CHEST

# A Systematic Review and Meta-Analysis Comparing Pigtail Catheter and Chest Tube as the Initial Treatment for Pneumothorax

*Su-Huan Chang, MD; Yi-No Kang, MA; Hsin-Yi Chiu, MD; and Yu-Han Chiu, MD, ScD*

**BACKGROUND:** The optimal initial treatment approach for pneumothorax remains controversial. This systemic review and meta-analysis investigated the effectiveness of small-bore pigtail catheter (PC) drainage compared with that of large-bore chest tube (LBCT) drainage as the initial treatment approach for all subtypes of pneumothorax.

**METHODS:** PubMed and Embase were systematically searched for observational studies and randomized controlled trials published up to October 9, 2017, that compared PC and LBCT as the initial treatment for pneumothorax. The investigative outcomes included success rates, recurrence rates, complication rates, drainage duration, and hospital stay.

**RESULTS:** Of the 11 included studies (875 patients), the success rate was similar in the PC (79.84%) and LBCT (82.87%) groups, with a risk ratio of 0.99 (95% CI, 0.93 to 1.05; $I^2 = 0\%$). Specifically, PC drainage was associated with a significantly lower complication rate following spontaneous pneumothorax than LBCT drainage (Peto odds ratio: 0.49 [95% CI, 0.28 to 0.85]; $I^2 = 29\%$). In the spontaneous subgroup, PC drainage was associated with a significantly shorter drainage duration (mean difference, −1.51 [95% CI, −2.93 to −0.09]) and hospital stay (mean difference: −2.54 [95% CI, −3.16 to −1.92]; $P < .001$) than the LBCT group.

**CONCLUSIONS:** Collectively, results of the meta-analysis suggest PC drainage may be considered as the initial treatment option for patients with primary or secondary spontaneous pneumothorax. Ideally, randomized controlled trials are needed to compare PC vs LBCT among different subgroups of patients with pneumothorax, which may ultimately improve clinical care and management for these patients.

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**KEY WORDS:** chest tube; pigtail; pneumothorax; thoracentesis; thoracostomy

**ABBREVIATIONS:** LBCT = large-bore chest tube; PC = pigtail catheter; RCT = randomized controlled trial; RR = risk ratio

**AFFILIATIONS:** From the Center for Evidence-Based Medicine (Drs Chang and H.-Y. Chiu; and Mr Kang), Department of Medical Education, Taipei Medical University Hospital, Taipei, Taiwan; School of Medicine (Dr Chang), College of Medicine, Taipei Medical University, Taipei, Taiwan; Division of Thoracic Surgery (Dr H.-Y. Chiu), Department of Surgery, Taipei Medical University Hospital, Taipei, Taiwan; Department of Education and Humanities in Medicine (Dr H.-Y. Chiu), School of Medicine, Taipei Medical University, Taipei, Taiwan; Department of Surgery (Dr H.-Y. Chiu), School of Medicine, Taipei Medical University, Taipei, Taiwan; Department of Animal Science and Technology (Dr H.-Y. Chiu), National Taiwan University, Taipei, Taiwan; and the Department of Nutrition (Dr Y.-H. Chiu), Harvard T.H. Chan School of Public Health, Boston, MA.

Drs Chang and Kang were co-first authors.

**CORRESPONDENCE TO:** Hsin-Yi Chiu, MD, Division of Thoracic Surgery, Department of Surgery, Taipei Medical University Hospital, 252, Wu-Xing St, Taipei 110, Taiwan; e-mail: chibinmaruko1111@gmail.com



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Pneumothorax, a potentially lethal respiratory disease, is a common presentation to the emergency department worldwide, and it affects > 20,000 patients per year in the United States. Pneumothorax can be categorized according to its etiology as primary spontaneous pneumothorax, secondary spontaneous pneumothorax, and iatrogenic or traumatic pneumothorax. Although a small spontaneous pneumothorax may resolve without treatment, for patients who are symptomatic (ie, significant dyspnea defined as deterioration in usual exercise tolerance[2]) and exhibit a larger pneumothorax (rim of air > 2 cm), simple aspiration or tube thoracostomy is necessary.[1] However, whether a small-bore pigtail catheter (PC) or a large-bore chest tube (LBCT) should be used as the initial treatment for pneumothorax remains controversial. For example, according to the American College of Chest Physicians Delphi consensus statement,[2] an LBCT (16F-28F) should be used for treating larger and unstable primary and secondary spontaneous pneumothorax; by contrast, the British Thoracic Society no longer recommends the use of the LBCT for primary and secondary spontaneous pneumothorax.[1] In addition, clinical guidelines are unclear regarding the management strategies for pneumothorax subtypes other than primary and secondary spontaneous pneumothorax. Due to the inconsistency and the paucity of evidence, substantial variations exist in the approaches used for the initial management of pneumothorax in clinical practice.[3] We therefore conducted a systematic review and meta-analysis to investigate the effectiveness of small-bore PC drainage compared with that of LBCT drainage as the initial treatment for different subtypes of pneumothorax.

## Materials and Methods

The study protocol was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[4] This research was exempted from institutional review board approval because it used only existing, publicly available data. The protocol of the present systematic review was registered online with PROSPERO, the international prospective register of systematic reviews (CRD42017078481).

### Search Strategy and Selection Criteria

We systematically searched PubMed and Embase for randomized controlled trials (RCTs) and cohort studies published up to October 9, 2017. Natural language terminology, Embase Subject Headings (Emtree) and Medical Subject Headings (MeSH) (pneumothorax, pneumothoraces, thoracentesis, drainage catheter, pigtail catheter, chest tube, and thoracostomy) with Boolean algebra were used to identify articles comparing PC drainage with chest tube drainage in the databases of PubMed, Embase, and Cochrane Library. The search was not limited to articles published in English.

The abstracts and full text of articles were screened for pertinent information. The inclusion criteria were defined a priori and were as follows: (1) RCTs or cohort studies (prospective or retrospective); (2) articles that reported outcomes (success rates, recurrence rates, complication rates, hospital stay, or prognosis) of primary and secondary spontaneous pneumothorax (or both), traumatic pneumothorax, or iatrogenic pneumothorax; and (3) articles that compared PC drainage vs LBCT drainage for the initial treatment of pneumothorax. We excluded studies on the newborn population and studies if they reported the outcomes for PC drainage or LBCT drainage only.

### Size Definitions of PC and Chest Tubes

Chest tubes are available in various sizes based on the external diameter, ranging from 6F to 40F. Typically, chest tubes may be straight or coiled at the end ("pigtail"). A small-bore chest tube is typically ≤ 14F, whereas an LBCT is typically > 14F in diameter. However, in the included studies, only one patient aged 17 years was treated with an LBCT sized 16F and was categorized into the chest tube group.[5]

### Data Extraction and Quality Assessment

Two reviewers (Y. N. K. and S. H. C.) independently extracted the data on the study design, setting, population descriptors, and outcomes. In the case of disagreement, other reviewers (H. Y. C. and Y. H. C.) served as the arbitrators. The Newcastle-Ottawa Scale was used to assess the methodologic quality and risk of bias of the included cohort studies, and the Cochrane Risk of Bias Tool was used for the included RCTs, as recommended in the Cochrane Handbook.[6,7] The appraisal tools are described in detail in e-Figure 1 and e-Table 1. The Cochrane Risk of Bias Tool comprises seven methodologic domains: (1) random sequence generation; (2) allocation concealment; (3) blinding of participants and personnel; (4) blinding of assessment; (5) incomplete outcome data; (6) selective reporting; and (7) other sources of bias. The Newcastle-Ottawa Quality Assessment Form comprises eight methodologic domains associated with a risk of bias that are categorized into three groups: (1) representativeness of the exposed cohort; (2) selection of the nonexposed cohort; (3) ascertainment of exposure; (4) demonstration that the outcome of interest was not present at the start of the study; (5) comparability of cohorts on the basis of the design or analysis controlled for confounders; (6) assessment of the outcome; (7) whether the follow-up was long enough for the outcomes to occur; and (8) and adequacy of follow-up of cohorts (e-Fig 1, e-Table 1).

Two reviewers (H. Y. C. and S. H. C.) independently evaluated the quality of the included studies by using the appraisal tools. A high-quality study was defined as one that met the criteria for ≥ 5 domains. In the case of disagreement, a third reviewer (Y. N. K.) served as the arbitrator. Potential publication bias was detected by using Egger's test, which was applied to measure the significance of asymmetry among the included studies. A funnel plot was generated to demonstrate publication bias and effectiveness (log-OR) against the standard error of log-OR (precision).

### Statistical Analysis

The primary outcomes were success rates and recurrence rates for PC and LBCT drainage performed for all types of pneumothorax. The secondary outcomes were complication rates, drainage duration, and hospital stay for these two types of chest drains. Subgroup analyses were also performed according to regions (United States, Asia, and Egypt), study design (RCTs and cohort studies), and types of

spontaneous pneumothorax (primary and secondary spontaneous pneumothorax).

The risk ratio (RR) and Peto OR with 95% CIs were estimated for categorical data and the mean difference (MD) with SD for continuous data. Heterogeneity among studies was quantified by using $I^2$ statistics; $I^2 > 75\%$, $> 50\%$, and $< 25\%$ were considered high, moderate, and low heterogeneity, respectively.[8] A random effect model was applied for all analyses. Two-sided $P$ values $< .05$ were considered statistically significant. Review Manager version 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) for Microsoft Windows was used for statistical analysis.

## Results

Figure 1 shows the flowchart for study selection. We initially identified 604 citation records. After excluding duplicates (n = 115), 489 citation records remained. Thereafter, the titles and abstracts of the 489 citation records were screened, and 457 ineligible studies were excluded. The full text of 32 articles was assessed to determine their eligibility. We excluded 21 citation records, comprising one correspondence, two conference abstracts (due to lack of information on the prespecified outcomes of interests), 16 non-RCT or cohort studies, one duplicate submission, and another study conducted on the neonatal population. Ultimately, 11 studies were included in the meta-analysis (Table 1).[3,5,9-17]

The 11 studies involved a total of 875 patients from four continents: one from Africa (Egypt), four from Asia (Taiwan and Hong Kong), one from Europe (Denmark), and five from North America (United States). Of the 11 included studies, two were RCTs[9,10] involving 62 patients, and nine were retrospective cohort studies[3,5,11-17] involving 813 patients. These patients were enrolled from 1973 to 2014. Seven of the included studies involved patients with spontaneous pneumothorax,[3,9,12,14-17] one study involved patients with mixed types of pneumothorax,[5] two studies involved patients with traumatic pneumothorax,[10,11] and one study involved patients with iatrogenic pneumothorax.[13]

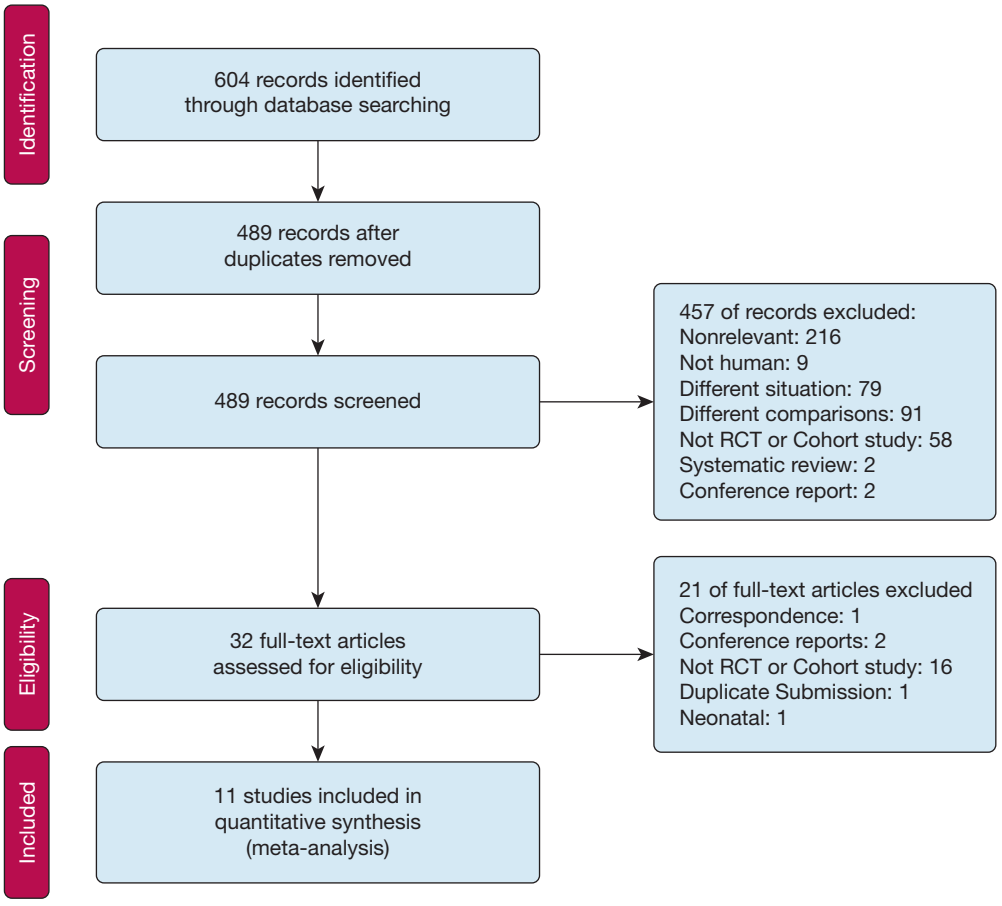


Figure 1 – *Study flow diagram. The study protocol was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement, with modifications. RCT = randomized controlled trial.*

**TABLE 1** ] Characteristics of Included Studies

| Study | Location | No. of Patients | Included Years | Study Design | Age (y) | | Sex (Female) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Pigtail | Chest Tube | Pigtail | Chest Tube |
| Dull and Fleisher[5] (2002) | United States | 23 with 27 insertions | 1993-1999 | Retrospective cohort | 16.9 | 17.7 | 2 | 1 |
| Hussein et al[9] (2017) | Egypt | 22 | January-June 2014 | RCT | 55.2 ± 10 | 56.4 ± 10 | 2 | 1 |
| Kulvatunyou et al[10] (2014) | United States | 40 | July 2010-February 2012 | RCT | 46 ± 4 | 46 ± 4 | 3 | 4 |
| Kulvatunyou et al[11] (2011) | United States | 221 | January 2008-December 2009 | Retrospective cohort | 43 ± 21 | 40 ± 18 | 27 (36%) | 31 (21%) |
| Kuo et al[12] (2013) | Taiwan | 33 | April 2000-October 2010 | Retrospective cohort | 15 (15, 16) | 16 (15, 17) | 2 | 4 |
| Laronga et al[13] (2000) | United States | 42 | January 1994-June 1998 | Retrospective cohort | NR | | | |
| Lee et al[14] (2010) | Hong Kong | 59 | January 1999-September 2007 | Retrospective cohort | 16 ± 1 | 16 ± 1 | 4 (22%) | 1 (4%) |
| Liu et al[15] (2003) | Taiwan | 102 | January 1997-September 2001 | Retrospective cohort | 27.2 ± 12.8 | 25.4 ± 9.2 | 13 | 10 |
| O'Rourke and Yee[16] (1989) | United States | 108 | 1973-1984 | Retrospective cohort | NR (unclear) | | NR(unclear) | |
| Riber et al[3] (2017) | Denmark | 134 | January 2009-December 2013 | Retrospective cohort | 33 (range: 17-76) | 32 (range: 15-95) | 19 (31.7%) | 19 (25.7%) |
| Tsai et al[17] (2006) | Taiwan | 91 | January 2002-September 2005 | Retrospective cohort | 59 ± 18 | 63 ± 19 | 13 | 2 |

| Study | Pneumothorax Type | Pneumothorax | | | | Tube Size | |
|---|---|---|---|---|---|---|---|
| | | Size | | Location (left/right) | | | |
| | | Pigtail | Chest tube | Pigtail | Chest tube | Pigtail | Chest tube |
| Dull and Fleisher[5] (2002) | Pneumothorax[a] | NR | NR | NR | NR | 6.5F-10.5F | 16F-32F |
| Hussein et al[9] (2017) | SSP | NR | NR | NR | NR | 14F | 30F |
| Kulvatunyou et al[10] (2014) | Traumatic pneumothorax | NR | NR | NR | NR | 14F | 28 Fr |
| Kulvatunyou et al[11] (2011) | Traumatic pneumothorax | NR | NR | NR | NR | 14F | NR |

*(Continued)*

**TABLE 1** *(Continued)*

| Study | Pneumothorax Type | Pneumothorax | | | | Tube Size | |
|---|---|---|---|---|---|---|---|
| | | Size | | Location (left/right) | | | |
| | | Pigtail | Chest tube | Pigtail | Chest tube | Pigtail | Chest tube |
| Kuo et al[12] (2013) | PSP | 70% (55.9, 87.5) | 59.1% (51.5, 75.6) | 6/4 | 14/9 | 8F-12F | NR |
| Laronga et al[13] (2000) | Iatrogenic pneumothorax | 1%-100% (median, 20%) | 10%-100% (median, 50%) | NR | NR | 8.5F | 20F-40F |
| Lee et al[14] (2010) | PSP | <50%: 7 (39%) | <50%: 8 (33%) | NR | NR | NR | NR |
| Liu et al[15] (2003) | PSP | 49.2 ± 25.3% | 53.6 ± 27.7% | 30/20 | 28/24 | 8F-10F | NR |
| O'Rourke and Yee[16] (1989) | SP[a] | 10%-35% | 10%-100% | NR | NR | NR | NR |
| Riber et al[3] (2017) | PSP | NR | NR | 20/40 | 34/40 | 12F-16F | ≥ 21F |
| Tsai et al[17] (2006) | SSP | 59 ± 22% | 47 ± 18% | 30/39 | 12/9 | 10F-14F | 20F-28F |

NR = no report; PSP = primary spontaneous pneumothorax; SP = spontaneous pneumothorax; SSP = secondary spontaneous pneumothorax.
[a]SP includes PSP and SSP.

### Success Rates

Overall, in the 11 included studies[3,5,9-17] involving 875 patients, the success rate was similar in the PC (293 of 367 [79.84%]) and LBCT (421 of 508 [82.87%]) groups for all pneumothorax types (RR, 0.99 [95% CI, 0.93–1.05]; $I^2 = 0\%$) (Fig 2). Moreover, in subgroups analyses categorized according to pneumothorax types, no significant differences were observed in the success rate between PC and LBCT. In the traumatic subgroup, the RR of success rate between the PC and LBCT groups was 0.97 (95% CI, 0.86-1.08), with acceptable heterogeneity ($I^2 = 35\%$). In the spontaneous pneumothorax subgroup consisting of seven studies,[3,9,12,14-17] the RR was 1.06 (95% CI, 0.95-1.18), with low heterogeneity ($I^2 = 0\%$). In the iatrogenic pneumothorax subgroup that consisted of only one study,[13] the RR was 0.97 (95% CI, 0.72-1.31). In the mixed pneumothorax subgroup that consisted of only one study,[5] the RR was 1.04 (95% CI, 0.76-1.42).

### Recurrence Rates

Only four studies involving patients with spontaneous pneumothorax reported recurrence rates.[3,12,14,17] The recurrence rate tended to be lower in the PC group (33 of 157 [21.02%]) than in the LBCT group (43 of 143 [30.07%]), although this difference did not reach statistical significance (RR, 0.78 [95% CI, 0.57-1.09]; $I^2 = 0\%$) (Fig 3).

### Complication Rates

The pooled data of nine studies indicated that the PC group (32 of 278 [11.51%]) had a lower complication rate than the LBCT group (72 of 436 [16.51%]; Peto OR, 0.63 [95% CI, 0. 39-1.03]; $I^2 = 26\%$) (Fig 4),[3,5,9-12,14,16,17] and this association was mainly driven by spontaneous pneumothorax. Specifically, the PC group had a significantly lower complication rate following spontaneous pneumothorax than the LBCT group (Peto OR, 0.49 [95% CI, 0.28-0.85]; $P = .01$; $I^2 = 29\%$).[3,9,12,14,16,17] However, in the traumatic subgroup analysis, the complication rate was similar in the PC and LBCT groups (Peto OR, 1.29 [95% CI, 0.37-4.51]; $I^2 = 0\%$).[10,11] In the trial[5] with mixed pneumothorax subgroup analysis (spontaneous, iatrogenic, and traumatic pneumothorax), no significant differences were observed in the complication rate between the groups (Peto OR, 1.95 [95% CI, 0.35-10.90]).

### Drainage Duration

Overall, the PC group had a significantly shorter drainage duration than the LBCT group (MD, −1.03 [95% CI, −1.84 to −0.23]; $P = .01$; $I^2 = 51\%$)

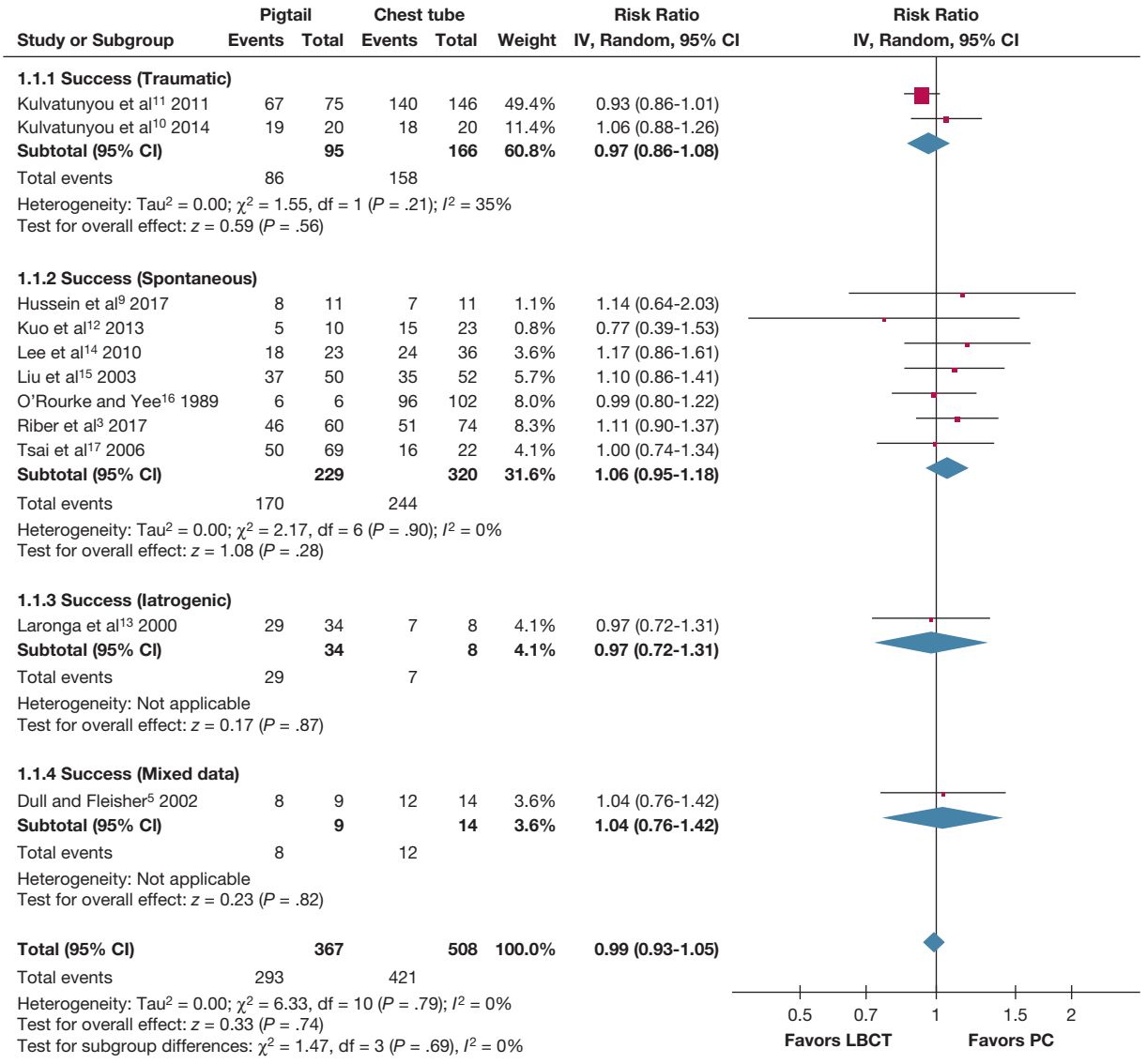


Figure 2 – *Comparison of success rates between the PC and LBCT groups. LBCT = large-bore chest tube; PC = pigtail catheter.*

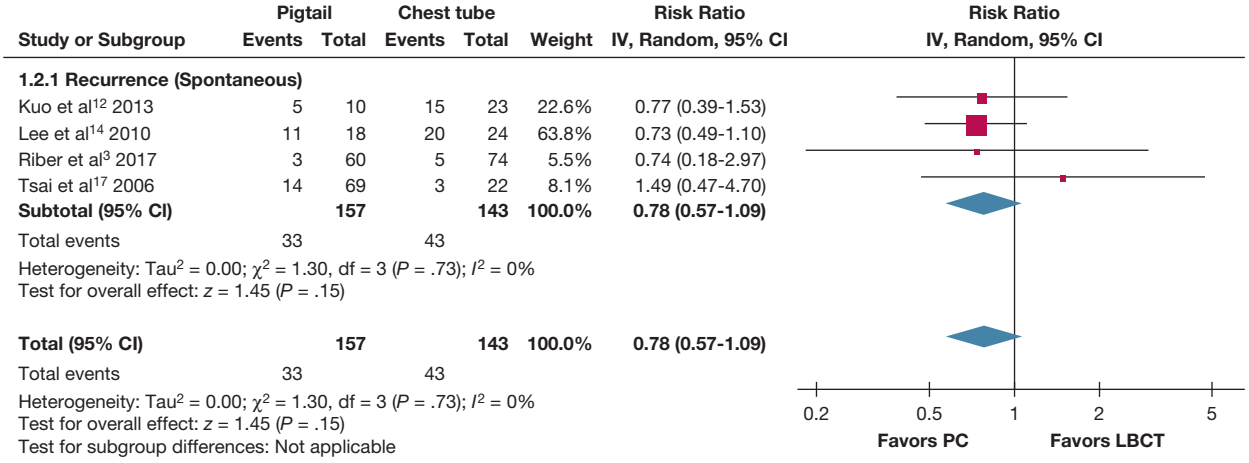


Figure 3 – *Comparison of recurrence rates between the PC and LBCT groups. See Figure 2 legend for expansion of abbreviations.*

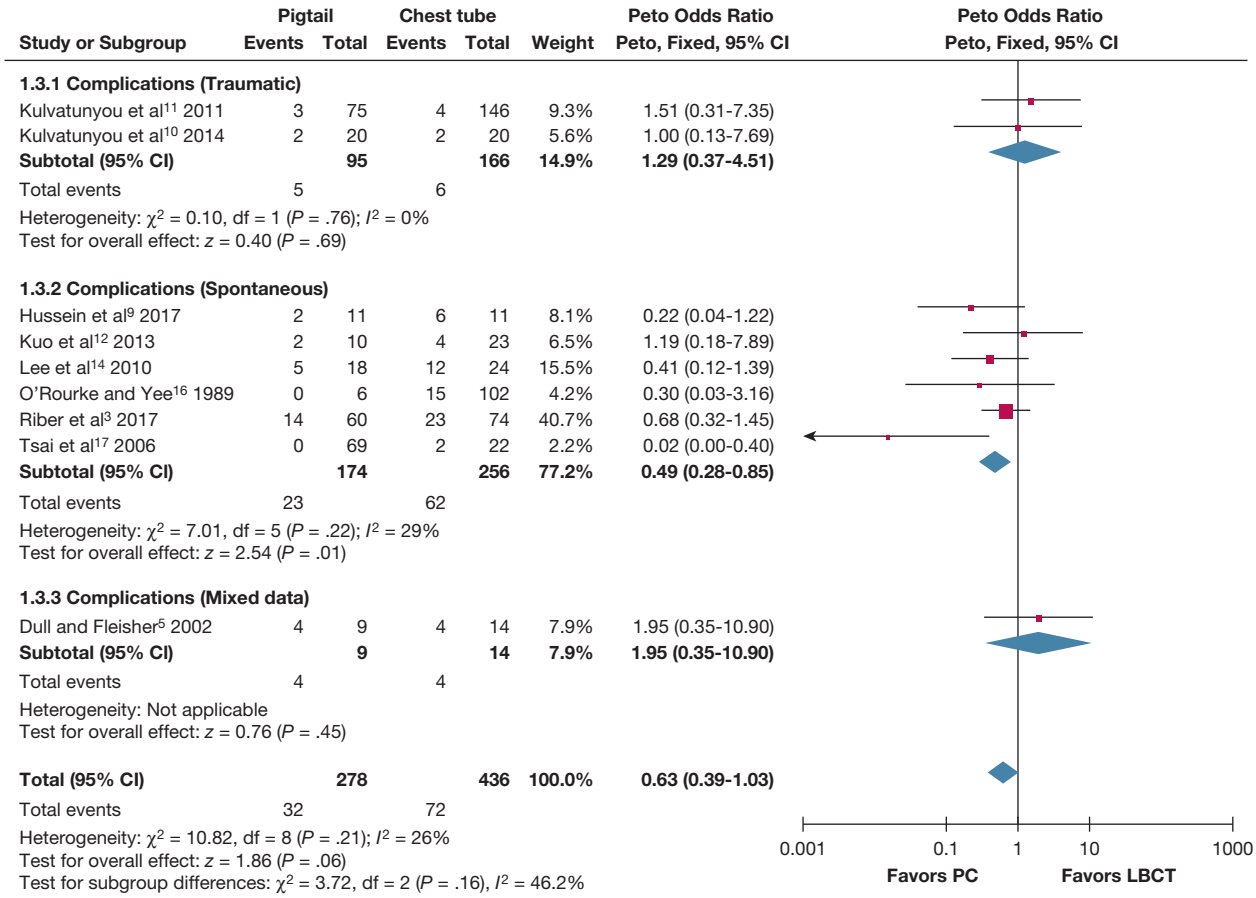


Figure 4 – *Comparison of complication rates between the PC and LBCT groups. See Figure 2 legend for expansion of abbreviations.*

(Fig 5).[3,5,9,11,17] These results were similar across different subtypes of pneumothorax, although the MDs were only significant for the spontaneous subgroup. In spontaneous subgroup analysis, the PC group exhibited a significantly shorter drainage duration (MD, −1.51 [95% CI, −2.93 to −0.09]).[3,9,17] In the traumatic subgroup, only one study reported drainage duration, which found no difference in drainage duration between the two groups (MD, −0.40 [95% CI, −0.92 to 0.12]).[11] Moreover, in the mixed pneumothorax subgroup analysis, no significant differences were observed in drainage duration between the two groups (MD, −1.70 [95% CI, −4.50 to 1.10]).[5]

## Hospital Stay

The length of hospital stay was significantly shorter in the PC group than in the LBCT group (MD, −2.54 [95% CI, −3.16 to −1.92]; $P < .001$; $I^2 = 0\%$) (Fig 6),[5,14,16,17] and this association was mainly driven by spontaneous pneumothorax (MD, −2.61 [95% CI, −3.24 to −1.98]; $P < .001$; $I^2 = 0\%$).[14,16,17] However, in the mixed pneumothorax subgroup analysis, no difference was observed between both groups (MD, −0.60 [95% CI, −3.90 to 2.70]).[5]

## Further Analysis

Subgroup analyses were performed to examine whether the results differ according to the study design (RCT or cohort) and regions (Asia, Egypt, Europe, and United States) (e-Figs 2-8). The results for the success rates, recurrence rates, and complication rates revealed no differences between the PC and LBCT groups regardless of the study design and region (e-Figs 2, 3, 5, and 6). In terms of drainage duration, all subgroup analyses according to the study design (RCT and cohort study) showed that patients who used a PC had a shorter drainage duration than those who used an LBCT (e-Fig 4). The result from the only RCT showed that the PC was associated with a shorter drainage duration than the LBCT (MD, −2.50 [95% CI, −4.00 to −1.00]; $P < .001$).[9] Moreover, the pooled result of cohort studies revealed that the PC was associated with a shorter drainage duration than the LBCT, with low heterogeneity (MD, −0.52 [95% CI, −0.95 to −0.09];

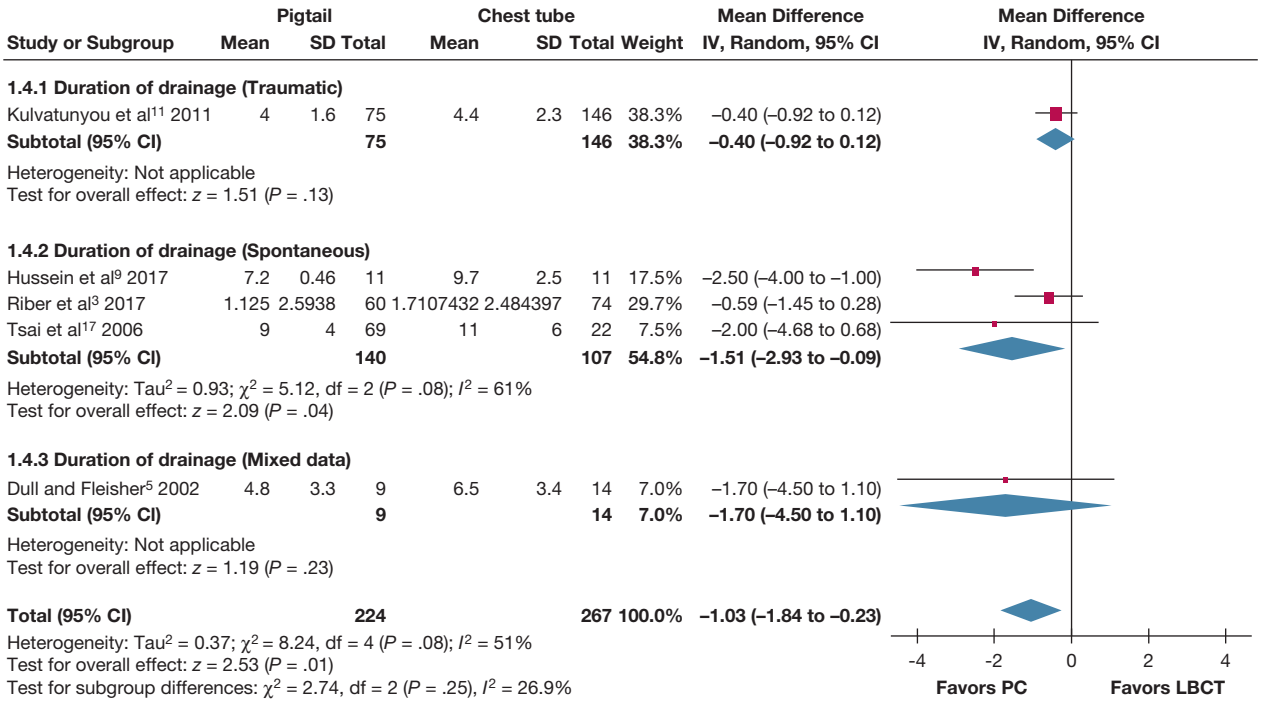


Figure 5 – *Comparison of drainage duration between the PC and LBCT groups. See Figure 2 legend for expansion of abbreviations.*

$P = .02$; $I^2 = 0\%$). In addition, only one study in Egypt showed that the drainage duration was significantly shorter in the PC group than in the LBCT group (e-Fig 7).[9] Moreover, studies in Asia, Europe, and the United States found that the PC may require a slightly shorter drainage duration than the LBCT.[3,5,17] In terms of hospital stay, which was only reported in cohort studies, both subgroup analyses according to regions (Asia and United States) showed that patients who used a PC had a shorter hospital stay than those who used an LBCT (e-Fig 8).[5,14,16,17] Heterogeneities in all aforementioned results were acceptable.

A subgroup analysis was also conducted according to the spontaneous pneumothorax type (primary, secondary, or mixed) (e-Figs 9-13). No differences were observed in success and recurrence rates between the PC and LBCT groups (e-Figs 9 and 10). However, among secondary

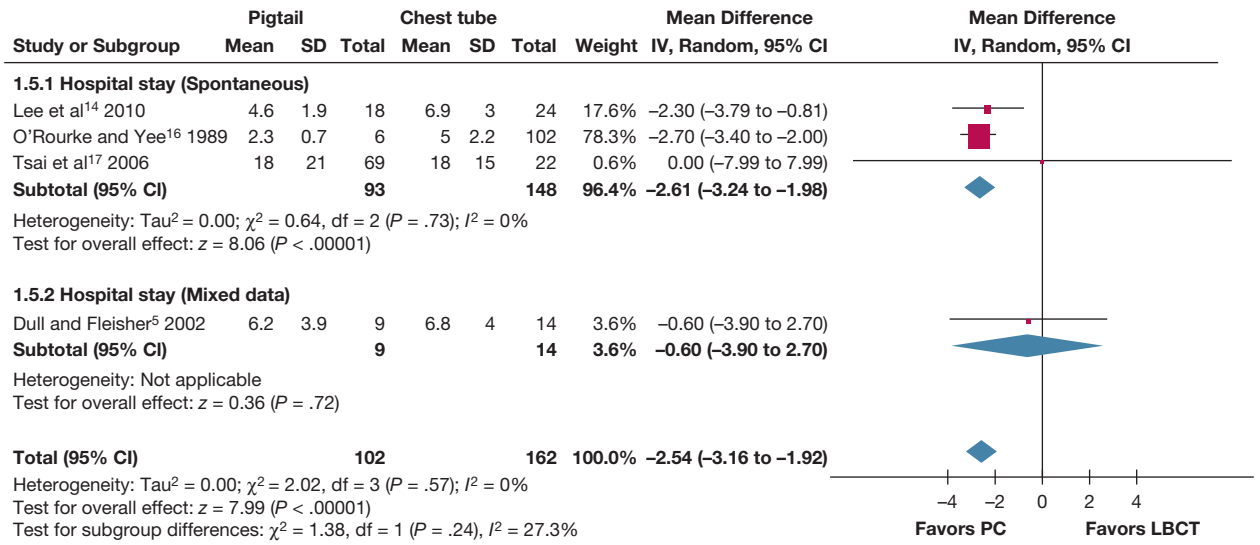


Figure 6 – *Comparison of hospital stay between the PC and LBCT groups. See Figure 2 legend for expansion of abbreviations.*

spontaneous pneumothorax, PC drainage (2 of 80 [2.5%]) had fewer complications than LBCT drainage (8 of 33 [24.24%]) (Peto OR, 0.13 [95% CI, 0.03–0.57]; $P = .007$; $I^2 = 51\%$) (e-Fig 10).[9,17] We also found that the PC group had a shorter drainage duration than the LBCT group, particularly in the secondary spontaneous pneumothorax subgroup (MD, −2.38 [95% CI, −3.69 to −1.07]; $P < .001$; $I^2 = 0\%$) (e-Fig 12). In primary spontaneous pneumothorax and mixed subgroup analyses according to hospital stay, the PC group had a shorter hospital stay than the LBCT group (MD, −2.54 [95% CI, −3.16 to −1.92]; $P < .001$; $I^2 = 0\%$) (e-Fig 13).

### *Publication Bias Detection*

Finally, based on the asymmetry of the funnel plot for insertion success, no significant unbalance was found in this meta-analysis (Fig 7). According to Duval and Tweedie's trim and fill analysis, the adjusted result was similar to the original result; the adjusted value was 0.971 (95% CI, 0.917 to 1.027) with Q = 10.135, and the original estimated value was 0.99 (95% CI, 0.933 to 1.051) with Q = 6.334. The Egger's regression intercept indicated no evidence of any asymmetry for the association of tubes with insertion success ($t = 1.834$ [95% CI, −0.176 to 1.687]). This result suggested that there was no significant publication bias in our meta-analysis. However, publication bias might be undetected given the small number of included studies.

## Discussion

Our meta-analysis revealed that PC drainage was as effective as LBCT drainage. Furthermore, compared with the LBCT group, the PC group had shorter drainage duration and hospital stay in patients with spontaneous pneumothorax and fewer complications in patients with secondary spontaneous pneumothorax.

Although the LBCT has been the dominant treatment of choice in pneumothorax patients for decades, in recent years, abundant literature has supported a paradigm shift toward the more routine use of PC for managing pneumothorax with varying severity. The advantages of a PC are smaller size, small incision, better patient comfort, and outpatient management. Some studies have suggested that PC drainage is cost-saving and may be a reasonable treatment approach for the first episode of large spontaneous pneumothorax.[18,19] However, the disadvantage of a PC is the lower flow rate.[20,21] The gas flow rates through a chest tube are related to various factors, as illustrated in the Fanning equation.[22] Generally, air has minimal viscosity; therefore, a small-bore PC may be sufficient for most air leaks resulting from pure alveolar-pleural fistula regardless of the classification of pneumothorax. Conversely, the LBCT can be reserved for refractory pneumothorax and in the emergent scenarios.[13]

Overall, the pooled estimate of the RRs for the success rate indicated that PC drainage was as effective as LBCT drainage for the management of pneumothorax irrespective of the subtypes. In previous studies, the success rate of spontaneous pneumothorax has ranged from 65% to 88% for the PC group and 72% to 80% for the LBCT group.[17,19,23] With regard to the recurrence rate, we could only include four studies of spontaneous

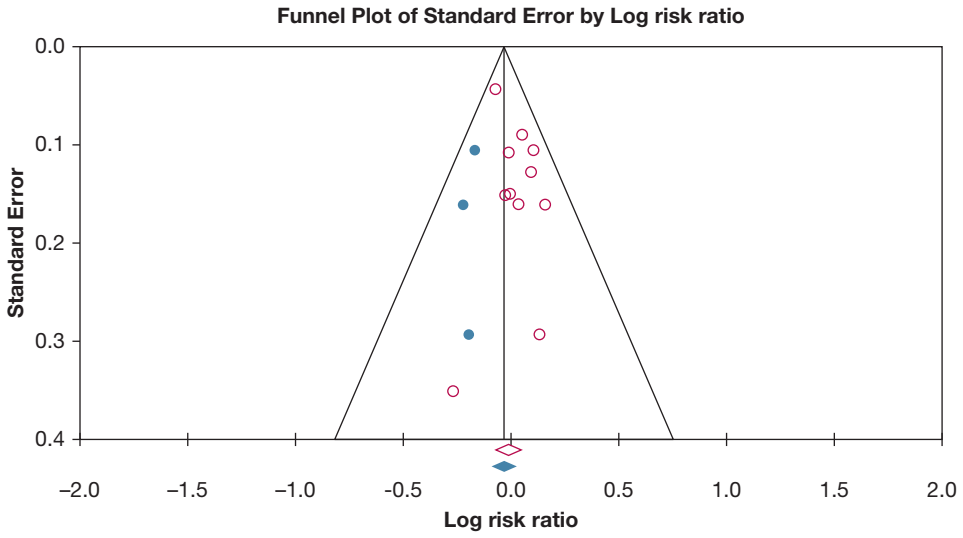


Figure 7 – *Funnel plot of insertion success for publication bias detection.*

pneumothorax,[3,12,14,17] and the pooled results showed no statistically significant differences between the PC and LBCT groups. A previous study suggested that secondary spontaneous pneumothorax associated with obstructive lung conditions and malignancy (but not infectious diseases) may benefit from PC treatment.[24] However, data on the recurrence rate in patients with traumatic or iatrogenic pneumothorax were lacking.

We found that the PC group had significantly lower complication rates than the LBCT group in both spontaneous (six studies)[3,9,12,14,16,17] and secondary (two studies)[9,17] subtypes. The most frequent complications of both groups were tube displacement and sepsis, followed by surgical emphysema.[9,17,25] Hussein et al[9] also found that these complications were more common in the failed cases than in the successful cases, with statistically significant differences. Moreover, the frequency of drainage complications was higher in the failed cases of the LBCT group than in the failed cases of the PC group. This result suggests that PC drainage may be considered as an initial treatment of choice for patients with secondary spontaneous pneumothorax given that the complication rate was lower even in the failed cases.

The present study reported highly significant reductions in drainage duration and length of hospital stay among patients with spontaneous pneumothorax who used a PC compared with those who used an LBCT. Specifically, two studies reported a significantly shorter drainage duration for PC drainage, with low heterogeneity.[9,17] However, the number of included studies was small. Further investigation of drainage duration and hospital stay is warranted.

The LBCT has long been the gold standard for most cases of thoracic trauma. In our meta-analysis, we included two articles pertaining to traumatic pneumothorax, which showed no significant differences in success rates, complication rates, or drainage duration between the PC and LBCT groups.[10,11] However, the two studies were conducted at the same institution. In addition, a few studies have suggested that the PC is preferable in selected patients with uncomplicated pneumothorax without hemothorax or nonemergency tube insertion.[26] In a recent study, Tanizaki et al[27] reported that for patients with chest trauma, drainage efficacy, complication rates, and need for additional invasive procedures did not differ between treatment with 20F to 22F small tubes (even in emergent situations) and LBCT treatment (28F). Nonetheless, because traumatic pneumothorax often occurs with other organ injuries, and its severity often varies across cases, additional studies are needed to delineate the indications and applications of the PC, taking into account associated complications such as hemopneumothorax, respiratory failure, tracheobronchial injury, tension pneumothorax, and flail chest.

Iatrogenic pneumothorax has recently become the most encountered type of pneumothorax compared with traumatic or spontaneous pneumothorax.[28] In most studies, the incidence of pneumothorax secondary to central vein catheter varies between 0.5% and 5%,[29] which ranks highest among the causes of iatrogenic pneumothorax.[30] Only one article included in our study focused on pneumothorax complicated by central vein catheter insertion,[13] and there was no difference in the success rate between the PC and LBCT groups (RR, 0.97 [95% CI, 0.72–1.31]) (Fig 2). No complications due to PC insertion were observed in this article. The mean PC drainage duration was 1.6 days for PC and 9.8 days for LBCT drainage. Galbois et al[31] included a total of 561 patients (130 patients with iatrogenic pneumothorax and others with spontaneous pneumothorax) who were treated with a PC (8F), and they reported that the rate of video-assisted thoracoscopy due to drainage failure was less frequent for iatrogenic pneumothorax than for primary spontaneous pneumothorax ($P < .001$). Although the authors did not compare the effectiveness of PC drainage with that of LBCT drainage, their results suggest that the PC may be used to effectively manage iatrogenic pneumothorax as well.

The present meta-analysis has some limitations. First, the five main outcomes were not completely assessed in all articles. Second, only two RCTs were included in our meta-analysis. Retrospective cohort studies have the natural limitation of selection bias and unmeasured confounders; therefore, more RCTs with a sufficient sample size should be conducted to confirm our results. In the meta-analysis, we analyzed the characteristics of patients obtained from individual studies. Thus, we could not conduct stratified analyses based on patient-level factors such as age, sex, smoking status, and the initial severity of pneumothorax. Furthermore, our included studies did not comprise patients with pneumothorax requiring mechanical ventilation, which is a group of patients in which further investigation and verification are required. Lastly, there were no studies comparing PC vs LBCT in patients with pneumothorax who were mechanically ventilated. Because patients with

mechanical ventilation have high risks of mortality[32] (ranging from 46% to 77%[33,34]), tube thoracostomy is routinely used as clinical management. Although a few studies found that the PC sized 7F to 10F can be an effective therapeutic option,[35] with a success rate of 68.6% and no major complications,[36] studies comparing the effectiveness of PC vs LBCT are lacking. Furthermore, the efficacy of PC drainage vs LBCT for barotraumatic pneumothorax remains unclear.

## Conclusions

To our knowledge, this study is the first meta-analysis and systematic review comparing PC and LBCT drainage as the initial management strategy for the first episode of pneumothorax. We found that for spontaneous pneumothorax, the drainage duration and hospital stay are shorter in the PC group. Furthermore, for secondary spontaneous pneumothorax, the complication rate is significantly lower in the PC group. Collectively, results of the meta-analysis suggest that the PC drainage may be considered as the initial treatment option for patients with primary or secondary spontaneous pneumothorax. Given the paucity of data on utility of PC vs LBCT in patents of traumatic and iatrogenic pneumothorax, as well as the lack of data in this meta-analysis for patients who are being mechanically ventilated, the findings should be interpreted cautiously. Additional studies, ideally multicenter RCTs, are needed to examine the comparative utility of small-bore vs LBCT among different subgroups of patients with pneumothorax, which may ultimately improve clinical care and management for these patients.

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