Original Article

Chest tube drainage versus needle aspiration for primary spontaneous pneumothorax: which is better?

Chengdi Wang[1*], Mengyuan Lyu[2*], Jian Zhou[3], Yang Liu[4], Yulin Ji[1]

[1]Department of Respiratory and Critical Care Medicine, [2]Department of Laboratory Medicine, [3]Department of Thoracic Surgery, [4]Department of Vascular Surgery, West China Medical School/West China Hospital, Sichuan University, Chengdu 610041, China

Contributions: (I) Conception and design: C Wang, M Lyu, Y Ji; (II) Administrative support: Y Ji; (III) Provision of study materials or patients: C Wang, M Lyu; (IV) Collection and assembly of data: J Zhou, Y Liu; (V) Data analysis and interpretation: M Lyu, J Zhou; (VI) Manuscript writing and revision: All authors; (VII) Final approval of manuscript: All authors.

*These authors contributed equally to this work.

Correspondence to: Yulin Ji. No. 37, Guoxue Alley, Chengdu 610041, China. Email: jiyulinscu@sina.cn.

Background: Needle aspiration and chest tube drainages are two main treatments for primary spontaneous pneumothorax (PSP). However, the application of needle aspiration or chest tube drainages has not reached a consensus. The aim of this study is to compare the needle aspiration with chest tube drainages in patients suffering with PSP and therefore help offer suggestions for clinical practice.

Methods: We searched literatures from PubMed, OVID and Web of Science from their inception to June 30, 2017. Continuous and dichotomous outcomes were expressed by weight mean difference (WMD) and risk ratio (RR) respectively, and each with 95% confidence intervals (CIs). We used the fixed effect or random effect model to perform quantitative synthesis.

Results: A total of 6 RCTs recruiting 458 participants were included in our analysis. On the basis of the six studies, our results indicated that compared with chest tube drainage applying needle aspiration shortened the hospital stay (WMD: −1.67 days; 95% CI: −2.25 to 1.08; P<0.001) and decreased hospitalization rate (RR: 0.40; 95% CI: 0.22–0.75; P=0.004). However, there was no difference regarding immediate success rate (RR: 1.01; 95% CI: 0.70–1.46; P=0.96) and one-year recurrence rate (RR: 0.89; 95% CI: 0.58–1.38; P=0.61).

Conclusions: In the light of this present research, it is necessary to apply needle aspiration into treating PSP to reduce hospitalization rate and shorten hospital stay. However, the two treatments have no significant difference with respect to immediate success rate, one-year recurrence rate, one-week success rate, three-month recurrence rate or complication rate.

Keywords: Spontaneous pneumothorax (SP); chest tube drainage; needle aspiration

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Introduction

Spontaneous pneumothorax (SP) is a worldwide health problem (1,2). The overall hospital admission rates for SP in the UK have been reported as 16.7/100,000 for men and 5.8/100,000 for women, with corresponding mortality rates of 1.26/million and 0.62/million per year between 1991 and 1995 (3). Pneumothorax is defined as the presence of air in the pleural cavity, between the lung and the chest wall (4,5) and is classified as spontaneous, traumatic, and iatrogenic pneumothorax (6). Spontaneous pneumothorax can also be classified as primary spontaneous pneumothorax (PSP) and secondary spontaneous pneumothorax (SSP) (7). PSP develops usually following bullae ruptures without any underlying pulmonary diseases, while secondary pneumothorax is usually caused by rupture of damaged lung tissue, and appears primarily in patients diagnosed with pulmonary disease, such as pulmonary emphysema (8).

Current treatments for pneumothorax include needle aspiration (9-11), chest tube drainage (12,13), video-assisted thoracic surgery (VATS) (14,15) and open surgical interventions (16,17). The needle aspiration could reduce the excessive air directly with a syringe through a needle, usually performed through the second or third intercostal space in the midclavicular line (10,18). Clinically, when aspiration is unsuccessful, patients will be managed with chest tube drainage (19), which uses negative pressure to reduce excessive air. The chest tube drainage is usually placed in the anterior pleural space passing through the sixth intercostal space into the pleural opening, turned anteriorly and directed to the specific position of the pneumothorax, and then connected to a Heimlich valve or an underwater seal with or without continuous suction (20,21). However, there has been a great controversy regarding the choice of treatments (22). The American College of Chest Physicians guidelines indicated that needle aspiration was to be rarely appropriate in any clinical circumstances (23). In contrast, the current British Thoracic Society (BTS) guidelines for the management of pneumothorax recommended simple aspiration as first-line treatment for all primary pneumothorax cases requiring intervention or therapy (24). Up to date, several researches have discussed this controversial problem but failed to reach definite consensus. Thus, it is meaningful to carry out this analysis and help present suggestions for clinical practice.

Methods

Search strategy

We searched studies in the PubMed, OVID and Web of Science from their inception to June 30, 2017 with the following terms: pneumothorax and chest tube, tube, chest drainage, drainage system, drainage, chest-tube, chest tubes or catheter and aspiration. The language was only restricted to English. And the references of relevant studies were also searched manually to identify potential eligible trials.

Inclusion and exclusion criteria

Included studies needed to: (I) be randomized controlled trails (RCTs); (II) research on patients suffering with PSP; (III) apply two different methods—needle aspiration and chest tube drainage independently.

Once the studies met one of the following criteria, they were excluded: (I) reviews, letters, animal experiments, conference abstracts and case reports; (II) patients had SSP or other underlying lung diseases; (III) the paper was not presented with English; (IV) some essential basic information was incomplete. Eligible studies were evaluated and identified by two independent reviewers according to the inclusion and exclusion criteria. Any disagreement was resolved carefully through discussion, and if necessary, the third researcher would adjudicate.

Quality assessment

Quality assessment is necessary for the eligible articles to ensure the accuracy of this analysis. With the guidance of the Cochrane Handbook for Systemic Reviews of Interventions, two independent investigators evaluated the risk of bias of including studies. Any difference was discussed carefully. The contents for evaluating the risk of bias including sequence generation and concealment of allocation (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessors (detection bias), incomplete outcome data addressed (attrition bias), free of selective reporting (reporting bias) and other bias.

Data extraction and management

Two authors independently extracted some data from eligible studies preliminarily, and any disagreement was solved with further discussion. The compared data included hospital stay, immediate success rate, one-year recurrence rate, hospitalization rate, complications rate, time of recurrence weeks and so on. While the basic data comprised the first author, publication year, countries, enrolled year, inclusion and exclusion criteria, sample size, chest tube drainage type, removal criteria, etc.

Statistical analysis

The risk ratio (RR) and weight mean difference (WMD) were measured to presented dichotomous and continuous outcomes, respectively. Meanwhile we calculated p value and 95% confidence intervals (CIs). If the P value <0.05, the results indicated statistical significance. Concerning the heterogeneity of these included studies, the Cochran's Q statistic and I^2 statistics were performed. When I^2>50%, we would choose random effect model in our analysis, otherwise fixed effect model. Furthermore, we performed the subgroup analysis to identify and explain the potential heterogeneity. We assessed publication bias by observing

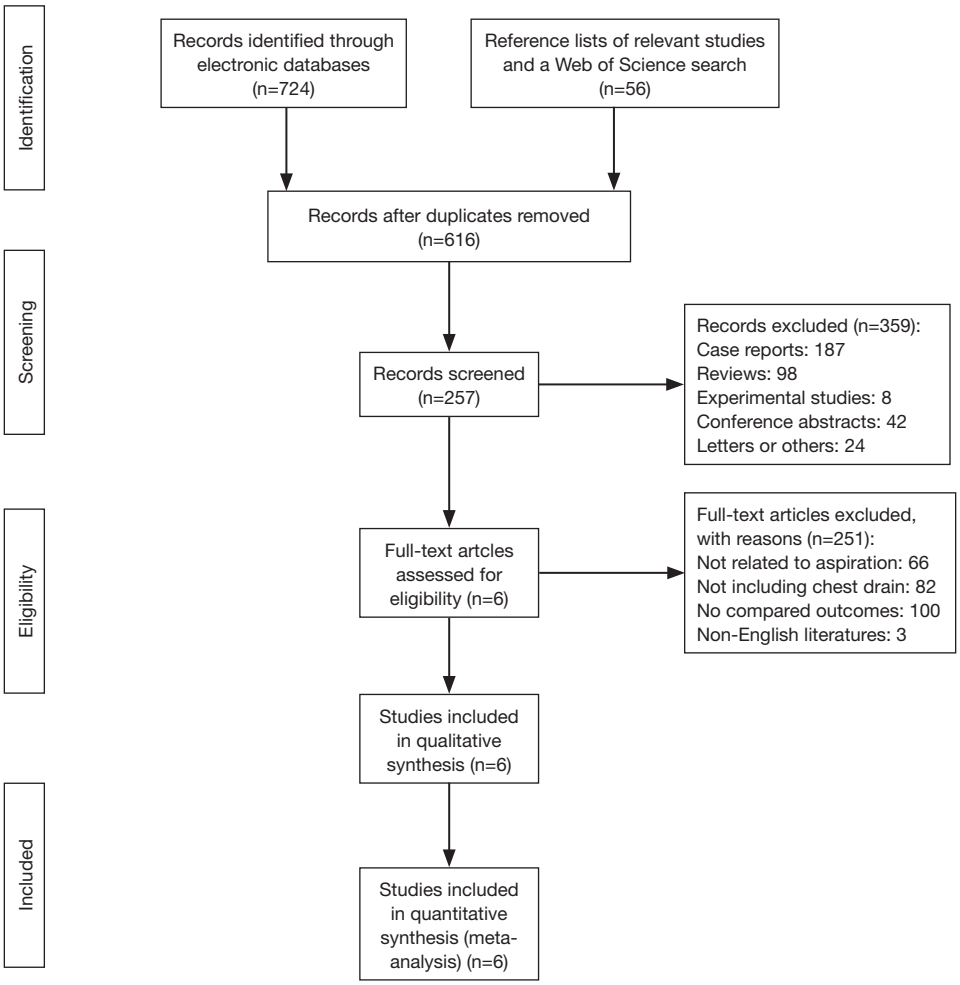

Figure 1 The PRISMA flow diagram of literature retrieval.

the funnel plots and performing Begg's test. We also performed sensitivity analysis to remove some low quality studies and repeated pooled analysis to ensure the accuracy of our analysis. All statistical analysis was performed by Review Manager V.5.3 (The Cochrane Collaboration, Software Update, Oxford, UK).

Results

Studies characteristics

A total of 780 articles were retrieved after literature search, and finally only 6 studies (25-30) enrolling 458 participants met our criteria. The included trials were published online between 1994 and 2017. The sample size of eligible studies ranged from 48 to 137 and the ethnicity included Asian and Caucasian. The reported types of needle aspiration included 16F, 18F, 16G, 16-18G, and 12F, 16F, 20F and 28F were the major types of chest tube drainages. All the recruited patients suffered from PSP. The mean age of the participants applied with needle aspiration ranged from 24.38 to 40.5, while the mean age of patients with chest tube drainages ranged from 23.5 to 40.9. The outcomes of the included studies were presented with hospital stay, immediate success rate, one-year recurrence rate, hospitalization rate complications rate, etc.

The PRISMA flow diagram of literature retrieval is shown in *Figure 1*. The main characteristics of the included randomized controlled trials are presented in *Table 1*.

Risk of bias

Two independent investigators evaluated the risk of bias of

Table 1 Main characteristics of the included randomized controlled trials

Study	Sample	Country	Enrolled year	Pneumothorax	A. type	C. type	A. age, mean (SD)	C. age, mean (SD)	A. group	C. group
Andrivet 1995	61	France	NA	SP	16F,18F	20F	32.0 (16.0)	33.0 (13.0)	33	28
Ayed 2006	137	Kuwait.	2001–2003	PSP	16G	20F	24.4 (4.4)	23.5 (4.8)	65	72
Harvey 1994	73	Britain	NA	SP	16–18G	NA	34.6 (15.0)	34.6 (13.1)	35	38
Ho 2011	48	Singapore	2004–2006	PSP	16G	12F	26.0 (8.6)	24.3 (6.1)	23	25
Noppen 2002	60	Belgium	NA	PSP	16G	16,20F	28.2 (11.6)	28.9 (8.9)	27	33
Thelle 2017	79	Norwegian	NA	PSP	16G	12–28F	40.5 (21.5)	40.9 (19.5)	42	37

A, aspiration; C, chest drains; NA, unavailable; SP, spontaneous pneumothorax; PSP, primary spontaneous pneumothorax.

Table 2 Risk of bias assessment

Study	Sequence generation	Concealment of allocation	Blinding of participants and personnel	Blinding of outcome assessors	Incomplete outcome data addressed	Free of selective reporting	Other bias
Andrivet 1995	Unclear	Unclear	Low	Low	Low	Low	Low
Ayed 2006	Low	Low	Low	Low	Low	Low	Low
Harvey 1994	High	Unclear	Low	Low	Unclear	Low	Low
Ho 2011	Low	Low	Low	Low	Low	Low	Low
Noppen 2002	Low	Low	Low	Low	Low	Low	Low
Thelle 2017	Low	Low	Low	Low	Low	Low	Low

the included studies. Andrivet [1995] had unclear risk of bias for sequence generation, concealment of allocation and low risk of bias for blinding of participants, personnel and outcome assessors, incomplete outcome data addressed, free of selective reporting and other bias. Ayed [2006], Noppen [2002] and Ho [2011] had low risk of bias for all aspects of bias we assessed. In terms of concealment of allocation, Andrivet [1995] and Harvey [1994] had unclear risk of bias. In our assessment, Harvey [1994] showed high risk of bias for sequence generation and unclear risk of bias for concealment of allocation and incomplete outcome data addressed. The graph of the risk of bias of the included studies is shown in *Table 2*, *Figures 2*,*3*.

Hospital stay

In six studies included, 225 participants were treated with needle aspiration compared with 233 to chest tube drainage. Five studies including 410 participants mentioned the hospital stay except Ho's research [2011]. With our analysis, we concluded that needle aspiration significantly shortened the hospital stay (WMD: –1.67 days; 95% CI: –2.25 to 1.08; P<0.001) (*Figure 4*). As for the heterogeneity, we confirmed low heterogeneity with I^2=0%. And there were no significant discoveries in the subgroup analysis for limited studies and low heterogeneity.

Immediate success rate

Four studies including 337 patients measured the immediate success rate. In our analysis, no significant difference were found between needle aspiration treatment and chest tube drainage (RR: 1.01; 95% CI: 0.70–1.46; P=0.96) (*Figure 5*). The same as the hospital stay, there were no significant findings in the subgroup analysis.

One-year recurrence rate

There were no significant difference regarding one-year recurrence rate between the patients applied with needle aspiration and chest tube drainage (RR: 0.89; 95% CI: 0.58–1.38; P=0.61)with analysis of three trials enrolling

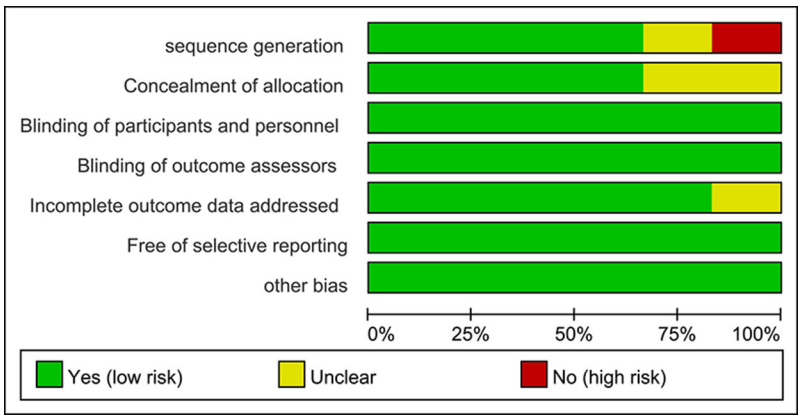

Figure 2 Graph of the risk of bias for the included studies.

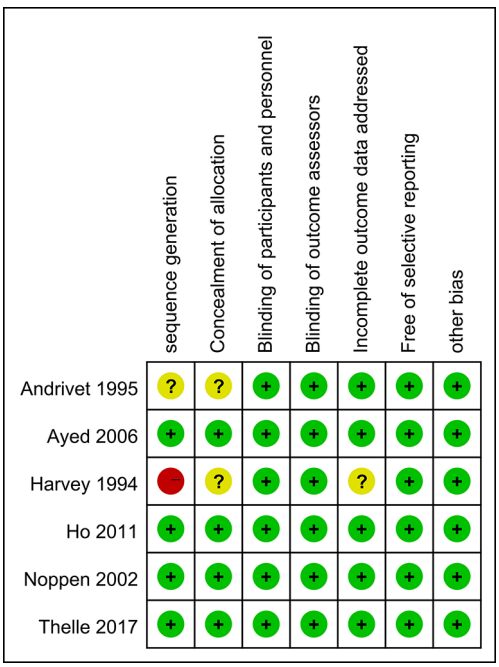

Figure 3 Graph of the risk of bias summary for the included studies.

262 patients (*Figure 6*). Low heterogeneity (I^2=0%) was identified. And subgroup analysis didn't get any meaningful findings.

Hospitalization rate

On the basis of 3 eligible trails included 245 subjects in total, we found needle aspiration group had lower hospitalization rate compared with chest tube drainage group (RR: 0.40; 95% CI: 0.22–0.75; P=0.004) (*Figure 7*).

Other parameters

To perform more comprehensive comparisons between the needle aspiration and chest tube drainage, we paid attention to the following parameters: one-week success rate, three-month recurrence rate, time of recurrence weeks, complications rate, the immediate complete retraction rate and total pain score. However, no significant difference was found. All of the main results of our analysis are shown in *Table 3*.

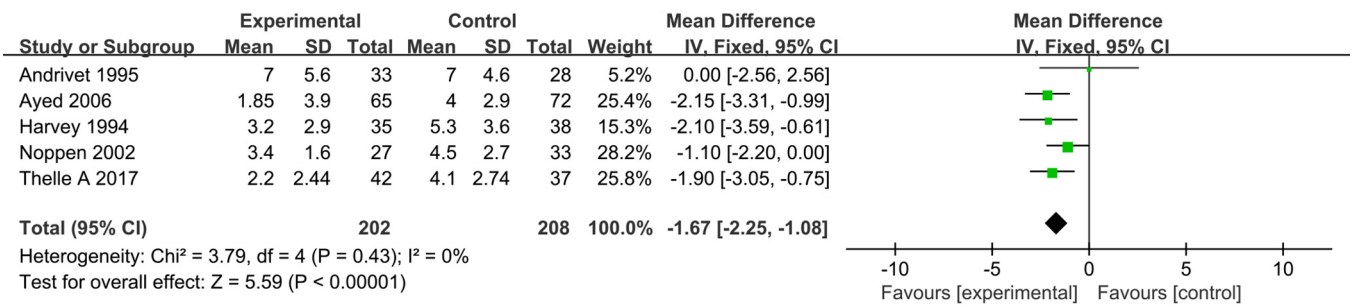

Figure 4 Meta-analysis of the effect of chest tube drainage or needle aspiration for primary spontaneous pneumothorax on hospital stay (WMD).

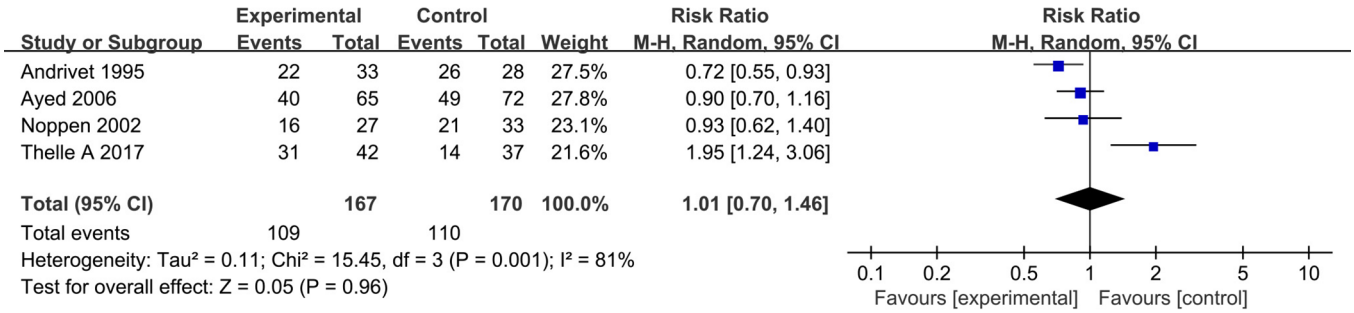

Figure 5 Meta-analysis of the effect of chest tube drainage or needle aspiration for primary spontaneous pneumothorax on immediate success rate (RR).

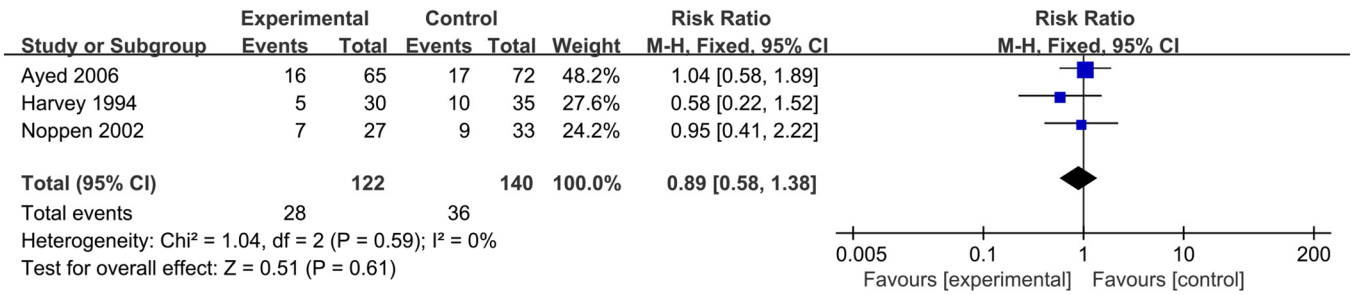

Figure 6 Meta-analysis of the effect of chest tube drainage or needle aspiration on one-year occurrence rate (RR).

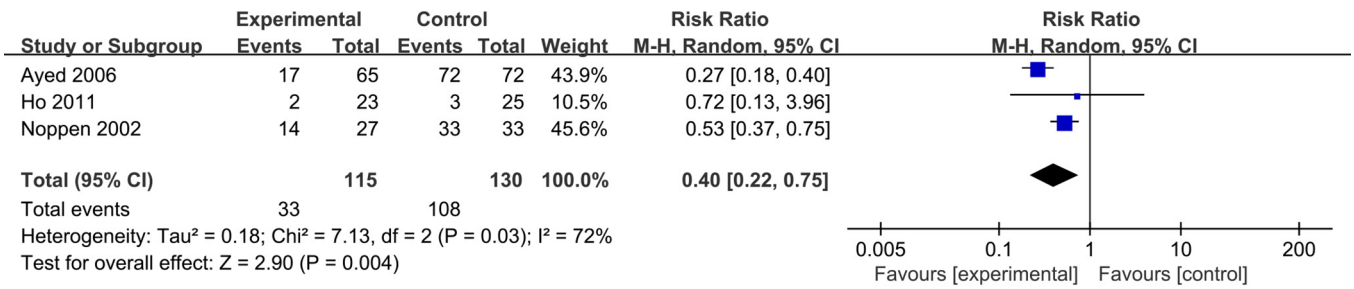

Figure 7 Meta-analysis of the effect of chest tube drainage or needle aspiration on hospitalization rate (RR).

Sensitivity analysis and publication bias

To discover potential heterogeneity, we performed sensitivity analysis. Through the symmetrical forest plots, we didn't find any potential and significant heterogeneity. Thus, it was not necessary to leave some low quality studies and repeat analysis of the remaining studies. Furthermore, no significant publication bias was identified by observing the funnel plots and performing Begg's test.

Discussion

We performed this present analysis to further assess the effects of needle aspiration and chest tube drainage on PSP patients. Compared with chest tube drainage, needle aspiration decreased hospital stay and hospitalization rate as the treatments for PSP. However, there was no statistical significance concerning immediate success rate, one-year recurrence rate, one-week success rate, three-month recurrence rate, time of recurrence weeks, complications rate, immediate complete retraction rate or total pain score.

Clinically, we usually used the hospital stay to evaluate the efficacy of specific therapies, which were related with cost and hospital performance (31,32). Through analyses based on six studies, we concluded that needle aspiration

Table 3 Main results of our analysis

Outcomes	No. studies	No. participants	Results				Heterogeneity		
			WMD/RR	95% CI		P	I^2	pH	Model
Hospital stay	5	410	WMD –1.67	–2.25	–1.08	<0.001	0%	0.43	Fixed
Ethnicity									
Caucasian	5	410	WMD –1.67	–2.25	–1.08	<0.001	0%	0.43	Fixed
A type									
<8F	4	349	WMD –1.76	–2.36	–1.16	<0.001	0%	0.56	Fixed
C type									
>16F	2	198	WMD –1.39	–3.40	0.62	0.18	56%	0.13	Fixed
NA	3	212	WMD –1.62	–2.32	–0.92	<0.001	0%	0.48	Fixed
Immediate success rate	4	337	RR 1.01	0.70	1.46	0.96	81%	0.001	Random
Ethnicity									
Caucasian	4	337	RR 1.01	0.70	1.46	0.96	81%	0.001	Random
A type									
<8F	3	276	RR 1.15	0.73	1.81	0.54	78%	0.01	Random
C type									
>16F	2	198	RR 0.81	0.64	1.02	0.07	40%	0.2	Fixed
NA	2	139	RR 1.34	0.64	2.79	0.44	83%	0.02	Random
One-year recurrence rate	3	262	RR 0.89	0.58	1.38	0.61	0%	0.59	Fixed
Ethnicity									
Caucasian	3	262	RR 0.89	0.58	1.38	0.61	0%	0.59	Fixed
A type									
<8F	3	262	RR 0.89	0.58	1.38	0.61	0%	0.59	Fixed
C type									
NA	2	125	RR 0.75	0.4	1.42	0.38	0%	0.45	Fixed
Hospitalization rate	3	245	RR 0.40	0.22	0.75	0.004	72%	0.03	Random
Ethnicity									
Caucasian	2	197	RR 0.38	0.19	0.76	0.006	85%	0.009	Random
A type									
<8F	3	245	RR 0.40	0.22	0.75	0.004	72%	0.03	Random
Other parameters									
One-week success rate	3	276	RR 1.05	0.96	1.16	0.26	0%	0.76	Fixed
Three-month recurrence rate	2	190	RR 1.19	0.62	2.3	0.6	49%	0.16	Fixed
Time of recurrence weeks	2	197	WMD 0.56	–6.27	7.38	0.87	85%	0.009	Random
Complications rate	2	185	RR 0.66	0.07	6.24	0.72	51%	0.15	Random
Immediate complete retraction rate	2	109	RR 1.45	0.87	2.42	0.15	0%	0.66	Fixed
Total pain score	2	121	WMD –1.96	–5.88	1.96	0.33	94%	<0.001	Random

A, aspiration; C, chest drains; NA, unavailable; RR, risk ratio; WMD, weighted mean difference; CI, confidence interval; P, P value of overall effect; p. H, P value of heterogeneity.

reduced the hospital stay significantly. However, this conclusion was still controversial. Andrivet (25) found that there were no significant difference between patients allocated to needle aspiration and chest tube drainage. The size of sample and weakness of methodology might be the influence factors. To identify and assess the potential heterogeneity of included studies, we performed subgroup analysis according to the ethnicity, the catheter's types of needle aspiration and chest tube drainage. However, no significant and valuable difference were found.

Different studies had different definitions of immediate success rate, which was an essential parameter to evaluate the quality of therapy. Aye and his colleagues (26) defined it as complete or nearly complete lung expansion immediately after the procedure of needle aspiration and absence of air leak, complete lung expansion, and tube removal within 3 days after insertion of chest tube. However, it was defined as complete lung expansion immediately after 24 hours for needle aspiration, while complete lung expansion, absence of air leak, and chest tube removal within 3 days of insertion for chest tube in the Parlak *et al.'s* research (33). Our result showed no significant difference between the two groups, and this pooled outcome was consistent with Kaneda *et al.'s* report(7).

Recurrence was relevant to long-term survival quality and associated with treatment efficacy (34). For our research, we used one-year recurrence rate to evaluate the effects of needle aspiration and chest tube drainage with no significant difference found between the two groups.

The severity of pneumothorax decided whether to be hospitalized (35). When pneumothorax became pretty serious, it would require hospitalization to intervene. And hospitalization rate was always measured to assess the severity of diseases (36). It revealed that using needle aspiration had lower hospitalization rate than chest tube drainage for the patients suffering from PSP with analysis of the 3 included studies. Among the three articles, Ho *et al.* (28) held the contrary opinion that there was no statistically significant difference between two treatments. We found the participants in this trial were Asian, while the others were Caucasian. However, no significant difference was found in subgroup analysis. In addition, the enrolled samples were pretty small compared to others. These two different aspects might affect the final results.

As a clinical technique, needle aspiration was simple, effective, and acceptable to patients (37,38). Irrespective of the size of pneumothorax, number of previous episodes, or whether the current condition was considered primary or secondary, needle aspiration would be recommended as an initial treatment for all spontaneous pneumothorax when intervention was necessary (39,40). It had been used widely with its characteristics of easy operation, safety and less pain (41,42). However the issue whether to apply needle aspiration for PSP had still remained controversial after consulting existing literatures. According to the current BTS guidelines, a flow chart for the treatment of PSP where "small" and "large" pneumothorax was classified based on the horizontal distance <2 or >2 cm between the chest wall and the side margin of the collapsed lung, respectively (43). And in the BTS guidelines updated in 2010, it suggested that the choice of a 2 cm distance was made at the level of the hilum to measure the ratio of the lung to the hemithorax diameter (3). Needle aspiration was shown to be associated with reduced hospitalization rate and length of hospital stay (3). This was in agreement with the Australian guidelines (44). Furthermore, Nishiuma and his colleagues (45) held the view that needle aspiration should be considered as the first choice in the management of mild and moderate PSP ("mild" was defined as the pneumothorax cranial to the level of collarbone area; "moderate" referred to intermediate between mild and severe pneumothorax; and "severe" was defined as the pneumothorax with completely collapsed lung), opposite to the view of Kuester (46). Low success rate of needle aspiration was the shortcoming pointed out most frequently. For example, Courtney and his colleagues (47), who researched on the management of spontaneous pneumothorax in a hospital in Northern Ireland from 1994 to 1996, reported a low success rate of aspiration for pneumothorax with only 2 of 7 cases succeeded. Based on further analysis, we pointed out several possible reasons to explain the lower success rate of needle aspiration, one of which might be the technological level directly associated with operation success. Different procedures were performed to treat spontaneous pneumothorax by different doctors, which would impact the prognosis. Besides, patients were various in the severity of pneumothorax. Different severity of pneumothorax also affected the success rate. Furthermore, we thought some factors such as individual physique, postoperative nursing level and the kind of instruments applied might also influence success rate.

Chest tube drainage referred to the placements of one or more intercostal drainage tubes connected to water seal system or suction system, which yielded maintenance until air leak disappeared and the chest X-ray showed complete lung expansion (48). Generally speaking, chest tube drainages were usually applied for patients suffering

from pneumothorax who should be admitted to hospital following the failure of needle aspiration (3). And other indications for chest tube drainage included hemothorax (49,50), pleural effusion (51-53), pleural empyema (54,55), and major thoracic surgery (56-58). The approaches to insert chest tube drainage into body parts include axillary or anterior approach. Some studies had showed that axillary approach was the most favorable and effective approach, and the success rates could reach 66–97% (26,59). However, no definite consensus on insertion methods had been reached. Chest tubes were generally divided into different types according to its sizes, such as small-bore (<14F), large-bore (>20F) (3) and other sizes, which was associated with the extent of the pain. The pain brought by chest tube drainage was reckoned the biggest weakness and most of the patients experienced short-lasting but intense pain when the chest tube drainage was removed (60). Some trials found small-bore chest tube drainages had the similar success rate to larger drainage but being less painful (61). To manage the inevitable pain, one of the most common complications of chest tube drainage insertion, we needed more details to notice and perform. Nevertheless, there was no denying that chest tube drainage still played an important role in the treatment of spontaneous pneumothorax.

To the best of our knowledge, there has been several meta-analyses to focusing on the comparison of aspiration and chest tube drainage of pneumothorax. However, they haven't reached a definite consensus yet. Compared with preexisting articles, the advantages of our research are as follows. Firstly, we enrolled more RCTs with larger samples to reach a relatively convinced conclusion. Kaneda (7) performed a meta-analysis in 2013, but they only researched on four trials enrolling 331 patients regarding three parameters, and they didn't perform any subgroup analyses, sensitivity analyses or assessments of quality. While Zehtabchi *et al.* (18) only recruited three RCTs with 270 patients in total. Secondly, we performed strict inclusion and exclusion criteria. Kim *et al.'s* research (62), which published in 2017, didn't differentiate PSP and SSP without any subgroup analyses. While we researched on PSP but SSP, and included one recent study published in this year. Thirdly, the ethnicity of our included studies comprised Caucasian and Asian, and we made further subgroup analysis aimed to find potential difference. However, the previous articles only enrolled Caucasian except Sun' study (63) which was written by Chinese. Finally, we measured more parameters including one-week success rate, one-year recurrence rate, time of recurrence weeks, etc. Further analyses with respect to more outcomes would be beneficial to giving more comprehensive and possible recommendations for clinic practice.

In general, this analysis included as many RCTs as possible in order to make reliable conclusions. More importantly, we performed further subgroup analyses so that we could identify and solve some potential problems. In addition, we referred to amount of literatures to discuss some current controversies. We made a brief review about the two kinds of treatments, analyzed possible causes about the controversy and put forward the viewpoints carefully based on previous systematical analysis. However, some limitations still existed: (I) incomplete information. Some authors didn't report some essential information, such as the inclusion and exclusion criteria, randomization methods. Only limited articles could be used for some parameters; (II) the heterogeneity among included studies. We noticed that some included studies mentioned only first episode of pneumothorax, while others allowed recurrence. It is impossible to differentiate between these in the results, and we think it could be acceptable in this meta-analysis. And we assessed the risk of bias of each eligible studies, and found 4 of 7 studies reported unclear risk of concealment of allocation. But all the heterogeneity tests for each analysis were well accepted. And no significant results were found in subgroup analysis; (III) limited studies. Six studies with 458 participants in total were included in our analysis, however, only 2 studies with 109 patients were eligible for our analysis about immediate complete retraction rate. Thus, the limited sample might have effects on the final outcomes, and more large-sample RCTs are warranted.

Conclusions

In the light of this present research, it is necessary to apply needle aspiration to treat PSP for reducing hospitalization rate and hospital stay. However, the two treatments have no significant difference with respect to immediate success rate, one-year recurrence rate, one-week success rate, three-month recurrence rate and complication rate.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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