therefore, they may be seen as a single bright echo. During the respiratory cycle the lung glides within the pleural cavity producing a phenomenon referred to as the visceral or pleural slide (chapter 3, online suppl. video 5). Adhesions between the pleura can be identified as hyperechoic bands running between the chest wall and lung parenchyma through anechoic or hypoechoic pleural fluid (fig. 3a, b). They may be simple or multiple forming loculations within the pleural space (fig. 4a–c). Pleural symphysis can be recognized by complete absence of pleural slide in combination with the identification of a single bright echo separating the lung parenchyma and chest wall structures. Of note, the preprocedure ultrasound can be suggestive of a nonexpandable lung leading the operator to abort the procedure and consider other therapeutic options (fig. 5a–c).

The skin is cleansed using chlorhexadine and the patient is draped in a sterile fashion. The patient is sedated (many
centers use a combination of fentanyl and midazolam) with care to maintain spontaneous respiration. Figure 6 demonstrates the equipment necessary to perform the procedure. Approximately 30–40 ml of 1% xylocaine is used for local anesthesia to the intercostal space and periosteum of the rib above and below the selected entry site. Upon puncturing through the parietal pleura, fluid is aspirated back. A 1- to 2-cm incision is made to the skin and the deeper tissues spread using forceps. The trocar is then inserted and a suction catheter passed through it into the pleural space to aspirate excess fluid that will limit inspection of the pleural cavity. The rigid optic or semirigid thoracoscope can then be used to inspect the pleural space, take biopsies and instill a sclerosant if necessary. A second port can be placed under direct visualization for diagnostic or therapeutic purposes, i.e. to pass biopsy forceps or catheter for insufflations of sclerosants, respectively. Upon completion of the procedure, a chest tube is directed posteriorly via the trocar and the optional second entry site sutured. The chest tube is fixed and the drain placed to suction until no further leak exists or no significant quantity of fluid is draining.

MT is generally considered a safe procedure, although the risks do include massive hemorrhage, trauma to the lung with persistent air leak and even death. Colt [7] prospectively evaluated thoracoscopy-related complications and adverse events in a large US center. Of the 52 MTs performed, only 1 patient with scleroderma developed a recurrent effusion with fever and leukocytosis requiring readmission and pleural drainage. There was 1 chest tube site infection and 1 small residual clinically insignificant pneumothorax following chest tube removal. Mortality for this procedure is quoted as <0.01% and a single case of bleeding requiring conversion to thoracotomy has been reported [8]. It should be noted that the low morbidity and mortality rates quoted are most certainly influenced by patient selection and experience.

The ideal patient for MT has a large uncomplicated pleural effusion. Unfortunately, malignancy and infection are both proinflammatory. Any manipulation of the pleural space can also lead to the production of inflammatory mediators such as tissue growth factor-β, tumor necrosis factor-α, tissue factor and plasminogen activator inhibitors 1 and 2. In short, these proinflammatory mediators serve to increase the intrapleural conversion of fibrinogen to fibrin and then downregulate the fibrinolytic pathway. They also stimulate the mesothelial cells to synthesize and secrete more proinflammatory cytokines. This dysregulation leads initially to the formation of fibrin strands and loculations and eventually to fusion of the visceral and parietal pleurae. This complex cascade of inflammation can result from even minimal disruption of inflamed pleura such as might occur with thoracentesis [9]. As was stated above, thoracoscopy is reserved for patients who despite thoracentesis and pleural biopsy remain as undiagnosed exudative effusions or alternatively for patients with pleural space infections. By definition, the patients being considered for thoracoscopy are at risk of having a complex pleural space running the spectrum from simple loculations, vascular loculations, focal areas of adhesion of the lung to the parietal pleura, to complete fusion of the pleural space (fig. 3, 4).

Traditionally, the selection of patients considered as good candidates for MT was based upon (1) the patient’s ability to tolerate an induced pneumothorax and (2) the ability to demonstrate that the lung completely falls away from the chest wall following the induction of a pneumothorax [10]. It is likely that these stringent selection criteria have contributed to a low rate of procedure-related complications. The lung falling away from the chest suggests that
there are no significant adhesions between the lung and the chest wall and is definitive proof that pleural symphysis has not occurred. The clinical implication of MT is that the lung is a safe distance from the chest wall such that lung perforation or sheering of vascular adhesions by the trocar or thoracoscope at insertion is less likely. The stringent selection unfortunately also means that patients with more complicated pleural pathology, who may benefit as much or more, may not be considered candidates. In addition, the pneumothorax is induced either the day prior to the procedure or a couple of hours before the procedure. It is documented by a standard 2-view chest radiograph. This requires hospital admission the day before the procedure or a 2-phase procedure with a 2 or more hour delay to induce the pneumothorax and perform X-rays.

Knowledge of pulmonary anatomy and pathology by the pulmonologist has historically been guided by clinical examination findings and by chest radiographs. Clinicians localized pleural effusions and identified the most appropriate sites to perform thoracentesis and chest tube placement, by demonstrating dullness to percussion and absence of breath sounds corresponding to areas of complete opacification on the X-ray. Complete atelectasis of a portion of the lung or alternatively elevation of an intra-abdominal structure may manifest in a similar fashion. In fact, a recent study by Diacon et al. [11] clearly showed that ultrasound guidance for thoracentesis not only improved the rate of appropriate site selection by 26%, but also avoided accidental organ puncture in 10%. This study compared the clinical skills of physicians with varying levels of experience to transthoracic ultrasound guidance for the localization of a puncture site for thoracentesis. Of note, they found no relationship between experience and the selection of a potentially erroneous puncture site. In addition, loculation or more complex pleural disease was a risk factor for selection of an inappropriate puncture site. If real-time image guidance is recommended as adjunct to clinical examination for simple thoracentesis, it is certainly important when placing...