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Original Contribution

Pigtail catheter for the management of pneumothorax in mechanically ventilated patients☆

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Abstract

Purpose: There has been a paucity of data regarding the efficacy and safety of small-bore chest tubes (pigtail catheter) for the management of pneumothorax in mechanically ventilated patients.

Methods: We conducted a retrospective review of mechanically ventilated patients who underwent pigtail catheter drainage as their initial therapy for pneumothorax in the emergency department and intensive care unit from January 2004 through January 2007 in a university hospital.

Results: Among the 62 enrolled patients, there were 41 men (66%) and 21 women (34%), with a mean age of 63.8 ± 20.3 years. A total of 70 episodes of pneumothoraces occurred in the intensive care unit, and 48 episodes of pneumothoraces (68.6%) were successfully treated with pigtail catheters. The average duration of pigtail drainage was 5.9 days (1–27 days). No major complications occurred through use of this procedure, except for pleural infections (n = 3, 4.2%) and clogged tube (n = 1, 1.4%). Comparing the variables between the success and failure of pigtail treatment, the failure group had a significantly higher proportion of F_{IO_2} <60% requirement (45.5% vs. 14.6%, *P* = .005) and higher positive end-expiratory pressure levels (8.7 ± 3.0 vs. 6.2± 2.3 mm Hg, *P* = .001) at the time of pneumothorax onset than the success group. Further comparing the efficacy of pigtail drainage between barotraumas and iatrogenic pneumothorax, pigtail catheters for management of iatrogenic pneumothorax had a significantly higher success rate than barotraumas (87.5% vs. 43.3%, *P* < .0001).

Conclusion: Pigtail catheter drainage is relatively effective in treating iatrogenic but less promising for barotraumatic pneumothoraces.

1. Introduction

Pneumothorax is a potentially life-threatening complication in the emergency department and intensive care unit (ICU), which usually requires prompt management. Previous studies have reported that the incidence of pneumothorax in the ICU ranges from 4% to 15% [1-4] and that most pneumothoraces can be classified into 2 categories:

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procedure-related pneumothoraces and mechanical ventilation-related barotraumas [5,6]. The procedure that most commonly causes pneumothoraces is thoracentesis, followed by vein/pulmonary artery catheterization and transbronchial lung biopsy [5,7]. Barotrauma is usually associated with the patients' underlying lung diseases, such as acute respiratory distress syndrome (ARDS) [8-11], aspiration pneumonia [3], *Pneumocystis carinii* pneumonia [12], and chronic obstructive pulmonary disease [4,13]. Overall, patients with procedure-related pneumothoraces have better outcomes than barotrauma-related pneumothoraces [5]. In addition, tension pneumothorax, concurrent septic shock, and prolonged ICU stay were significant independent risk factors for mortality [5,6].

Reviewing the literature, there has been a paucity of data regarding the management of pneumothorax in mechanically ventilated patients [14,15]. The US guidelines recommend use of larger (24F-28F) chest drains for patients with spontaneous pneumothorax who may later need mechanical ventilation, which is to allow a high flow state to manage large air leaks generated by positive pressure ventilation [15]. However, few data are available with regard to small-bore chest tubes in the management of pneumothorax in patients receiving positive pressure ventilation.

We have previously reported our experience in treating patients in a general ward with primary and secondary spontaneous pneumothorax using small-caliber chest tube (pigtail) drainage with excellent outcomes [16-18]. We also had experience in draining pleural effusions in critically ill patients using ultrasound-guided pigtail catheters [19]. The aim of this study was to evaluate the clinical outcome, efficacy, and safety of pigtail catheters in the treatment of pneumothorax in mechanically ventilated patients in the ICU and to investigate whether there are any differences between treating iatrogenic or barotraumatic pneumothoraces.

2. Materials and methods

2.1. Patients

From January 2004 through January 2007, the medical records and chest roentgenograms of all mechanically ventilated patients whose conditions were diagnosed as pneumothorax in the emergency room and medical ICU of China Medical University Hospital (a 1700-bed tertiary medical center with a 44-bed medical ICU) were reviewed carefully. Patients who required mechanical ventilation and underwent insertion of a pigtail catheter as their initial therapy for pneumothorax were enrolled in the study. The diagnosis of pneumothorax required that the following criteria were met: evidence of air accumulation in the pleural space by chest roentgenograms or chest tomography, and air drainage by thoracentesis or chest tube thoracostomy. All patients with mechanical ventilation were screened daily by the intensivists, respiratory therapists, and nursing staff according to the weaning protocol [20]. The ventilator settings, including tidal volume and positive end-expiratory pressure (PEEP) titrated for patients with acute lung injury or ARDS were guided by a protocol that included a lung protection strategy [21]. In mechanically ventilated patients, tidal volume was set to maintain a plateau pressure below 30 cm H_2O in most cases and no greater than 35 cm H_2O in all patients. Sedation and neuromuscular blockers were also used according to protocol [22]. The institutional review board at China Medical University Hospital approved the study protocol.

2.2. Data collection

The following information was collected for each patient receiving mechanical ventilation: demographic data (age, sex, height, weight, smoking history, and underlying diseases), acute physiology and chronic health evaluation (APACHE) II scores [23] at the time of ICU admission, primary indication for mechanical ventilation, type of pneumothorax, location and size of pneumothorax, ARDS event [24], ventilator setting; primary and secondary management for pneumothorax, length of stay in the ICU and total hospitalization, duration of pigtail drainage, and management outcomes. Ventilator parameters including peak inspiratory pressure, plateau pressure, PEEP, fraction of inspired oxygen (F_{IO_2}), and tidal volume were recorded during the onset of the pneumothorax.

2.3. Definition

The pneumothoraces were classified as "barotraumatic" and "iatrogenic." Iatrogenic pneumothorax was defined as the development of extrapulmonary air resulting from an invasive procedure to the chest, such as thoracentesis, central venous catheterization, bronchoscopy, and pericardiocentesis [5,7]. Ventilator-associated barotrauma was defined as the development of air outside the tracheobronchial tree resulting from presumptive alveolar rupture and manifested by at least one of the following: interstitial emphysema, pneumothorax, pneumomediastinum, pneumoperitoneum, or subcutaneous emphysema [6,8]. The occurrence of ventilator-associated barotrauma is increased in patients with severe underlying lung disease, especially in patients with ARDS, pneumonia, or chronic obstructive lung disease. The pigtail catheter was removed if the lung expanded well after drainage with no more air drained from the tube. Pigtail tube removal was considered successful if no more residual air was seen in the follow-up chest radiographs. On the other hand, treatment failure was defined as progression of pneumothorax size despite pigtail drainage or no significant improvement in chest radiographs with persistent air leak in the 48 hours of follow-up. If resolution of the pneumothorax failed using pigtail drainage, insertion of a large-bore chest tube (24F-32F) was performed.

2.4. Procedure for pigtail catheter insertion

The entire procedure, including examination by chest ultrasound and insertion of the pigtail catheter, was performed by an experienced emergency physician or intensivist (also a pulmonologist) at the bedside in the emergency room or ICU. Percutaneous pigtail catheters (SKATER, PBN Medicals, Denmark) were all single-lumen polyurethane coiled catheters, sized 12F to 16F, used in conjunction with a wire and dilator and connected to a negative-pressure drainage system with 10 cm H_2O pressure applied. Before inserting the catheter, a chest ultrasonic examination was performed to locate the puncture site and further confirm the diagnosis of pneumothorax by ultrasonographic pattern (gliding sign, lung point sign, and comet tail artifact) [25-29]. After determining the insertion site, the catheter was inserted using the modified Seldinger technique, with insertion of the needle and syringe over a rib and gentle aspiration of a syringe to locate the pneumothorax in the pleural space. Finally, the pigtail catheter was attached to a water seal chest drain system. The pigtail tubes were secured properly, and the nursing staff was trained to monitor the tubes vigilantly and to continuously inspect to prevent tension pneumothorax. A chest radiograph was performed immediately after the procedure. Generally, a chest radiograph was performed every day for the first 3 days. Thereafter, chest radiographs were obtained every 3 days or when clinical conditions changed.

2.5. Statistical analysis

Demographic and descriptive data are given as mean ± 1 SD and were compared using a two-tailed Student *t* test. Categorical variables were compared using the chi-square or Fisher's exact test, when appropriate (SPSS statistical software for Windows, Chicago, Ill; statistical significance, $P < .05$). The clinical outcomes of the treatments with the pigtail catheters were determined by evaluating resolution of the pneumothorax.

3. Results

From January 2004 through January 2007 (3-year interval), a total of 5358 patients were admitted to our ICU. Eighty mechanically ventilated patients (1.5%) received diagnoses of pneumothorax in the emergency room and the ICUs during this period of time. In our hospital, physicians routinely perform insertion of a pigtail catheter as initial treatment for pleural disease (pneumothorax or pleural effusions) in the emergency room and medical ICUs [19], and surgeons customarily perform the insertion of large-bore chest tubes for pleural diseases. As a result, 71 ventilated patients received pigtail catheters as initial therapy for pneumothorax in the emergency room and medical ICUs, and the other 9 patients received large-bore chest tubes as their initial therapy for pneumothorax in the surgical ICU. Among the 71 mechanically ventilated patients who received the pigtail catheter as the initial therapy, 9 patients were excluded because the patients expired as a result of their underlying diseases on the same day as the pigtail insertion and, thus, could not be evaluated. All these 9 patients died of shock, and their follow-up chest radiographs all showed full lung expansion. Eventually, 62 patients were enrolled in this study, and there were a total of 70 episodes of pneumothorax occurring during the emergency room and ICU stay.

3.1. Characteristics and underlying diseases

Among the enrolled 62 patients, there were 41 men (66%) and 21 women (34%), with ages ranging from 17 to 91 years (mean, 63.8 years). The mean APACHE II score on the first day of ICU admission was 19.6 ± 8.3. Thirty-five patients (56.5%) had right-side pneumothoraces, 19 patients (30.6%) had left-side, and 8 patients (12.9%) had bilateral pneumothoraces. The most common primary indication for endotracheal intubation was pneumonia (n = 37, 59.7%), followed by sepsis (n = 7, 11.3%), and neurological disorder (n = 8, 12.9%). Concomitant underlying diseases were frequently found at the time of admission, and the most common was malignancy (n = 18, 29.0%) followed by hypertension (n = 15, 24.2%) and diabetes mellitus (n = 15, 24.2%) (Table 1).

3.2. Treatment outcome, complications, and mortality

As shown in Fig. 1, 48 episodes of pneumothorax (68.6%) were successfully treated with pigtail catheters. Among 22 of the 70 episodes that were not resolved with pigtail catheter drainage, one patient subsequently underwent thoracoscopy with pleurodesis, five patients later died of complications from their underlying disease, and 16 patients underwent large-bore chest tube drainage. Of these 16 patients who underwent large-bore chest tube drainage, 2 patients also failed a subsequent 28F to 32F thoracostomy tube and were required to undergo surgical pleurodesis. The average duration of pigtail drainage was 5.9 days (1-27 days). Overall, 37 patients (59.7%) died during their ICU stay, but none of them died of pneumothorax. No major complications occurred through the use of this procedure, except for 3 patients who developed pleural infections and 1 patient in whom the tube was occluded by a blood clot. The pathogens associated with the 3 pleural infections were all *Staphylococcus aureus*, and these patients were all immunocompromised (2 malignancies and 1 uremia). Complica-

Table 1 Characteristics of 62 patients with pneumothoraces in the emergency department and ICU

Characteristics	Patient no. (%)
Age (y) (mean ± SD)	63.8 ± 20.3
Sex (male/female)	41/21
Smoking	23 (37.1)
APACHE II score (mean ± SD)	19.6 ± 8.3
Primary indication for intubation	
Pneumonia	37 (59.7)
Sepsis	7 (11.3)
Neurological disorder	8 (12.9)
Upper airway obstruction	4 (6.5)
Post-surgery	3 (4.8)
COPD	3 (4.8)
Miscellaneous	1 (1.6)
Underlying diseases	
Malignancy [a]	18 (29.0)
Hypertension	15 (24.2)
Diabetes mellitus	15 (24.2)
Chronic airway disease [b]	13 (21.0)
Congestive heart failure	7 (11.3)
Uremia	6 (9.7)
Cerebral vascular disease	6 (9.7)
Previous tuberculosis	5 (8.1)
Hepatic cirrhosis	5 (8.1)
AIDS	2 (3.2)

COPD indicates chronic obstructive pulmonary disease.
[a] Included lung cancer (n = 2), extra-pulmonary cancer (n = 16).
[b] Included asthma (n = 1), chronic obstructive pulmonary disease (n = 11), and bronchiectasis (n = 1).

Table 2 Comparison of successful and failed pigtail treatment in 70 episodes of pneumothoraces in the ER and ICU

	Success (n = 48)	Failure (n = 22)	*P*
Age	63.3	61.7	.765
Sex (male/female)	27/21	20/2	.004
Body mass index	19.6 ± 4.0	19.2 ± 3.6	.726
APACHE II scores	20.0 ± 9.0	19.0 ± 7.4	.637
Smoking	15	12	.063
Pneumothorax side (right/left)	30/18	13/9	.221
Days from start of mechanical ventilation to pneumothorax	5.5 ± 7.5	10.1 ± 9.6	.034
ARDS event	13 (27.1)	11 (50.0)	.061
Ventilator setting			
FIO_2 <60%	7 (14.6)	10 (45.5)	.005
PEEP	6.3 ± 2.3	8.7 ± 3.0	.001
Tidal volume	520.7 ± 105.3	483.8 ± 115.1	.207
PIP	30.7 ± 5.9	32.3 ± 5.7	.329
Plateau pressure	25.4 ± 3.9	24.7 ± 3.7	.548
ICU stay (d)	12.4 ± 8.2	18.8 ± 10.3	.007
Total hospitalization (d)	34.1 ± 30.4	42.3 ± 39.5	.346
Pigtail intubation time (d)	6.0 ± 5.3	5.8 ± 6.3	.901
Complications	3 (6.3)	1 (4.5)	.775
Mortality	28 (57)	13 (61)	.952

PIP indicates peak inspiratory pressure.

tion events were managed with adequate drainage, antibiotic use, correct coagulopathy, and replacement or adjustment of the tube by a physician. Analyzing the variables between the 2 groups (Table 2), more of the patients who failed the pigtail drainage required FIO_2 <60% (45.5% vs 14.6%, P = .005), and they had higher PEEP setting (8.7 ± 3.0 vs 6.2 ± 2.3, P = .001) at the time of pneumothorax onset than patients whose pigtail drainage was successful.

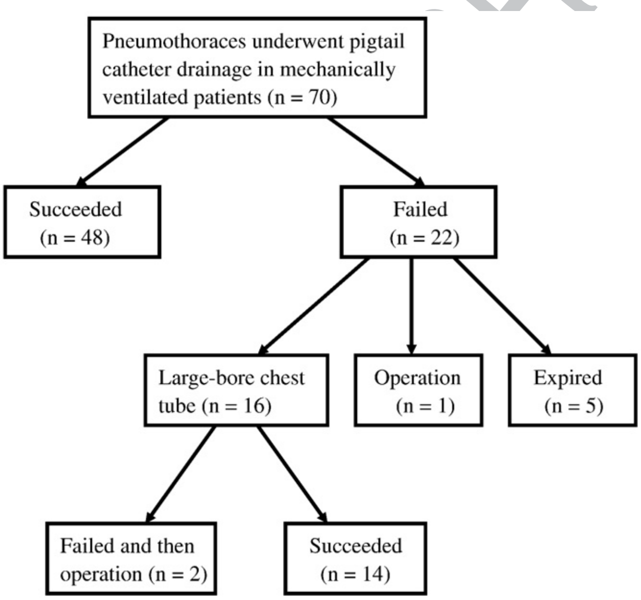

Fig. 1 Flow chart representing the treatment outcomes of 62 patients with 70 episodes of pneumothoraces undergoing pigtail catheter as their initial management in the ICU.

3.3. Barotraumatic and iatrogenic pneumothoraces

Among the 70 episodes of pneumothorax, 30 (42.9%) were associated with barotraumas and the other 40 were iatrogenic pneumothoraces. Underlying lung diseases for patients with barotraumas included pneumonia (n = 25, 83%), chronic obstructive pulmonary disease (n = 3, 10%), interstitial lung disease (n = 1, 3%), and asthma (n = 1, 3%). The 40 episodes of iatrogenic pneumothorax were caused by transbronchial lung biopsy (n = 3, 7.5%), central venous/pulmonary artery placement (n = 31, 77.5%), and thoracentesis (n = 6, 15%). Comparing the efficacy of pigtail drainage between barotraumatic and iatrogenic pneumothorax, use of pigtail catheters for management of iatrogenic pneumothorax had a significantly higher success rate than for barotraumatic (87.5% vs. 43.3%, P < .0001). In addition, patients who developed ventilator-associated barotraumatic pneumothoraces had a significantly longer interval from the start of mechanical ventilation to occurrence of pneumothorax (10.4 ± 8.4 vs 4.3 ± 7.5 days, P < .05), a higher incidence of ARDS events (67% vs 10%, P < .05), and a longer ICU stay (19.5 ± 9.3

Table 3 Clinical characteristics and outcomes of barotrauma and iatrogenic pneumothoraces undergoing pigtail catheter drainage in the ER and ICU

	Barotrauma (n = 30)	Iatrogenic (n = 40)	*P*
Age	56.6	67.5	.027
Sex	23/7	24/16	.142
BMI	20.2 ± 3.2	18.9 ± 4.2	.199
Smoking	15 (50)	12 (30)	.089
Pneumothorax side (right/left)	15/15	28/12	.089
Pneumothorax size (large)	25 (83)	34 (85)	.683
APACHE II score	17.5 ± 6.8	21.4 ± 9.3	.054
Successful pigtail treatment	13 (43.3)	35 (87.5)	.001
Days from start of mechanical ventilation to pneumothorax	10.4 ± 8.4	4.3 ± 7.5	<.05
F_{IO_2} <60%	9 (30)	8 (20)	.334
ICU stay (d)	19.5 ± 9.3	10.6 ± 7.3	<.05
Total hospitalization (d)	41.1 ± 34.7	33.3 ± 32.5	.337
Duration of pigtail intubation (d)	6.2 ± 5.2	5.8 ± 5.9	.742
Mortality	20 (67)	21 (52.5)	.234

BMI indicates body mass index.
Q3 *P < .05 compared with the pneumonia subgroup.

vs 10.6 ± 7.3 days, $P < .05$) than patients who had iatrogenic pneumothoraces (Table 3).

4. Discussion

To the best of our knowledge, this is the first retrospective study reporting the efficacy and safety of drainage using a small-bore chest tube (pigtail catheter) as the initial treatment in mechanically ventilated patients who developed pneumothoraces in the emergency room and medical ICUs. Our study showed that the overall success rate was 68.6%, (barotraumatic: 43.3%, iatrogenic: 87.5%), and the complication rate was 5.7%. Therefore, in our series, the use of pigtail catheters with a water seal drainage system appears to be a safe and promising technique in the treatment of pneumothoraces under positive pressure ventilation.

In this study, patients who failed pigtail catheter drainage seemed to have significantly higher PEEP levels (8.7 ± 3.0 vs. 6.3 ± 2.3 mm Hg, $P = .001$) than patients who were successfully treated with pigtail catheters. According to our ventilator setting protocol for ARDS [30], high PEEP levels were usually applied for those patients. Therefore, higher PEEP levels may reflect more severe underlying pulmonary conditions. In this vicious cycle, the effects of PEEP may raise airway pressures and aggravate air leakage [31].

The interval from start of mechanical ventilation to occurrence of pneumothorax caused by barotrauma was 10.4 days, which was significantly longer than that in the iatrogenic pneumothoraces (4.3 days). This was because most invasive procedures were performed within the first three days of ICU admission, but the patients with ARDS usually developed pneumothorax in the late stages (>2 weeks) [32].

Little is known about the small-bore chest tube for treating iatrogenic pneumothoraces in patients under positive pressure ventilation. Reviewing the literature, the success rate of small-bore chest tubes for treating iatrogenic pneumothoraces was about 71% to 85% [33-35]. Our data showed an 87.5% success rate for treatment with the pigtail catheter in patients who developed iatrogenic pneumothoraces in the ICU. Thus, we strongly suggest that the pigtail catheter can be used as first-line therapy for iatrogenic pneumothoraces under positive pressure ventilation.

Traditional large-bore chest tubes usually produce much more chest wall trauma than pigtail catheters because the physician must make an incision into the chest wall, bluntly dissect the intercostal tissues, and place the tube into the pleural space. Furthermore, insertion requires significant force, which may cause inadvertent damage to the chest wall and the underlying organs. The advantage of the pigtail method is that it is easy and simple to perform for the physician and involves less trauma and discomfort for the patient. To further enhance safety, we performed this procedure under ultrasonic guidance. A chest ultrasonic examination was performed before the procedure for the following reasons: (1) to confirm the diagnosis of pneumothorax with an echo finding (lung sliding or gliding sign, lung point sign, comet tail artifact) [25-29] and (2) to evaluate the presence of pleural effusion and locate the solid organ positions to prevent hollow organ perforation.

There were some limitations to our study. First, this was a retrospective study, and we do not have comparative results from large-bore chest tubes in mechanically ventilated patients with pneumothoraces. However, the results in our series are still promising and similar to those of a previous study that showed a success rate of 55% when large-bore chest tubes were inserted to treat pneumothoraces in the ICU [5]. Second, the number of enrolled patients in our series was too small to further analyze possible factors predicting treatment failure. A larger prospective and randomized trial is necessary to confirm our results.

In conclusion, this is the first report of the utility of pigtail catheters in the management of mechanically ventilated patients with pneumothoraces. Our study shows that drainage using pigtail catheters is relatively effective in iatrogenic pneumothoraces but less promising in barotraumatic pneumothoraces.

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