Management of primary spontaneous pneumothorax in Chinese children

CME

Lilian PY Lee 李寶儀
Miranda HY Lai 黎曉欣
WK Chiu 趙華強
Michael WY Leung 梁偉業
Kelvin KW Liu 廖鑑榮
HB Chan 陳衍標

Objectives To (1) determine the demographics of Chinese children admitted with primary spontaneous pneumothorax, (2) suggest how they may be quantified radiologically, (3) compare the difference in outcomes after their primary management by thoracentesis and chest tube insertion, and (4) review the local experience with surgical intervention for such children.

Design Retrospective, descriptive study.

Setting Acute tertiary public hospital, Hong Kong.

Patients Consecutive patients younger than 18 years and admitted with primary spontaneous pneumothorax between 1 January 1999 and 30 September 2007.

Main outcome measures Hospital stay and risk of recurrence after thoracentesis versus chest tube insertion.

Results Seventy-seven patients with 114 episodes of primary spontaneous pneumothorax were reviewed. They were significantly taller ($P<0.001$) and thinner ($P<0.001$) than the population mean percentile. Both the Light index and Collins formula were accurate in quantifying pneumothorax volume, but as the former was simpler and more user-friendly, this was more applicable in children. Thoracentesis resulted in shorter hospital stays (mean, 4.6; standard deviation, 1.9 days) than chest tube insertion (6.9; 3.0 days), but there was no significant difference in the recurrence rates within 6 months ($P=1.0$), 1 year ($P=0.9$), and 2 years ($P=0.1$). Insignificant pneumothorax was treated with observation alone in 16% of the patients. For patients with a clinically significant pneumothorax, thoracentesis and chest tube insertion were successful in 78% and 67%, respectively ($P=0.34$). The success rate of video-assisted thoracoscopic surgery was 89%, and postoperative recurrence occurred more commonly in patients without a lung bleb.

Conclusion Chinese children with primary spontaneous pneumothorax exhibited similar demographic characteristics to Caucasian children. Light index is simple and accurate for quantifying pneumothorax volume in children. Conservative treatment including observation, thoracentesis, and chest tube insertion should suffice for most patients with first episode of primary spontaneous pneumothorax. Early surgery is warranted for any patient who fails conservative treatment, for which video-assisted thoracoscopic surgery is safe and effective.

Key words
Chest tubes; Child; Pneumothorax; Recurrence; Treatment outcome

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United Christian Hospital, Kwun Tong, Hong Kong:
Department of Paediatrics and Adolescent Medicine
LPY Lee, FHKCPaed, FHKAM (Paediatrics)
WK Chiu, FHKCPaed, FHKAM (Paediatrics)
HB Chan, FRCPCH, FHKAM (Paediatrics)
Department of Radiology and Organ Imaging
MHY Lai, MB, ChB, FRCR
Division of Paediatric Surgery, Department of Surgery
KKW Liu, FHKAM (Surgery), FRCS
Division of Paediatric Surgery, Department of Surgery, Queen Elizabeth Hospital, Hong Kong
MWY Leung, FHKAM (Surgery), FRCS

Correspondence to: Dr LPY Lee
Email: leepyl@ha.org.hk

Introduction

Primary spontaneous pneumothorax (PSP) occurs in healthy people without clinically apparent lung disease.[1] It may result in absence from school, hospital admission, and significant morbidity. While the treatments vary, accurate quantification of its size is important because it helps determine treatment.[2] For PSPs that are small and clinically asymptomatic, conservative treatment by observation alone is accepted. For larger PSPs, both thoracentesis and chest tube insertion are established treatment modalities, though which is the better option remains unclear. In view of uncertainties in diagnosis and treatment, we therefore conducted this review in corresponding Chinese patients to: (1) determine their demographics, (2) compare different radiological methods for quantifying pneumothorax volume, (3) compare the difference in outcomes after thoracentesis versus chest tube insertion, and (4) provide recommendations for PSP treatment.

Methods

Patient selection

Patients were recruited from the United Christian Hospital, a 1400-bed acute tertiary public hospital in Hong Kong serving a regional population of 900 000 inhabitants. Consecutive patients younger than 18 years and admitted with PSP during the period from 1 January 1999 to 30 September 2007 were included. Those with secondary spontaneous pneumothorax (due to pre-existing lung diseases, traumatic and iatrogenic factors) were excluded.

Data collection

Medical records were retrieved by the Clinical Data Analysis and Reporting System using the ninth revision of the International Classification of Diseases, Clinical Modification codes: 512.8 for spontaneous pneumothorax, and 512.0 for spontaneous tension pneumothorax. Data abstracted included patient demographics, presenting symptoms, treatment modalities on admission, volume of air aspirated, length of hospital stay, episodes of recurrence, indications for surgery, and final outcome. The patients were contacted by phone and their electronic patient record was accessed from the Clinical Management System to retrieve information on any subsequent episodes and/or surgery performed in other hospitals.

Quantification of size of pneumothorax

Chest X-rays on admission were retrieved and were all commented by the same paediatric radiologist, who was blinded to all other clinical data. The size of the pneumothorax was quantified by two methods. The Light index (Box[3]) calculates the volume from cubes of the average lung diameter and the average hemithorax diameter. The Collins formula (Box[4]) derives the volume by summation of the interpleural distances measured at three locations, versus the pneumothorax size measured by helical computed tomography (CT). The amount of air aspirated (retrieved from each patient's medical record) was presumed to be the 'actual' volume of the pneumothorax.

Treatment protocol

The British Thoracic Society (BTS) Research Committee issued the first guideline concerning the treatment of PSP in 1993.[5] They reported that thoracentesis and chest tube drainage were equally successful in first and recurrent episodes of spontaneous pneumothorax.[5] Our department adopted the use of chest tube insertion as the initial treatment of PSP, unless the pneumothorax was just a 'small rim of air around the lung', for which observation was used.[5] Referral for surgery was made if the pneumothorax persisted for more than 3 days.

This BTS guideline was revised in 2003.[6] Thoracentesis was suggested as the first step in

華籍兒童原發自發性氣胸的治療方法

目的 找出華籍兒童原發自發性氣胸的人口學數據、提出利用影像學把數據數量化的方法、比較胸腔穿刺術和胸管置入術的治療結果、及回顧本地手術治療的經驗。

設計 回顧及描述性研究。

安排 香港一所公立急症醫院。

患者 1999年1月1日至2007年9月30日期間，所有18歲以下因原發自發性氣胸而入院的病人。

主要結果測量 胸腔穿刺術和胸管置入術後病人的住院期及復發風險。

結果 本文回顧77位病人共114個原發自發性氣胸的病發個案。與一般人口的平均百分比比較，病人明顯較高（P<0.001）及較瘦削（P<0.001）。Light index及Collins方程式皆能準確把氣胸體積數量化；而前者由於簡單及容易使用，因此對兒童較為適合。住院期方面，胸腔穿刺術病人平均4.6天（標準差1.9天），比胸管置入術病人（平均6.9天、標準差3.0天）為短；但兩者復發率在6個月（P=1.0）、1年（P=0.9）及2年（P=0.1）沒有顯著分別。16%為輕微原發自發性氣胸患者純粹作隨訪觀察。至於接受胸腔穿刺術和胸管置入術的較嚴重患者中，成功率分別為78%及67%（P=0.34）。影像胸腔鏡手術的成功率為89%。術後復發普遍發生在沒有肺氣泡的患者身上。

結論 華籍兒童原發自發性氣胸的人口學特徵與白人兒童相若。Light index使用簡單，並能準確地把兒童氣胸體積數量化。對於原發自發性氣胸的首發患者，保守療法如隨訪觀察、胸腔穿刺術和胸管置入術已足夠。假如保守療法不見成效，應盡早進行手術；而影像胸腔鏡是安全及有效的手術。

BOX.

Light index[3]

$Y = (A^3 - B^3)/A^3$

Percentage volume of a pneumothorax (Y) approximates to the ratio of the cube of the hemithorax diameter (A) to the collapsed lung diameter (B).

Collins formula[4]

$Y = 4.2 + [4.7 \times (A + B + C)]$

Y = percentage pneumothorax size

A = distance between lung apex and the uppermost point of the pleural cavity

B = distance between the midpoint of the upper half of collapsed lung to the hemithorax

C = distance between the midpoint of the lower half of collapsed lung to the hemithorax

TABLE 1. Body height, body weight, and body mass index of patients with primary spontaneous pneumothorax

Demographics (test value: 50th percentile)	Mean (%)	Standard deviation (%)	Mean difference (95% confidence interval)	P value
Mean height percentile	64	26	14 (8 to 20)	<0.001
Mean weight percentile	37	24	-13 (-19 to -8)	<0.001
Mean body mass index	30	23	-20 (-26 to -15)	<0.001

the management of PSP for patients who required intervention.[6] Since January 2005, our department adopted the 2003 guideline and managed all patients requiring intervention with thoracentesis. Significant pneumothorax was defined as the presence of a visible rim of more than 2 cm between the lung margin and the chest wall.[6] Thoracentesis was repeated for persistent significant air collection. A chest drain was inserted after failure of the second thoracentesis. Referral for surgery was mandated if the pneumothorax persisted for more than 3 days despite a chest drain.

Successful outcome was defined as sustained complete or near-complete re-expansion of the lung for at least 24 hours after treatment. All patients were followed up after discharge. The mean duration of follow-up was 4.2 years.

Statistical analysis

Patient demographic characteristics and progress summaries were compiled from descriptive data analysis. For analysing continuous variables, one- and two-sample *t* tests were used; whereas the Chi squared test was used to compare categorical data. Pearson correlation coefficients were computed for measuring the association between continuous variables.

This study was approved by our Institutional Review Board for research.

Results

Seventy-seven patients with 114 episodes of PSP were admitted between 1 January 1999 and 30 September 2007. The numbers of patients admitted before and after January 2005 (ie when the new BTS guideline was adopted) were 58 and 56, respectively. At the time of diagnosis, the mean patient age was 16 years (range, 14-18 years), the male-to-female ratio was 10:1, and 11 (14%) were smokers. Chest pain (n=113, 99%) with or without dyspnoea (n=31, 27%) was the most common presenting symptom. About two thirds (n=75, 66%) suffered a left-sided pneumothorax. Using the middle 50th percentile information and applying the one-sample *t* test, our patients were significantly taller (P<0.001) and thinner (P<0.001) than the population mean. Similarly, the body mass index was also significantly lower for the corresponding mean population percentile (P<0.001) [Table 1].

Of the 114 admissions of pneumothorax, 85 admission chest X-rays could be retrieved and analysed by the same paediatric radiologist. The size of the pneumothorax was quantified by both the Light index and the Collins formula, both correlated well with the actual volume; Pearson's correlation coefficients being 0.846 and 0.841, respectively (P<0.001).

Twelve (16%) of the patients with a clinically insignificant pneumothorax were treated by observation alone. Of the 65 patients not deemed suitable for observation, six (9%) had absolute indications for surgery (four had haemopneumothorax and two had tension pneumothorax). The remaining 59 patients were treated with either thoracentesis (n=23, 30%) or chest tube insertion (n=36, 47%), depending on whether the admission was after or before January 2005 (Fig).

All 12 patients treated by observation were successfully discharged within 7 days. In all, four patients had surgery; three had clinically significant recurrence with persistent air leak despite chest tube insertion, and one for bilateral apical bullae. Surgery was performed between 3 months and 3 years after the first occurrence of these children. The child with bilateral apical bullae was electively admitted for surgery 6 months after the first PSP.

Among the 23 patients having thoracentesis as the initial primary intervention, 18 were successfully treated. Significant recurrence occurred in four patients, who were treated with thoracentesis and chest tube insertion. The recurrences occurred between 19 days and 7 months after the first PSP. Two of these patients received surgery for persistent air leak, and two were successfully treated by thoracentesis (thus surgery having been refused by the parents). Five of the 23 patients required an additional chest drain after failure of primary thoracentesis. Three of these resolved successfully, whereas two with persistent air leaks underwent subsequent surgery.

For the 36 patients who primarily treated with chest tube insertion, 24 were successfully treated, but the remaining 12 underwent surgery for persistent air leak. Eleven of the 24 patients successfully treated with a primary chest drain had significant recurrences, with persistent air leak and surgery was performed subsequently. Nine patients experienced recurrences within 2 years of the first PSP and two after 4 years.

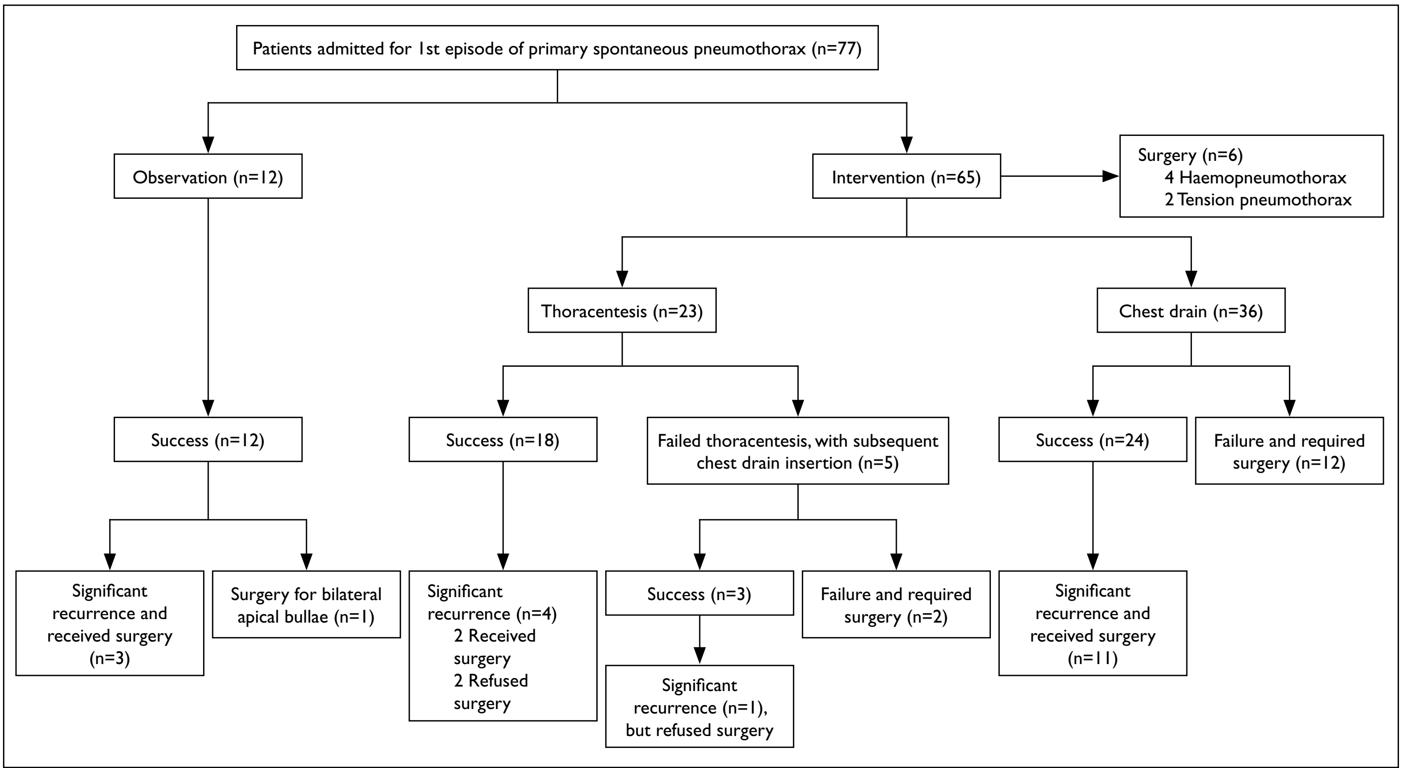

FIG. Flowchart showing outcomes of different treatment groups

The success rates of thoracentesis and chest tube insertion as primary treatments were 78% (18/23) and 67% (24/36), respectively (P=0.34), indicating comparable success rates with both interventions. The overall success rate of conservative treatment (including observation, thoracentesis, and chest tube insertion either alone or in combination) for the first episode of PSP was 80% (57/71).

The baseline characteristics of patients primarily treated with thoracentesis and chest tubes were comparable (Table 2). Corresponding outcomes including length of hospital stay, and recurrence within 6 months, 1 year, and 2 years are shown in Table 3. In our series, the length of hospital stay was significantly shorter in the thoracentesis group (P=0.006). The overall recurrence rate after successful primary conservative treatment was 27% (16/59). As shown in Table 3, there was no statistically significant difference in recurrence rates between the two groups at 6 months, 1 year, and 2 years, indicating that thoracentesis as the initial intervention was not associated with a higher recurrence rate.

A total of 37 patients underwent surgery because of persistent air leak (despite chest drain), haemopneumothorax, tension pneumothorax, and bilateral pneumothorax. Apical pleurodesis or pleurectomy with or without bullectomy via video-assisted thoracoscopic surgery (VATS) was the procedure used in our unit (Table 4).

TABLE 2. Baseline characteristics of patients with primary spontaneous pneumothorax having thoracentesis and chest drains

Characteristic	Thoracentesis (n=18)	Chest drain (n=24)	P value
Sex			0.074
Female	4 (22%)	1 (4%)	
Male	14 (78%)	23 (96%)	
Mean (SD*) age (years)	16 (1)	16 (1)	0.263
Mean (SD) body height (cm)	169 (7)	173 (6)	0.112
Mean (SD) body weight (kg)	52 (6)	52 (5)	0.898
Mean (SD) body mass index (kg/m^2)	18 (2)	17 (2)	0.209
Light index ≤50%†	7 (39%)	8 (33%)	0.710

* SD denotes standard deviation

† Owing to missing chest X-ray, the number of chest X-rays retrieved and analysed was 17 and 15 for the thoracentesis group and chest drain group, respectively

TABLE 3. Outcomes of patients primarily treated by thoracentesis and chest drains

Outcomes	Thoracentesis (n=18)	Chest drain (n=24)	P value
Mean (SD*) length of hospital stay (days)	4.6 (1.9)	6.9 (3.0)	0.006
Recurrence in 6 months	3 (17%)	4 (17%)	1.000
Recurrence in 1 year	4 (22%)	5 (21%)	0.914
Recurrence in 2 years	4 (22%)	11 (46%)	0.114

* SD denotes standard deviation

Bleb(s) was/were found in 70% (26/37) of the patients. Four patients had postoperative recurrence,

TABLE 4. Indications for surgery following primary spontaneous pneumothorax

Indications for surgery	No. of patients (n=37)
Persistent air leak	30 (81%)
Haemopneumothorax	4 (11%)
Tension pneumothorax	2 (5%)
Bilateral pneumothorax	1 (3%)

TABLE 5. Patient numbers with pathologically confirmed bleb and postoperative recurrence

Postoperative recurrence	With bleb (n=26)	Without bleb (n=11)	Total (n=37)
Yes*	1 (4%)	3 (27%)	4 (11%)
No	25 (96%)	8 (73%)	33 (89%)

* P=0.036

giving a success rate of 89% (33/37). Among the latter, one was found to have another upper lobe bleb on the ipsilateral side 2 years after surgery. This patient was treated by bullectomy with extensive mechanical and chemical pleurodesis. In the remaining three patients, no bleb was found during the second surgery, all of whom were treated by extensive mechanical and chemical pleurodesis. Postoperative recurrence risk was significantly greater in 'without-bleb' than 'with-bleb' patients (27% vs 4%, P=0.036; Table 5).

Discussion

Demographic characteristics

The annual incidence of PSP is 7.4 to 18 per 100 000 men and 1.2 to 6 per 100 000 women.[1] It generally occurs in tall, thin males between the ages of 10 and 30 years[1]; the reported male-to-female ratio of PSP being 6.9:1.[7] In our series of 77 patients (114 episodes) with PSP encountered within a period of 8 years and 9 months, the male-to-female ratio was 10:1. The subjects were also taller, thinner, and had lower body mass index values than the general population.

The percentage having chest pain and shortness of breath as presenting symptoms was similar to that in other paediatric series.[7] About one seventh of our patients were smokers. In our series, there was also a predilection for left-sided pneumothorax, as in previously reported studies.[7,8]

Radiological quantification of pneumothorax for children

The Collins formula is derived from the summation of the interpleural distances measured at three locations versus the pneumothorax size measured by helical CT.[4] The Light index is calculated from the cubes of the average lung diameter and the average hemithorax diameter.[3] Both are widely used for estimating pneumothorax volume.

Using linear regression and correlation analyses, a study by Noppen et al[9] provided proof that the size of PSP estimated by Light index associates well with the amount of air manually aspirated.[9] The quoted correlation (r=0.84, P<0.0001) corresponds to that derived in our study. However, Noppen's study[9] might be biased towards moderate and large pneumothoraces, since small pneumothoraces are often treated by observation (without drainage). The same limitation also applied to our study.

The accuracy of the Collins formula was validated by the excellent correlation (r=0.98, P<0.0001) between percentage pneumothorax size estimated by the formula and that calculated using helical CT.[4] However, we observed that the Collins formula was generally associated with a larger pneumothorax size than that estimated by the Light index, and some of the values were greater than 100% (up to 160% without evidence of tension pneumothorax on chest X-ray). The most likely reason was that the Collins formula was derived from a sample of adults and did not take account of thoracic size. Our paediatric patients had smaller thoraces and were significantly taller and thinner than the general population, leading to a possible overestimation of pneumothorax volume. In comparison with the Collins formula, the Light index is simpler and more user-friendly. Given its high correlation with PSP volume, we propose that it should be the method of choice in paediatric practice.

Because of record retrieval failure, only 85 pre-aspiration chest X-rays were accessed. The correlation might have been better still if all of the chest X-rays could have been analysed, which was a limitation due to the retrospective nature of our study. Another limitation was the use of volume of aspirated air as a reflection of pneumothorax volume. The amount of aspirated air may not truly reflect the actual volume, because there was usually small amount of residual air in the thoracic cavity after the procedure. In this series, we did not review post-aspiration chest X-rays to estimate the size of any residual pneumothorax. Comparison between the pre-aspiration and post-aspiration chest X-rays taken immediately after thoracentesis may give a more accurate correlation with pneumothorax volumes extracted. However, this would have been technically difficult and not at all practical.

Outcomes following thoracentesis versus chest drain as primary treatment for primary spontaneous pneumothorax

Patients treated by thoracentesis had a shorter hospital stay compared with those treated by chest tube insertion. Thoracentesis is safe and simple to perform, entails a lower dose of systemic analgesia and inflicts less pain. Our results conformed with a previous report that thoracentesis was more advantageous than chest tube insertion based on lower total pain scores and shorter hospital stays.[10] Another study showed that chest drain insertion involved more pain and more analgesic use.[11] Other possible complications of chest tube drainage include: malposition, kinking or blockage of chest drains, surgical emphysema, pleural infection,[6] and wound problems.

The risk of recurrence of primary spontaneous pneumothorax following conservative treatment is about 54% within the first 4 years.[12] According to a survey of several studies involving widely varying follow-up periods (0.25-10 years), the average recurrence rate was 30% (range, 16-52%).[13] Most recurrences occurred within 6 months to 2 years after the initial pneumothorax.[1] The recurrence rate after successful primary conservative treatment in our patient series without a bleb was 27%.

Recurrence rates after PSPs initially treated by thoracentesis versus chest tube insertion had been compared. A systematic review by Devanand et al[14] summarised the results of three randomised controlled trials[10,15,16] and concluded that there was no significant difference in PSP recurrence rates at 3 and 12 months. A more recent study with the largest patient pool in 2006 by Ayed et al[17] also found no significant difference in recurrence rates 1 and 2 years after either form of initial treatment. A similar finding was also noted in our series.

In our series, the success rate of thoracentesis was 78%. Devanand et al[14] reported that the success rate of simple aspiration varied from 67 to 93%, which concurred with our results. Noppen et al[16] found no statistically significant difference between recurrence rates after thoracentesis and chest tube insertion, indicating they were similar in efficacy.

Effectiveness of video-assisted thoracoscopic surgery for primary spontaneous pneumothorax

Open thoracotomy has been the 'gold standard' for surgery following pneumothorax. Contemporary advances in surgical technique favour minimally invasive procedures in the form of VATS. It is used to resect blebs (if any), the likely underlying cause of PSP, as well as to create pleural adhesions to prevent recurrence. In a Korean study,[18] blebs were confirmed to be present in 85% of patients undergoing thoracotomy. In another series, 78 to 95% of patients presenting with PSP had endoscopically visible blebs or bullae.[19] In our series, 70% of patients undergoing VATS had blebs.

The reported recurrence rate of spontaneous pneumothorax after VATS is 2 to 14%,[1] and was 11% in our series. Ayed and Al-Din[20] reported that the rate was low (0-3%) after surgery if blebs were identified. In our series, after surgery, of 26 patients with blebs, one had a recurrence (4%). The latter underwent bullectomy with apical pleurectomy yet endured a recurrence 2 years later; a bleb was found again at the upper lobe, though the recurrence might have been caused by a new bleb. This patient was subsequently treated with bullectomy and more extensive mechanical and chemical pleurodesis.

Postoperative recurrence was more frequent in patients without blebs or bullae being noted, the rate being 27%.[20] Our study also supported this finding in that a significantly higher percentage of 'non-bleb' patients (27%) had postoperative recurrence (Table 5). The exact reason for this observation remains unknown. The underlying pathology of the 'non-bleb' group is obscure and may not be definitely amendable to surgery. The 'with-bleb' group had an underlying pathology eradicated by apical bullectomy plus apical pleurectomy and thus the risk of further recurrence was minimised.

Our overall experience in managing primary spontaneous pneumothorax and treatment recommendations

For the first episode of PSP, 16% of our patients were treated with observation alone. Over half (58%) were successfully treated by thoracentesis and/or chest tube insertion. The remaining 26% underwent surgery for persistent air leak, haemopneumothorax, and tension pneumothorax.

For all patients presenting with PSP, the treatment flow advocated in the BTS guideline 2003 is recommended. Thoracentesis is suggested as the initial treatment for significant volumes, as it is less invasive and results in comparable recurrence rates and efficacy as chest tube insertion. Early referral for surgery is recommended for patients who fail conservative treatment. For patients with haemopneumothorax and tension pneumothorax, urgent surgical referral is suggested after initial stabilisation.

Conclusion

Our patients with PSP showed similar demographic characteristics as in other studies.[1,7] For quantification of the pneumothorax volume (as suggested by the BTS guideline), the modified Light index was accurate and simple to perform. Thoracentesis is a well-accepted initial intervention for PSP. Compared with chest tube drainage, it leads to shorter hospital stays without an increase in recurrence rate. Conservative treatment including observation, thoracentesis and chest tube insertion suffice for most patients with first episode of PSP. Early referral to surgery is warranted for those whose PSP fails to resolve with conservative treatment. Video-assisted thoracoscopic surgery is a safe and effective therapeutic approach for such patients.

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