Anesthesiology 2007; 106:1112–9

Incidence of Chest Tube Malposition in the Critically Ill

A Prospective Computed Tomography Study

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Background: **Malposition of percutaneously inserted chest tubes is considered as a rare complication in critically ill patients. Its incidence, however, remains uncertain. The aims of the study were to assess the true incidence of chest tube malposition in critically ill patients and to identify predicting factors.**

Methods: **The authors prospectively studied 122 chest tubes percutaneously inserted in 75 consecutive critically ill patients. For clinical reasons independent of the study, thoracic computed tomography scanning was performed in 63 patients, allowing direct visualization of 106 chest tubes. Based on these findings, chest tube position was classified as intrapleural, intrafissural, or intraparenchymal. Factors predicting chest tube malposition were analyzed by univariate and multivariate analysis.**

Results: **The mean delay between chest tube placement and thoracic scan was 3.5 ± 2.9 days. Twenty-two chest tubes were diagnosed as being intrafissural (21%), and 10 were diagnosed as being intraparenchymal (9%). The only predicting factor associated with the risk of malposition was the use of a trocar for the percutaneous insertion of the chest tube ($P = 0.032$).**

Conclusions: **Malposition was detected in 30% of percutaneously inserted chest tubes, a higher incidence than previously reported. Avoiding the use of a trocar may reduce significantly the incidence of chest tube malposition.**

PERCUTANEOUS chest tube insertion is routinely performed in surgical wards, intensive care units (ICUs), and pneumology. Retrospective studies[1–3] have reported mainly complications of limited morbidity such as accidental endotracheal tube removal, cutaneous orifice infection, recurrent pneumothorax or hemothorax, and inefficient drainage. Recently, more severe complications have been described, including empyema and chest tube malposition, possibly associated with thoracic or abdominal organs injuries (perforation, laceration, or compression). Based on chest radiographs, the incidence of chest tube malposition is less than 3% in trauma patients[1,2,4,5] and in patients hospitalized in medical critical care unit or internal medicine service.[3]

Three retrospective studies, however, reported a greater incidence of serious events complicating chest tube malposition. One autopsy study evidenced two lung lacerations in 18 patients with percutaneous chest tubes.[6] In 51 trauma patients with emergency tube thoracostomy performed before hospital admission,[7] thoracic computed tomography (CT) demonstrated a malposition rate of 26% (including 7% intraparenchymal and 12% intrafissural tubes). In another study, CT assessment of pleural drainage in 26 patients with empyema[8] identified three intraparenchymal and 8 intrafissural tubes. In these studies, frontal radiographs were inadequate for detecting chest tube malposition, whereas CT offered the sole possibility to assess correctly tube position.

A prospective study was undertaken to assess chest tube malposition incidence in critically ill patients. Adequacy of the chest tube position was assessed using both bedside chest radiography and CT that is now routinely performed in critically ill patients.[9–16] Factors predisposing to chest tube malposition were analyzed.

Materials and Methods

Patients

From May 2003 to April 2004, all patients admitted to the surgical ICU of La Pitié-Salpêtrère Hospital (University School of Medicine Pierre and Marie Curie) in whom a chest tube was percutaneously inserted were prospectively enrolled. Clinical indications of pleural drainage were left to the attending physicians. According to a technique previously described, bedside lung ultrasound was used to diagnose pleural effusion or pneumothorax,[17] but chest tube insertion was never performed under ultrasound control. Chest tubes (24 to 32 French; SIMS Portex Limited, Kent, United Kingdom) were always inserted with the patient lying in the supine position, usually by a lateral route and according to each physician's preference: using either a short trocar or the blunt dissection method. Once inserted, tubes were connected to a pleural drainage unit (suction level −20 cm H_2O), and each physician completed a sheet detailing indication and modalities of tube insertion. Patient demographic data, chest radiographs, and CT analysis were collected until ICU discharge. All bedside chest radiographs were screened for chest tube malposition (kinked tube or tube surrounded by a round-like lung condensation). CT indications were left to the attending physician. Physicians were informed of the chest tube position, so they could remove, leave in place, or change

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Received from the Surgical Intensive Care Unit Pierre Viars, Department of Anesthesiology and Critical Care, and the Service de Radiologie Polyvalente Diagnostique et Interventionnelle, Hôpital Pitié-Salpétrière, Assistance Publique Hôpitaux de Paris, University School of Medicine Pierre et Marie Curie, University of Paris 6, Paris, France. Submitted for publication July 28, 2006. Accepted for publication January 23, 2007. Support was provided solely from institutional and/or departmental sources. Presented in part at the Annual Meeting of the European Society of Anaesthesiology, Vienna, Austria, May 8, 2005 (Eur J Anaesth 2005; 22[suppl]:A605).

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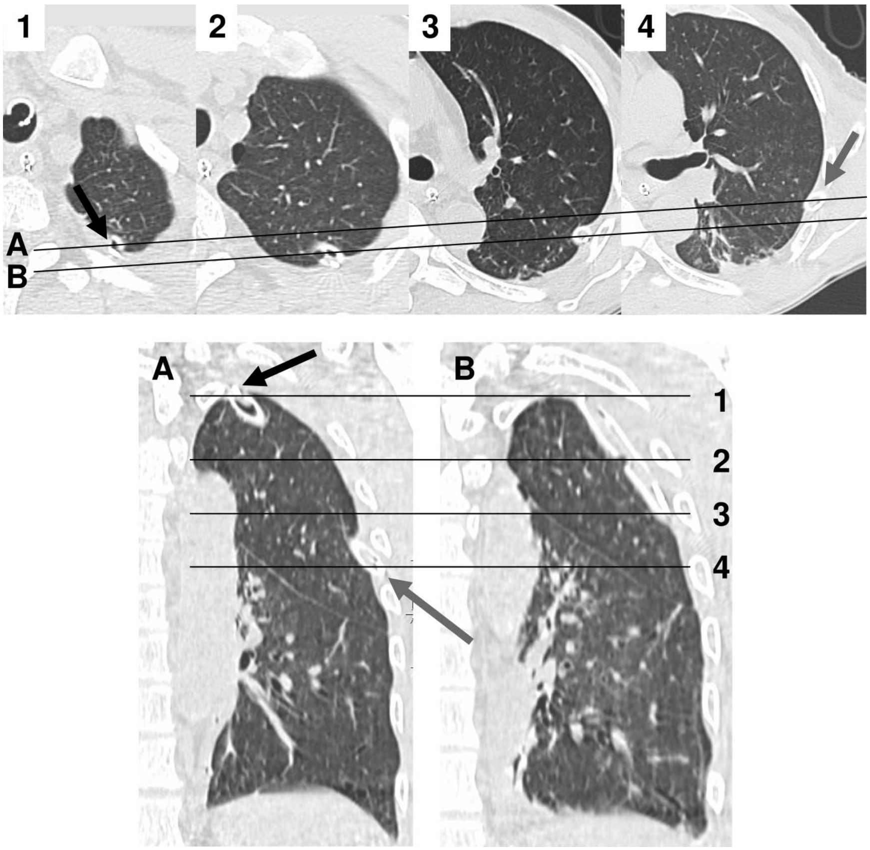

Fig. 1. Computed tomography aspect demonstrating the intrapleural position of a chest tube. On axial computed tomography sections, the chest tube is visualized from its entry in the left hemithorax (*image 4*) to its extremity (*image 1*), *via* its intrapleural route (*images 2* and *3*). Frontal reconstructions confirm the intrapleural position of the chest tube: *Plane A* shows both the entry (*gray arrow*) of the chest tube and its distal tip (*black arrow*), and *plane B* shows the ascending and lateral intrapleural route of the chest tube.

the tube. Chest tubes were usually removed if no air leak was present for 24–72 h (after clamping them for 24 h if they had been inserted for a pneumothorax) and if liquid drainage was less than 100 ml/day. The study was a part of a routine diagnostic strategy aimed at optimizing respiratory status of the patients, and informed consent was not judged to be necessary by the Comité Consultatif pour la Protection des Personnes en Recherche Biomédicale of La Pitié-Salpêtrière Hospital. After ICU discharge, each enrolled patient received a written information document about the study. None of them expressed concern about their participation.

High-resolution Computed Tomography Scanning

An experienced physician and a medical student transported patients to the Department of Radiology with an Osiris ventilator (Taema, Anthony, France). Electrocardiography, pulse oximetry, and systemic arterial pressure were continuously monitored.

High-resolution CT of the whole lung was performed using a multislice multidetector scanner. Mechanical ventilation was maintained during CT acquisition of 0.6- to 2.5-mm-thick contiguous sections allowing, if necessary, sophisticated reconstructions. CT data were stored on computerized discs.

Chest tube position was assessed on the first CT performed in each patient. On transversal CT sections, the tube was considered as pleural if it was always in close contact with the parietal pleura. If not, a radiologist (Y.B.) reanalyzed computerized data for determining its position: pleural (fig. 1), intrafissural (fig. 2), or intraparenchymal (fig. 3). A tube was considered as intraparenchymal if at least one part of its intrathoracic course was entirely surrounded by lung parenchyma, at distance of both the visceral pleura and a main, minor, or accessory fissure.[18] Intrafissural or intraparenchymal chest tubes were considered as malpositioned. Residual pleural effusion, cephalad or caudal tube direction, anterior or posterior tube location, and intercostal space of entry into the thorax were also recorded.

Statistical Analysis

Continuous variables are expressed as mean ± SD, and categorical ones are expressed as a percentage of patients of the relevant group. Quantitative variables were compared using nonparametric tests, and categorical ones were compared using the chi-square test or Fisher exact test when necessary. A P value less than 0.05 was considered significant. Statistical calculations were performed using Statview® 5.0 for Windows (SAS Institute Inc., Cary, NC).

Results

Indication and Technique of Chest Tube Insertion

In 75 patients, 122 tubes were inserted for pneumothorax and/or sterile pleural effusion complicating the

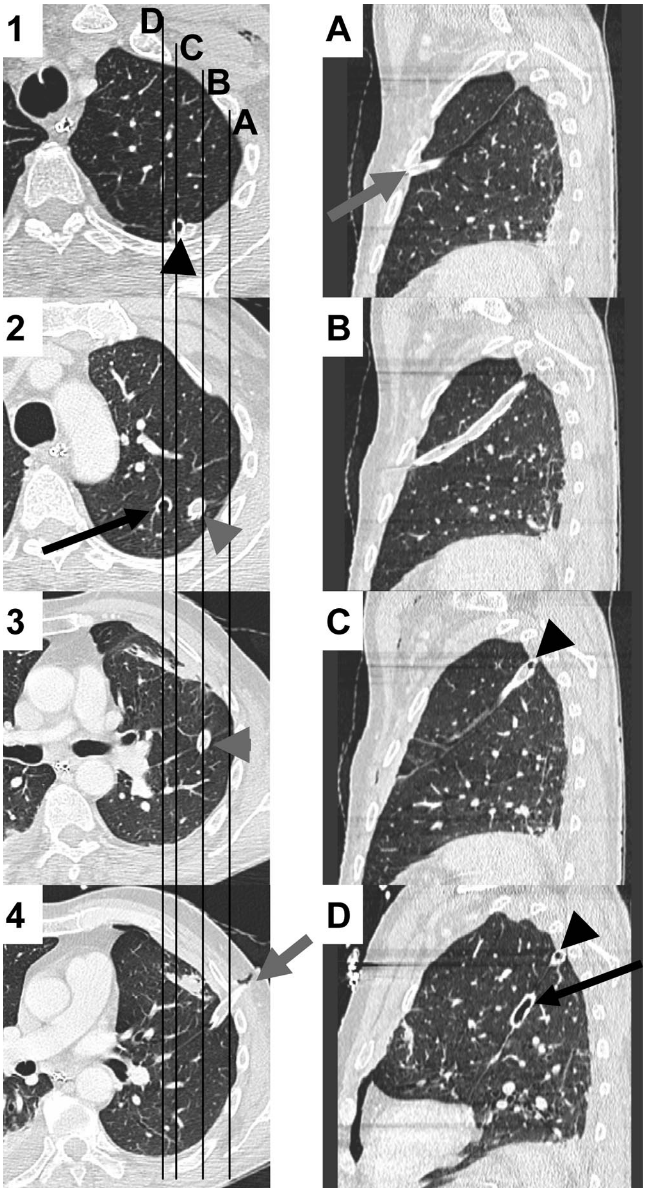

Fig. 2. Computed tomography aspect demonstrating the intrafissural position of a chest tube. On axial computed tomography sections, the chest tube is visualized from its entry in the left hemithorax (*image 4*, *gray arrow*) to its extremity (*image 2*, *black arrow*), *via* its intrafissural route (*images 2* and *3*, *gray arrowheads*) including a loop at the distal tip of the fissure (*image 1*, *black arrowhead*). Because the left fissure is visible only on *images 1*, *3*, and *4*, an intraparenchymal route can be suspected on *image 2*. Sagittal reconstructions, however, clearly demonstrate the intrafissural position of the chest tube: *Plane A* shows the entry of the chest tube in the left fissure (*gray arrow*); *plane B* shows the intrafissural route of the chest tube; *plane C* shows a loop of the chest tube at the distal tip of the left fissure (*black arrowhead*); and *plane D* shows the chest tube descending into the left fissure, medially to its ascending route (*black arrow*).

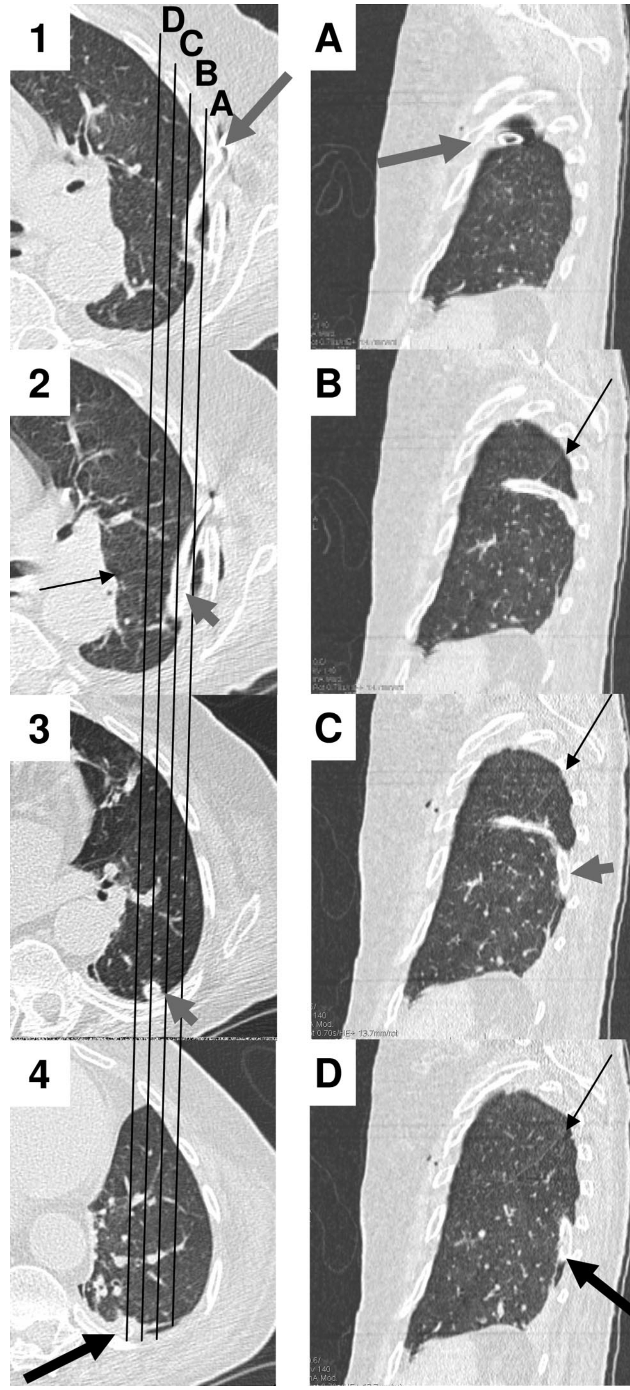

Fig. 3. Computed tomography aspect demonstrating the intraparenchymal route of a chest tube. On axial computed tomography sections, the chest tube is visualized from its entry in the left hemithorax (*image 1*, *gray arrow*) to its extremity (*image 4*, *thick black arrow*), *via* its posterior (*image 2*) and descending intrathoracic route (*image 3*, *gray arrowhead*). The presence of the left fissure at the vicinity of the tube (*image 2*, *thin black arrow*) raises the possibility of an intrafissural position. Sagittal reconstructions clearly demonstrate the intraparenchymal position of the chest tube: *Plane A* shows the entry of the chest tube in the left upper lobe (*gray arrow*); *plane B* shows the intraparenchymal route of the chest tube, passing from the upper to the lower lobe through the left fissure (*thin black arrow*); *plane C* shows the entry of the chest tube in the posterior pleural space (*gray arrowhead*); and *plane D* shows the chest tube descending into the posterior pleural space (*thick black arrow*).

course of mechanical ventilation (table 1). They were inserted on the midaxillary line by senior physicians, fourth-year residents, or medical students (under the supervision of a senior physician). We included 106 tubes in 63 patients who had CT scans for lung morphol-

Table 1. Clinical Characteristics of Patients with a Chest Tube

	All Chest Tubes (n = 122)	Tube Position Assessed by CT (n = 106)	Tube Position Assessed by Radiography (n = 16)	*P* Value*
Patients				
n	75	63	16	
Age, yr	51 ± 19	50 ± 19	59 ± 13	0.064
Weight, kg	74 ± 15	74 ± 15	76 ± 14	0.51
Height, m	1.71 ± 0.09	1.71 ± 0.09	1.72 ± 0.06	0.93
BMI	25.0 ± 4.0	25.0 ± 4.1	25.7 ± 3.6	0.50
BMI > 30, % of total	10.7	10.4	14.3	0.68
Male patients, %	78	76	87	0.36
Initial SAPS II score	39.5 ± 16.7	39.8 ± 17.2	37.1 ± 13.8	0.57
Multiple trauma, %	41.8	43.4	45.5	0.42
Surgery, %	51.6	49.1	68.8	0.18
Duration of ICU stay, days	40 ± 41	39 ± 37	43 ± 49	0.68
Mortality, %	14.8	14.2	18.8	0.70
Operators				
Medical students, %	11.1	11.8	7.1	0.99
ICU residents, %	52.5	51.7	57.2	0.78
ICU staff, %	36.4	36.5	35.7	0.99
Indication for tube placement				
Pleural effusion, %	57.3	55.7	68.7	0.42
Pneumothorax, %	40.2	43.4	18.8	0.10
Hemothorax, %	19.7	19.8	18.8	0.99
Technique and condition of thoracic drainage				
Mechanical ventilation, %	88	90	80	0.38
Inserted in the ICU, %	59.5	59.4	60	0.99
Insertion with a trocar, %	88.5	89.6	81.3	0.39
Right chest tube, %	52.5	51	62.5	0.43
Midaxillary line, %	95.9	95.3	100	0.99
Duration of drainage, days	9.7 ± 8	10.2 ± 8	4.6 ± 3	0.0002
Inefficient drainage, %	11.5	10.4	18.7	0.65

P indicates the statistical comparison between two categories of chest tubes: those whose positions were assessed using thoracic computed tomography and those whose positions were assessed using bedside chest radiography.

* Mann–Whitney test for quantitative values; Fisher exact test for categorical ones.

BMI = body mass index; ICU = intensive care unit; SAPS II = Simplified Acute Physiology Score II.

ogy analysis in acute respiratory distress syndrome or bronchopneumonia (42.2%), thoracic trauma or surgery (30.1%), empyema or hemothorax or lung abscess (10.4%), inefficient pleural drainage (9.4%), or difficult weaning from mechanical ventilation (7.5%). Delay between drainage and the first CT was 3.5 ± 2.9 days. The 16 chest tubes that were not assessed using CT were removed earlier than the 106 chest tubes assessed using CT ($P < 0.0002$; table 1). Very likely, shorter drainage duration reduced the opportunity to obtain a CT during the pleural drainage period. Other patient characteristics were similar between the two groups.

Chest Tube Position

Computed tomography revealed that 32 of 106 chest tubes (30.2%) were malpositioned: 22 were intrafissural (20.8%), and 10 were intraparenchymal (9.4%). Two tubes, classified as intrapleural, had a pleural distal tip but lateral holes in the chest wall. For another tube, CT could not ascertain its position: It was suspected to be intrathoracic but extrapleural (fig. 4). This tube (inserted with a trocar) was inefficient for draining pneumothorax. It was replaced by another tube that was fully efficient. It was finally classified as intrapleural. Six of 10 intraparenchymal tubes and 15 of 22 intrafissural tubes had a pleural distal tip.

Seven malpositioned chest tubes and 20 pleural ones were assessed on two to four CT scans. The analysis yielded identical tube position, except for one right tube inserted for hemopneumothorax in a multiple trauma patient: CT performed just after the drainage revealed that the tube was in the minor fissure with its extremity in the posterior pleural space, whereas 4 days later, a second CT showed it in pleural position. This tube was classified as intrafissural. Repeated CT indicated that tube position remained unchanged over time, even after several patient transportations to the CT department.

A CT was performed just before thoracic drainage in 21 pleural, 11 intrafissural, and 6 intraparenchymal tubes. The pleural space width at the tube insertion site was measured: 25 tubes (66%) were inserted in a virtual pleural space, and only 13 (34%) were inserted directly in the pleural collection. Among 25 tubes inserted in a virtual pleural space, 6 were intraparenchymal, *versus* none of the 13 tubes inserted directly in the pleural collection ($P = 0.076$).

Physicians suspected 2 malpositioned tubes (1 intraparenchymal and the 1 possibly inserted between the pa-

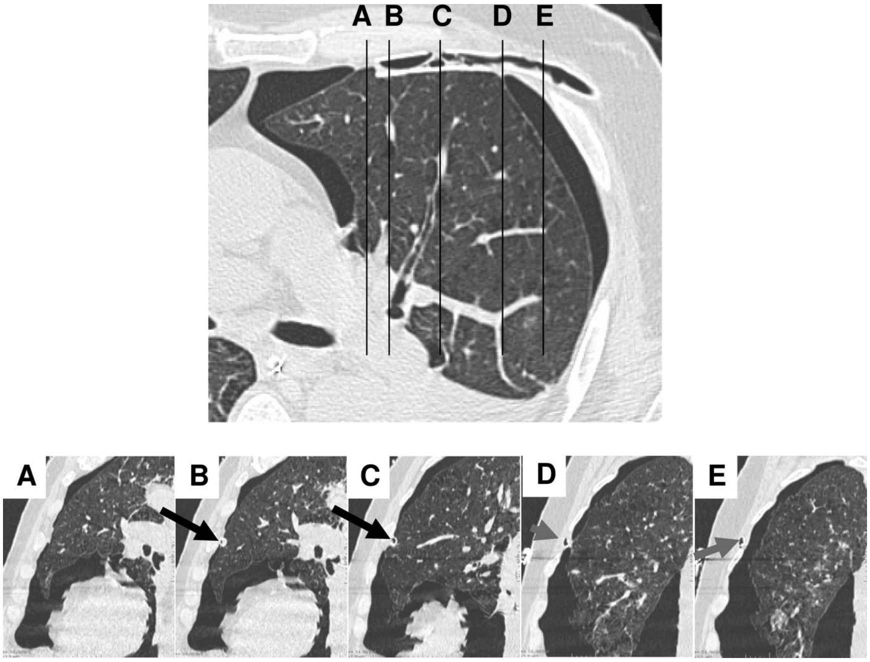

Fig. 4. Computed tomography aspect suggestive of an intrathoracic and extrapleural chest tube. The intrathoracic but extrapleural position of the chest tube is suspected on an axial computed tomography section showing its route within the left hemithorax (*top figure*). Sagittal reconstructions following *planes A* to *E* show the tube within the fourth intercostal space (*image E*, *gray arrow*), then entering the left hemithorax through a pleural adhesion (*image D*, *gray arrowhead*), and lying in this pleural adhesion until its distal extremity without reaching the pleural space (*images C* and *B*, *black arrows*). This radiologic aspect may traduce (1) an extrapleural malposition, (2) a tube in a tightly loculated pleural space, and (3) a subpleural intraparenchymatous tract, because the two pleural folds are too thin to be visible on computed tomography sections.

rietal pleura and the chest wall) on clinical aspects, but none on chest radiography aspects. Physicians asked for a CT scan pleural drainage control in 32 cases (but it was a secondary request in 22 cases). We reviewed 103 CT reports written by radiologists unaware of the protocol (9 intraparenchymal, 21 intrafissural, and 73 intrapleural tubes). Sensitivity, specificity, and negative and positive predictive values of these reports in detecting malpositioned tubes were 23%, 49%, 63%, and 18%, respectively. Among the 9 intraparenchymal tubes, two were correctly diagnosed, 4 were falsely reported in a correct position, and 3 were not described.

Factors Associated with Malposition of Chest Tubes

Patient characteristics, indication for thoracic drainage, and operator skills were not associated with an increased incidence of malposition (table 2). The only parameter significantly linked to an increased incidence of malposition was the use of a trocar ($P = 0.032$). Physician experience using trocar or blunt dissection was not statistically different ($P = 0.4$).

Right hemithorax drainage was associated with a higher occurrence of malposition ($P = 0.047$), but it was entirely related to tubes inserted in the minor fissure ($P = 0.0012$). The incidence of intraparenchymal tubes or positioned in the main fissure was not different between right and left hemithoraces ($P = 0.95$).

Chest radiographs revealed no chest tube surrounded by lung condensation aspects, and kinked tubes in 18.9% of pleural tubes *versus* 28.1% in malpositioned ones ($P = 0.29$).

Consequences of Chest Tube Malposition

No additional mortality could be directly attributed to chest tube malposition. Two intrafissural tubes were inefficient and required a new drainage. One intraparenchymal tube was complicated by bronchopleural fistula, lung abscess, empyema, and septic shock. Three intraparenchymal tubes were associated with inefficient drainage, necessitating a new drainage in two patients and a thoracotomy in one (for undrained hemothorax). Six intraparenchymal tubes were asymptomatic: Three were removed promptly after their diagnosis on CT, and three were removed 5, 5, and 20 days later because of delayed CT reconstructions. Nine intraparenchymal tubes were removed without significant bleeding or air leak. Duration of mechanical ventilation, thoracic drainage, ICU stay, mechanical ventilation, and necessity for tracheotomy were not increased by chest tube malposition.

Discussion

Our study provides compelling evidence that malposition of percutaneous chest tube is a more frequent complication than expected in critically ill patients drained for pneumothorax or pleural effusion. Using CT, 21% of chest tubes were found to be intrafissural and 9% were found to be intraparenchymal. This study also demonstrates that clinicians and radiologists do not pay enough attention to the CT detection of chest tube malposition: Only 23% of malpositions were reported by radiologists, probably because they focused mainly on the reason why the CT was requested by clinicians.

Confounding Factors for Evaluation of True Incidence of Chest Tube Malposition

Intrathoracic malpositions other than intrafissural or intraparenchymal placement remain difficult to ascertain

Table 2. Clinical and Technical Characteristics Associated with Chest Tube Malposition

	Malposition (n = 32)	Adequate Position (n = 74)	*P* Value*
Patients	22	52	
Age, yr	48.4 ± 18.6	50.5 ± 19.5	0.50
Weight, kg	73.5 ± 20.3	73.9 ± 12.3	0.57
Height, m	1.70 ± 0.11	1.72 ± 0.09	0.25
BMI	25.2 ± 4.8	24.9 ± 3.7	0.81
BMI > 30, % of total	12.5	9.5	0.73
Male patients, %	68.8	78.4	0.30
Initial IGS II score	39 ± 17.8	40.2 ± 17	0.84
Multiple trauma, %	50	40.5	0.37
Pneumonia, %	43.8	50	0.55
Predisposing factors, %†	37.5	39.2	0.87
Previous homolateral drainage, %‡	18.8	16.2	0.75
Abnormal chest radiography, %§	28.1	18.9	0.29
Operators			
Medical students, %	11.5	11.9	0.99
ICU residents, %	46.2	54.2	0.49
ICU staffs, %	42.3	33.9	0.46
Indication for chest tube placement			
Pleural effusion, %	50	58.1	0.44
Pneumothorax, %	43.8	43.2	0.96
Hemothorax, %	21.9	18.9	0.73
Conditions of chest tube drainage			
Mechanical ventilation, %	81.3	93.2	0.08
Insertion with trocar/blunt dissection	32/0	63/11	0.032
Right chest tube, %	65.6	44.6	0.047
Lateral route, %	93.8	95.9	0.64
Level of insertion (intercostal space)	4.2 ± 1.2	4.4 ± 1.5	0.61
Cranial orientation, %	58.6	59.1	0.99
Initial volume of drainage‖	620 ± 576	646 ± 596	0.79

* Mann–Whitney test for quantitative values; chi-square or Fisher exact test for categorical ones. † Previous homolateral thoracotomy, pleural drainage, empyema, thoracic traumatism or sternotomy. ‡ During the intensive care unit (ICU) stay. § Kinked chest tubes or chest tubes surrounded by condensed parenchyma. ‖ Milliliters of pleural effusion or hemothorax during the first 48 hours, n = 22 and 52.

BMI = body mass index; IGS II = Initial Gravity Score II.

on CT. Tubes can be intrathoracic but extrapleural, between the chest wall and parietal pleura, as demonstrated in one of our patients (fig. 4). Tubes may also be inserted into the lung parenchyma, just beneath the visceral pleura: Such a malposition was suspected for 10 tubes that were positioned along the visceral pleura and surrounded by condensed lung parenchyma. Finally, 5 of them were considered intrapleural and 5 were considered intrafissural. Secondary tube migration from a fissure to the pleural space was documented in one patient, between the first and the fourth day of drainage. Because CT of 33 drains considered as "pleural" were performed at the fourth day of drainage or later, additional intrafissural tubes may have been missed initially.

Patients undergoing CT could be the most severe ones, a condition that may predispose to chest tube malposition. However, 87% of the chest tubes could be assessed on CT. Clinical characteristics and severity score were not different between patients who underwent CT and those who did not (table 1). In addition, malposition rates seem similar in these two groups: 3 of the 16 tubes that were not assessed on CT were highly suspected of malposition. All had an erratic route on bedside radiography and were removed for inefficient drainage, and one tube (the only one of our series) demonstrated a typical radiologic pattern of malposition: condensed lung parenchyma around the tube that persisted after tube removal. Unfortunately, this tube could not be assessed on CT.

Furthermore, a tube inserted in an accessory fissure may be falsely interpreted as intraparenchymal. This bias was systematically examined and ruled out. For anatomical reasons, a tube inserted laterally may enter the left minor fissure (present in 9% of normal lungs and complete in only 35% of cases) and three other incomplete accessory fissures (observed in less than 2% of normal lungs, with a maximal depth of 20 mm, which is inferior to the observed distance between malpositioned tubes and visceral pleura).[19,20]

Finally, an overestimation of the incidence of chest tube malposition is unlikely in the current study, whereas an underestimation cannot be totally ruled out.

Complications Resulting from Chest Tube Malposition

Morbidity of intrafissural chest tubes is poorly described, but severe complications have been reported, such as bronchiolar erosion necessitating thoracotomy,[8] right pulmonary artery branch injury complicated by an aneurism requiring surgical repair (unpublished case report of Sacha Mussot, M.D., Department of Thoracic Surgery, Marie Lannelongue Hospital, Montsouris, France, orally presented to our department staff on December 4, 2004), or inefficient drainage.[7,8,21] Complications resulting from intraparenchymal insertion of chest tubes include life-threatening bronchopleural fistula necessitating thoracotomy,[8] lung abscess necessitating lobectomy,[7] and lung bleeding necessitating thoracotomy[2] but may remain totally asymptomatic,[6,22] as 9 cases in our series. In such situations, the intraparenchymal route of the tube avoids large pulmonary vessels and bronchi, leading to rapid pulmonary clotting and preventing the onset of significant air leak. Surprisingly, our study showed that malpositioned tubes were efficient in terms of pleural drainage, probably because 66% of them went right through the lung or a fissure, so that their distal tip was intrapleural.

Factors Associated with Chest Tube Malposition

Physician experience was not identified as a predisposing factor for malposition, although 12% of thoracic drainages were performed by medical students and 50% were performed by residents. Medical students inserting a chest tube were tightly supervised by a surgically dressed physician, who selected the patient and guided the procedure step by step. Complications related to student inexperience were, therefore, limited. Most residents were in the last 6 months of their 4-yr training and, therefore, could be considered as "young" staff members rather than inexperienced residents.

Right-sided placement results in significantly more tubes to be intrafissural because minor fissure is often in the area of chest tube insertion *via* the lateral route, but it does not result in more tubes to be intraparenchymal or in the main fissure.

Pleural adhesions are classically considered as a risk factor for chest tube malposition.[1,6,23–25] In our study, however, factors predisposing to pleural adhesions (pneumonia, history of thoracotomy, empyema, thoracic drainage, or chest trauma) were not associated with an increased incidence of chest tube malposition. Pleural adhesions or anatomical predisposition to chest tube malposition most often remain ignored and may be frequently involved in the physiopathology. A systematic digital exploration of the pleural cavity, preceding drainage and searching for pleural adhesions, is to be recommended but was not evaluated in the current study.

In fact, the thoracic drainage technique played a key role in the incidence of chest tube malposition. The deleterious role of a trocar has been previously suspected.[1,26–28] To our knowledge, this is the first study demonstrating a significant statistical link between its use and chest tube malposition. A tube in a rigid metallic trocar is, by itself, more susceptible to cause lung injury than a flexible tube directly inserted in the pleural space. It is even more dangerous when the tube is inserted where the lung is still in close contact with the parietal pleura, as demonstrated in our study.

In conclusion, the incidence of chest tube malposition was found to be as high as 30% in critically ill patients who underwent a thoracic CT scan for various clinical reasons. The only identified risk factor was the use of a trocar during tube insertion. Being aware of this complication, ICU physicians should reevaluate the benefit/risk ratio of pleural drainage and prefer a blunt dissection of the chest wall to the use of a short trocar. In addition, if a CT is performed after pleural drainage, physicians should systematically ask the radiologist to check the chest tube position, because neither clinical nor radiologic signs are sensitive enough to detect tube malposition.

The authors thank Ramon Aimé, Karine Paumier, Christelle Proux, and Nadine Thomas for their contribution in collecting digital recording of all of the computed tomography scans (X-ray Technicians, Service de Radiologie Polyvalente Diagnostique et Interventionnelle, Hôpital Pitié-Salpétrière, Assistance Publique Hôpitaux de Paris, University School of Medicine Pierre et Marie Curie, University of Paris 6, Paris, France) and Desa Marinkovic (Secretary, Surgical Intensive Care Unit Pierre Viars, Department of Anesthesiology and Critical Care, Hôpital Pitié-Salpétrière, Assistance Publique Hôpitaux de Paris, University School of Medicine Pierre et Marie Curie, University of Paris 6) for her contribution in typing and sending the information document to the patients.

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