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Primary pneumothorax: Should surgery be offered after the first episode?

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Abstract

Surgery is the recommended and most effective means of preventing the recurrence of primary spontaneous pneumothorax (PSP). However, the conventional belief amongst most clinicians is that surgery should not be routinely offered to patients with an uncomplicated first episode of PSP. The view that surgery should be reserved for recurrent episodes of ipsilateral PSP is based on an apprehension regarding traumatic thoracic surgery combined with a perception that recurrences after a single episode of PSP are unlikely. Modern advances in minimally invasive thoracic surgery have now dramatically reduced the morbidity of PSP surgery. Such surgery is now safe, effective and causes minimal indisposition for patients. On the other hand, modern clinical data suggests that recurrence rate of PSP is perhaps much higher than previously assumed, with more than half of patients experiencing a second episode within several years of the first. With such new appreciations of the current situation, it is appropriate to now consider offering surgery to patients even after the first episode of PSP.

Key words: Health economics; Health policy; Outcomes; Pleural space (drainage, management); Pleurodesis; Pneumothorax; Surgery; Thoracoscopy; Video-assisted thoracic surgery

Core tip: Traditional guidelines advise that surgery is unnecessary for patients suffering a first episode of primary pneumothorax. However, such thinking was based on an incomplete picture of the frequency of recurrence and on older, relatively traumatic surgical approaches. Today, advanced surgical techniques allow effective bullectomy and pleurodesis to be safely delivered with only minimal morbidity or inconvenience to patients. Evidence is also emerging that recurrence may be more common than previously believed. It is perhaps time to allow clinical practices to catch up with modern medicine, and to consider surgery even after a first episode of primary pneumothorax.

SCOURGE OF PRIMARY PNEUMOTHORAX

Primary spontaneous pneumothorax (PSP) is one of the most common emergent conditions encountered by pulmonologists, thoracic surgeons and clinicians involved in acute care medicine. Officially, the reported incidence of PSP is said to be 18-28/100000 cases per annum for men and 1.2-6/100000 for women[1,2]. However, because PSP mainly affects younger people, the actual incidence amongst "high risk" age groups (adolescents and young adults) might be substantially higher still. In the authors' experience, whenever a class of college students is asked if any of them or their friends has experienced a pneumothorax, there is almost invariably at least one hand that will go up. That is how common and important a condition pneumothorax is in real life. Indeed, one of the authors of this article has himself suffered from recurrent PSP.

Sadly, for the young patient being treated for PSP, the experience can be unpleasant. The air in the pleural space causes symptoms[3]. The increased relative collapsing/stretching of the partly deflated lung in a pneumothorax situation over-stimulates the visceral pleural stretch receptors causing the pain and discomfort felt. The partial deflation of the lung also means collapse of the small terminal airways and alveoli, while the relative compressibility/expansibility of the air in the pneumothorax acts like a "shock absorber" impeding the chest wall and diaphragm's ability to efficiently inflate and deflate the lung, thus leading to dyspnea. In certain situations-notably tension and bilateral pneumothorax-the patient's life could be threatened by the physiological compromise. Even in less dramatic presentations, a patient's circumstance can make the occurrence of PSP a potentially grave consideration - for example, if he/she needs to travel by air frequently or is a keen diver[2,3].

Once the patient is seen by a doctor for PSP, the treatment itself can be disagreeable. Depending on size of the pneumothorax and the presence of symptoms, acute management of a PSP can be achieved by conservative management (sometimes with so-called "oxygen therapy" as an adjunct)[4], or by active intervention-namely needle aspiration or chest drain insertion[2]. Conservative management and needle aspiration may entail a period of admission, observation and repeated attendances for review to exclude re-accumulation. Chest drain insertion can be a potentially traumatic experience: involving pain on insertion, during drainage and on removal[5-7].

It would therefore seem to make perfect sense that if a patient should ever suffer an episode of PSP efforts should be made to prevent it ever happening again. And to prevent recurrence, an effective solution has already been available for decades: surgery. However, despite the obvious need to prevent recurrence and the accessibility of the solution, the prevailing dogma in the medical world is that surgery is *not* offered for the first episode of PSP[2,8]. This is a view based essentially on two arguments: (1) the potential harm of surgery is not inconsiderable; and (2) the risk of recurrent PSP after a first episode is not high enough to justify exposing the patient to such potential harm.

This article seeks to re-examine these arguments in the light of more recent clinical evidence. In this article, we do not discuss the acute management of PSP. We advise adherence to the latest international guidelines for initial management[2,8]. Instead, we propose a challenge to traditionalist views on definitive management with strategies to prevent recurrence. The objective is to answer the question: is it time for clinicians to change the paradigm? With modern understanding and advances, should patients with a first episode of PSP now be routinely offered surgery?

TRADITIONAL VIEW OF SURGERY

Definitive management of PSP is considered after the patient's acute presentation has been adequately resolved, and aims to prevent recurrence. In practice, recurrence prevention is achieved by achieving two things: (1) bleb excision; and (2) effecting pleurodesis.

Subpleural blebs and bullae are found at the lung apices during surgery and on CT scanning in up to 90% of cases of PSP and these blebs are thought to play a role in its occurrence[9,10]. In patients who suffer recurrent PSP after previous surgery, residual or incompletely excised blebs are believed to be the reason for recurrence in up to 70%[11]. It is therefore a firmly held belief amongst surgeons that effective removal of these blebs must form an essential part of any definitive PSP treatment.

Pleurodesis is to fuse the visceral and parietal pleura together, thereby obliterating the pleural space in which pneumothorax might recur. Such pleurodesis is created by triggering aseptic inflammation of the pleura, with the resulting fibrosis giving the required inter-pleural symphysis. This can be done using chemical agents, autologous blood or surgical trauma to induce the inflammation[2,12]. Of these methods, surgery is well established to be significantly more effective, hence guidelines recommend that other methods should only be used if a patient is either unwilling or unable to undergo surgery[2,8]. As PSP patients tend to be young and otherwise fit, surgery is the approach for definitive management in the vast majority of cases. Furthermore, surgery is the only feasible means for visualization and resection of the primary culprit lung blebs.

In terms of surgical approach used, however, open thoracotomy and pleurectomy is traditionally held to be the "gold standard"[13]. This approach said to provide the lowest recurrence rate (approximately 1%). However, open thoracotomy-involving a long incision typically 8-20 cm long and forcible spreading apart of

the ribs during the entirety of the operation-is one of the most painful of all surgical incisions[14-17]. Persistent dysesthetic burning pain or aching can occur in up to 50%-70% of patients at two months or more after thoracotomy[15,16]. In 5% of these patients, the pain has been described as "severe and disabling", and over 40% of patients may still have some degree of pain at one year after surgery. In turn, such pain is well known to result in increased post-operative complications and reduced quality of life after surgery.

It is in such a context that current clinical practice guidelines tend to avoid use of surgery for patients with only a single episode of PSP. The trauma-not only physical but also perhaps psychologically-of receiving such major surgery for a generally benign disease was considered excessive if the recurrence rate is not high. The 2003 British Thoracic Surgery Guidelines for the management of spontaneous pneumothorax specifically refer to open thoracotomy as the "gold standard" for surgical management[13]. With this standard in mind, it is unsurprising that clinicians would be reluctant to offer surgery. This is reflected in those guidelines listing the indications for surgery to only be: second ipsilateral pneumothorax; first contralateral pneumothorax; synchronous bilateral spontaneous pneumothorax; tension pneumothorax; persistent air leak after chest drain insertion; and spontaneous haemothorax[2,13]. First episode PSP is deliberately excluded. In a similar context back in 2001, the oft-quoted American College of Chest Physicians Consensus Statement on the management of spontaneous pneumothorax explicitly states that "procedures to prevent the recurrence of a primary spontaneous pneumothorax should be reserved for the *second* pneumothorax occurrence"[8].

It is therefore evident that views on surgical indications are influenced by the perceived harm from surgery. Over the past decade or more since the above guidelines, the trauma from thoracotomy remains inescapable. What has changed, though, is the view of whether open thoracotomy remains the surgical approach of choice.

VIDEO-ASSISTED THORACIC SURGERY: THE NEW "GOLD STANDARD"?

Over the past 20 years, minimally invasive video assisted thoracic surgery (VATS) has been established to be a safe and effective alternative to open thoracotomy for the management of PSP[10,18].

Conventional VATS for PSP is performed using a 3-port technique[18-20]. A 10 mm wound is used for placement of a video-thoracoscope, and two 10 mm wounds are further placed for insertion of instruments. Through these 3 small ports, any visible bullae, blebs or areas of frank emphysema-like changes on the visceral pleura are excised using a surgical staple-resection device. Pleurodesis is then induced by either rubbing of

the parietal pleura using an abrasive material (usually a coarse synthetic mesh) or by stripping of the parietal pleural from the chest wall like peeling off wall-paper (pleurectomy). Although pleurectomy is said to achieve slightly lower recurrence rates than pleural abrasion, it is a more traumatic procedure for the patient, and often a combination of the two is used[2]. Post-operatively, a chest tube is kept in situ for 1-2 d to facilitate lung re-expansion and maximize apposition of the visceral and parietal pleura. VATS has been fully established to be a safe operation, with a mortality risk well below 1%.

With VATS, not only are the small wounds more cosmetically appealing, but the avoidance of rib-spreading and reduction of soft tissue trauma significantly decreases surgical morbidity. There has been an abundance of clinical evidence proving this. In a prospective randomised controlled trial, Waller *et al*[21] studied two groups of 30 patients undergoing surgery for pneumothorax by VATS and open pleurectomy. It was reported that in the VATS group, the post-operative analgesic requirement, hospital stay and compromise in lung function were all less than in the thoracotomy group. In another randomized trial, Sekine *et al*[22] compared VATS with transaxillary pleurectomy and found that VATS caused less compromise to gas exchange, probably due to reductions in chest wall pain, chest wall deformity and peripheral atelectasis. Many other similar studies and case series have consistently demonstrated the advantage of VATS in terms of: less intra-operative blood loss, less post-operative pain, shorter lengths of hospital stay, better cosmesis and fewer wound complications[23-25]. Such evidence was consolidated in a meta-analysis in 2004 when Sedrakayan *et al*[26] found that in the treatment of pneumothorax, VATS was associated with shorter length of hospital stay and less use of analgesics than thoracotomy. A systematic review in 2008 further concluded that VATS offered reductions in length of hospital stay, analgesic requirements, and post-operative pulmonary dysfunction[27].

In return for the lower morbidity, VATS does not compromise on the efficacy of the pleurodesis. There was an early scare when one early meta-analysis suggested recurrence rates following VATS could be higher than after open surgery[28]. However, a weakness of that paper was that 15 of the 29 studies included in the meta-analysis were reported prior to 1997[27]. In the last ten years VATS has been increasingly used for the treatment of pneumothorax and earlier outcomes may not reflect present results[29]. Furthermore, in a prospective randomised controlled trial, it was shown that surgical treatment failures tended to occur in patients having treatment for secondary spontaneous pneumothorax, so that that VATS would be superior to open surgery if PSP alone were considered[21]. Sawada *et al*[23] also found in a retrospective non-randomised study for patients with PSP that there was no statistically significant difference between VATS or

thoracotomy in terms of recurrence rates. The most recent systematic review concluded that VATS has been shown to be comparable to open pleurectomy in the treatment of spontaneous pneumothorax[27].

The combination of lowered morbidity with equivalent efficacy at preventing recurrence means that open thoracotomy should no longer be regarded as the first line approach for the surgical management of PSP[24-26]. Today, VATS has become the approach of choice by surgeons throughout the developed world, and it is rare to find traumatic open surgery being offered to young patients with a benign condition such as PSP. Compared to the 2003 version, the latest British Thoracic Surgery Guidelines for the management of spontaneous pneumothorax published in 2010 pointedly no longer uses the words "gold standard" in relation to open thoracotomy[2,13]. Instead, it is very noticeable that when the latest guidelines advised surgical pleurodesis for specific circumstances (such as pregnancy), VATS is the only approach named and open thoracotomy is nowhere to be seen.

ADVANCES IN SURGERY FOR PNEUMOTHORAX

With VATS replacing open thoracotomy as the current surgical approach of choice, should thresholds for offering surgery to PSP patients remain so high? Over the years, there have actually already been a number of clinical series suggesting that surgery after a first episode of PSP may offer advantages over non-surgical management (Table 1). Nowadays, the answer is further swinging increasingly in favor of surgery because advances in the performance and understanding of surgical pleurodesis have emerged that further improve outcomes for PSP patients.

Needlescopic VATS for pneumothorax
Despite the acknowledged benefits of VATS in reducing post-operative pain and morbidity[19,20], it is not capable of completely eliminating pain. After VATS for pneumothorax, up to 20%-30% of patients can still experience discomfort for up to several years[30,31]. In Hong Kong, we have previously reported that 52.9% of patients receiving VATS for PSP experienced paresthesia as a post-operative complication distinct from their wound pain after a median of 19 mo after surgery[18].

A number of alternative approaches have been suggested over the years. One is to perform pleuroscopy (also known as "medical thoracoscopy") for talc powder poudrage to induce chemical pleurodesis[3,32]. However, this method has still never been shown to offer recurrence rates as low as proper surgery and is therefore only recommend for "patients who are either unwilling or too unwell to undergo a VATS procedure"[2,8]. Another approach is the use of robotic surgical systems for pneumothorax surgery[33]. However, robot assisted

surgery: does not reduce wound number or size; increases the cost, time and complexity of surgery; and has never been proven to offer any outcome advantages over VATS for treating PSP. Ten years after the introduction of the robotic systems, these have never fully been established as a mainstream option for PSP surgery.

To date, arguably the most significant advance has been a further evolution of VATS: Needlescopic VATS[34-36]. Compared to the 10 mm wide ports used for conventional VATS, Needlescopic VATS uses a video-thoracoscope and instruments only 2-3 mm in diameter, thereby greatly reducing the size of the ports. The tiny wounds ensure not only reduced pain, but cause less compression of the intercostal nerves during manipulation intra-operatively. Needlescopic VATS was first used for sympathectomy surgery to treat palmar hyperhidrosis and sympathectomy disorders, and has been shown to reduce pain and paresthesia compared to conventional VATS[18,35,36].

For PSP, when the patient comes to the operating theatre, there is typically already a chest drain in situ. Unless this is infected, that chest drain wound can be sterilized and used as an instrument port for insertion of a standard surgical staple-resection device to resect any lung blebs. In addition, one or two 2-3 mm ports are placed for the insertion of the needlescopic video-thoracoscope and a needlescopic grasping instrument[36]. Inside the chest, exactly the same procedure of bleb resection, pleurectomy and pleural abrasion can be performed as in conventional VATS.

We have previously reported our preliminary results comparing the Needlescopic VATS approach used for 68 pleurodesis procedures for PSP (53%), with the conventional VATS approach used for 61 (47%)[35]. No mortality or major complications occurred in all patients. Recurrence rates between the Needlescopic VATS and conventional VATS groups were similar at up to 60 mo (2.9% *vs* 8.2% respectively, $P = 0.31$). There was a strong trend for shorter mean length of hospital stay in the Needlescopic VATS group ($P = 0.07$). Mean pain scores at rest and on movement were consistently lower in the Needlescopic VATS group on each day during the post-operative stay, although the differences failed to reach statistical significance. The mean time until patients resumed work was over 6 d shorter in the Needlescopic VATS group, although again this barely failed to reach statistical significance. On telephone interview, patients in the Needlescopic VATS group reported significantly better mean scores for satisfaction with surgical wound cosmesis (6.4 *vs* 4.9, $P < 0.01$), with the incisions becoming virtually completely invisible within a couple of weeks after surgery. Similar results have also been noted by other studies, which have found that patients receiving nVATS reported less residual neuralgia and better wound satisfaction[37,38]. The use of nVATS was also consistently shown to yield a low recurrence rate

Table 1 Summary of the key studies on surgical definitive management after a first episode of spontaneous pneumothorax

Ref.	No. of patients	Chest drain duration	Length of stay	Complications	Follow-up	Recurrence	Cost	Other
Schramel *et al*[64]	149 first episode PSP VATS: 70 Chest drain: 79	(Both first and recurrent episode included)	(Both first and recurrent episode included)	(Both first and recurrent episode included)	Chest drain: 96 ± 18 mo VATS: 29 ± 10 mo	1 yr: VATS (3%) < CD (19%) 2 yr: VATS (4%) < CD (22%)	VATS < Chest drain (total cost of 1 hospital stay + waiting time) Cost of treating recurrence: VATS similar to Chest drain	If waiting time (4.4 d for VATS) not considered, cost NS Chest drain patients, if have recurrence, were management by thoracotomy
Torresini *et al*[65]	70 Chest drain: 35 VATS: 35	VATS: 3.9 d Chest drain: 9 d	VATS: 6 d Chest drain: 12 d	Prolonged air leak > 6 d: VATS: 5.7% Chest drain: 11.4%	12 mo	VATS: 2.8% Chest drain: 22.8%	VATS: $1925 Chest drain: $2750 (also included cost of recurrence)	Secondary pneumothorax included Chest drain arm: 2 VATS arm: 4
Chou *et al*[67]	VATS: 51	2 d (54%)	3 d (54%)	No	38 mo	0	-	
Margolis *et al*[68]	VATS: 156	-	2.4 ± 0.5 d	No	2-96 mo (median: 62 mo)	0	-	Talc poudrage for all patients intra-op
Sawada *et al*[23]	281 Chest drain: 181 Thoracotomy: 13 VATS: 87	-	Chest drain: 14.5 d Thoracotomy: 22.2 d VATS: 8.3 d (*P* < 0.001)	-	13-163 mo (mean: 78.3 mo) Not specified for first episode cases	Chest drain: 54.7% Thoracotomy: 7.7% VATS: 10.3% (*P* < 0.001) (Thoracotomy *vs* VATS: *P* = 0.61)	-	Length of stay analysis included both first and recurrent episodes
Chen *et al*[69]	52 Chest drain: 22 VATS: 30	-	VATS: 4.8 Chest drain: 6.1 (*P* = 0.034)	VATS: 6.7% Chest drain: 27.3% (*P* = 0.058)	3-38 mo (mean 16 mo)	VATS: 3.3% Chest drain: 22.7% (*P* = 0.038)	Total cost of 1 hospital stay VATS: $1273 Chest drain: $865	All patients had failed initial needle aspiration

VATS: Video assisted thoracic surgery; PSP: Primary spontaneous pneumothorax.

of 2.8%-4.6% (after follow-up period of 8-36.9 mo), which is comparable to conventional VATS[35,37-39].

For patients with PSP, perhaps the greatest attraction of Needlescopic VATS is the low "cost" in terms of morbidity and cosmesis. With Needlescopic VATS, since the patient has a chest drain wound in situ already (which is used as a surgical port), having the surgery means only adding two tiny 2-3 mm wounds that become virtually invisible after a week. In return, the patient receives effective definitive therapy to allow a normal, fully active lifestyle virtually free from worry about future recurrence.

Another approach for minimizing trauma with VATS pleurodesis is to use a Single Port (or Uniportal) VATS approach[40-43]. This technique involves a 20-25 mm incision through which the video thoracoscope along with two roticulating instruments are used side-by-side. Whether the reduction in number of incisions offsets the increase in overall length and trauma of incisions is a subject for future clinical study.

Table 2 summarizes the results of clinical studies evaluating the above "next generation" VATS approaches for the surgical treatment of pneumothorax.

Influences of post-operative analgesia

The whole reason for operating in PSP is to achieve pleurodesis, and for that there must be good apposition between the visceral and parietal pleura. To a certain degree, suction on the chest drain after surgery will help this - and for this reason, it is always advisable to maintain some negative pressure after any pleurodesis procedure (surgical or chemical) until the moment the chest tube is removed[44]. But the other key factor is for the patient to maintain good inspiratory effort to inflate the lung from within. Deep breathing exercises and use of an incentive spirometer are essential components of this. The better the lung expands, the better the inter-pleural contact-and in turn this should in theory lead to better pleurodesis and lower recurrence rates. If the patient is in pain after surgery, this will obviously affect the ability to breathe in deeply or use the incentive spirometer. Therefore, effective post-operative pain control is important for effective pleurodesis.

For post-operative analgesia, opiates are not preferred. These not only have a potentially negative effect of unwanted respiratory depression, but they can make a patient dizzy or nauseated and thereby reduce post-operative mobility and compliance with breathing exercises - negating the advantages that minimally invasive surgery should be achieving. With advanced VATS techniques for a relatively simple

Table 2 Summary of the key studies on "next generation" video assisted thoracic surgery for pneumothorax

Ref.	No. of patients	Mean operating time	Mean blood loss	Mean chest drain duration	Mean post-operative length of stay	Post-op pain Scores	Follow-up	Recurrence	Residual wound discomfort	Wound satisfaction
Chen *et al*[37]	nVATS: 28 cVATS: 35	nVATS: 76.9 ± 25.5 cVATS: 83.6 ± 29.5 min (P = 0.34)	-	nVATS: 2.7 ± 1.7 d cVATS: 3.5 ± 2.0 d (P = 0.11)	nVATS: 4.3 ± 2.0 d cVATS: 5.1 ± 2.0 d (P = 0.106)	10-point VAS score on post-op Day 1, 2 and 3 nVATS similar to cVATS	Mean 8 mo	nVATS: 3.6% cVATS: 0 (P = 0.44)	nVATS < cVATS (P = 0.021)	nVATS > cVATS (P = 0.043)
Jutley *et al*[40]	uVATS: 16 cVATS: 19	-	-	uVATS: 4.6 ± 2 d cVATS: 3.9 ± 2.1 d (P = 0.35)	uVATS: 4.6 ± 2.1 d cVATS: 4.1 ± 1.0 d (P = 0.35)	4-point VAS Mean score: uVATS: 0.4 ± 0.5 cVATS: 0.8 ± 0.7 (P = 0.06) Maximum score: uVATS: 1.4 ± 0.9 cVATS: 2.6 ± 0.9 (P < 0.001)	uVATS: 9.4 ± 6.6 mo cVATS: 32.1 ± 9.9 mo	uVATS: 0 cVATS: 5.3%	uVATS: 14% cVATS: 58%	-
Salati *et al*[41]	uVATS: 28 cVATS: 23	uVATS: 72.3 min cVATS: 68.7 min (P = 0.67)	-	-	uVATS: 3.8 d cVATS: 4.9 d (P = 0.03)	-	uVATS: 13 mo cVATS: 39 mo	uVATS: 10% cVATS: 13% (P = 0.62)	uVATS: 35% cVATS: 94% (P < 0.001)	-
Chou *et al*[38]	nVATS: 106 cVATS: 89	nVATS: 82.36 ± 35.58 min cVATS: 99.78 ± 35.74 min (P = 0.008)	nVATS: 16.67 ± 25.90 mL cVATS: 24.36 ± 26.86 mL (P = 0.04)	-	nVATS: 4.85 ± 3.18 d cVATS: 5.14 ± 3.24 d (P = 0.5)	10-point VAS score nVATS: 4.80 ± 2.1 cVATS: 8 ± 1.7 (P < 0.001)	nVATS: 34.9 ± 12.5 mo cVATS: 69.2 ± 14.5 mo	nVATS: 2.8% cVATS: 1.1% (P = 0.4)	-	-
Yang *et al*[42]	uVATS: 27 cVATS: 13	uVATS: 74.6 ± 22.8 min cVATS: 72.4 ± 20.2 min (P = 0.77)	-	-	uVATS: 2.3 ± 0.7 d cVATS: 2.5 ± 0.8 d (P = 0.72)	10-point VAS score on post-op Day 0, 1, 2 uVATS similar to cVATS	uVATS: 2.1-7 mo cVATS: 2.3-8.2 (P = 0.13)	uVATS: 3.7% cVATS: 7.7% (P = 0.7)	uVATS: 33.3% cVATS: 76.9% (P = 0.01)	uVATS: 70.4% cVATS: 30.7% (P = 0.03)
Sihoe *et al*[35]	nVATS: 68 cVATS: 61	45 ± 19 min	3 ± 25 mL	2.4 ± 0.8 d	3.8 ± 2.2 d nVATS < cVATS (P = 0.07)	10-point VAS mean score: nVATS < cVATS (trend)	Up to 60 mo	nVATS: 2.9% cVATS: 8.2% (P = 0.31)	-	10-point VAS mean score: nVATS < cVATS (P = 0.04)

cVATS: Conventional VATS; nVATS: Needlescopic VATS; uVATS: Uniportal VATS; VAS: Visual analog scale; VATS: Video assisted thoracic surgery.

operation for PSP, simple oral analgesics such as paracetamol are often sufficient, with a mild opiate such as tramadol reserved only for breakthrough pain.

What has become increasingly clear today is that non-steroidal anti-inflammatory drugs (NSAIDs) should not be given. These are without doubt very effective pain-killers when used after major thoracic surgery, such as lung cancer resections. The problem is that the procedure of pleurodesis by definition calls for the induction of inflammation to give rise to inter-pleural fibrosis. Using a drug whose nature is explicitly "anti-inflammatory" therefore seems completely contradictory to the purpose of the operation. To our knowledge, there have been only a handful of studies looking at the effect of NSAIDs on pleurodesis in animal models[45-48]. To summarize, NSAIDs given to animals receiving pleurodesis were found to reduce the amount of inter-pleural collagen deposition and the density and quality of pleural adhesions. These animal studies have generated sufficient concern that there have already been calls to avoid all routine use of NSAIDs following pleurodesis in humans[48].

Influences of post-operative chest drainage

As noted above, negative pleural pressure following surgery facilitates better contact between the visceral and parietal pleura after pleurodesis, potentially contributing to better outcomes[44].

The traditional water seal chest drain systems require connection to an external suction source (either "wall" suction or a noisy air pump device) whenever negative pleural pressure is required. One the patient is connected *via* the chest drain to such an external suction source, he/she is essentially shackled as though a ball-and-chain were clamped on. This is not only inconvenient for the patient, but also detrimental to effective lung expansion exercises.

We now use a portable digital chest drainage system for all of our PSP patients who have received VATS[49,50]. This system is a small, portable box connected to a patient's chest tube that has an internal, battery-powered suction mechanism delivering any level of negative pressure set by the clinician. Even with negative pressure applied, the patient is free to mobilize even on the day of surgery. This complements the faster physical recovery expected of Needlescopic and Single Port VATS. The digital chest drain system has an in-built digital air flow monitor that accurately displays in real-time the flow of air coming out of the chest tube from the patient's thorax, providing an objective quantification of any air leak after surgery. The reliability gives surgeons the confidence to remove drains after a zero air flow reading for just several hours, instead of waiting for the traditional 24 h of "no bubbling" *via* the water seal before removal. We have previously reported significantly reduced chest drain durations and lengths of stay for our patients using these new digital chest drain systems[49]. On the hand, the need for re-insertion of chest drains after removal is also lower with the digital systems-reflecting the greater reliability of a "no air leak" reading with the digital system when compared to the traditional water seal system.

When removing the chest drain, there is also a better appreciation nowadays of what is important. Clamping of the drain before removal is unnecessary, and neither is a period of disconnection from suction to an underwater seal[51,52]. Clinical research has shown zero benefit of the latter when compared to removal of chest tubes after continuous suction. Indeed, it is the authors' worry that discontinuation of suction can allow sucking of a small volume of air in the tubing above the water seal back into the chest, thereby creating a small degree of inter-pleural separation that is undesirable after pleurodesis. Whether to remove the chest tube at the end of maximal inspiration or expiration is also probably not very important[53]. Instead, what is perhaps more important about chest drain removal is the use of a closing suture[52]. This prevents re-entry of air into the chest, stops leakage of fluid out, and also provides a better cosmetic result after healing of the chest drain wound.

THE NATURAL HISTORY OF PRIMARY PNEUMOTHORAX REVISITED

The advances in surgery have made an operation much less intimidating for patients and the physicians looking after them. However, no matter how minimally invasive surgery becomes, there can be no justification for offering it unless the disease treated has a poor prognosis when managed non-surgically. In this regard, the magic figure so lovingly and blindly trusted by generations of medical students, clinicians and textbook authors over the years has been the mythical "30% chance of recurrence"[44,54]. In the mind of the average layman-or even clinician-this means that after a first episode of PSP, if the patient is given proper initial acute management (conservative, needle aspiration, or chest drain insertion) and is then left alone, there is a 70% chance that he will never have another episode again. In other words, if nothing is done, then more likely than not, that first episode is also the last. If that is the case, it is obvious that surgery should not be offered on the first episode. It was argued that only after the second episode did the risk of subsequent recurrences rise high enough to justify major surgery[54,55].

However, what this simplistic view fails to take into account is that such figures often do not state over what length of time patients were followed up for, and whether follow-up was complete. If a cohort of patients is followed up for an extended period of many years, it is intuitive that the accumulated recurrence rate after that period would be higher than if the cohort was only followed up for several months. For example, in one study the recurrence rate for 19 young patients with PSP who were treated conservatively was reported as being "26.3%"[56]. This figure is close to that mythical "30% chance of recurrence". However, closer scrutiny reveals that follow-up times in such a cohort varied from as short as 0.4 years to 6.9 years. Of the recurrences, some occurred at over 12 mo after the first episode. It follows that if all patients had been followed up for long enough then the observed recurrence rate would have been higher.

In recent years, studies have shown that recurrence rates of spontaneous pneumothorax can exceed 50% in patients that have been followed up for up to 5 years[3,57,58]. When patients are followed for 4 years the risk of recurrence of PSP is as high as 54%[2,59]. This is the figure now officially quoted in British Thoracic Society guidelines. This fact deserves careful consideration for a moment. This means that an 18-year-old young man with a first episode of PSP will have an over 50% chance of having another episode before he reaches his 22nd birthday. He could be abroad studying or travelling on a long-haul flight when that recurrence happens. Even if he finds medical attention in time, he will have to undergo another painful (and

potentially risky) chest drain insertion. And during all this time before the recurrence, there will be the worry of when the recurrence will strike-a situation not unlike having the Sword of Damocles hanging overhead.

The question that faces clinicians nowadays is therefore: if effective surgery can be performed with such low morbidity, and if recurrence is more likely than not, why not offer surgery even after the first episode of PSP? Why wait for the second episode with the inherent problems that brings when it is likelier the patient will have a recurrence than won't?

ARE THERE ANY REMAINING EXCUSES NOT TO OFFER SURGERY?

Despite the lowered morbidity of surgery and the higher-than-expected recurrence rate, there are still some potential arguments against offering surgery for the first episode of PSP.

Alternative non-surgical means of pleurodesis
If one of the arguments in favor of surgical pleurodesis today is that the trauma and morbidity has been reduced, then one could presumably argue that any approach that is even less traumatic than surgery should be even better. Chemical pleurodesis is usually effected by means of injecting talc or antibiotics into the pleural space to trigger inflammation and then fibrosis. In the British Thoracic Society guidelines, tetracycline was recommended as the first line sclerosant therapy in both primary and secondary pneumothoraces[2]. However, it was expressly remarked that "the incidence of late recurrence is 10%-20% which is unacceptably high compared with surgical methods of pleurodesis"[60-62], and therefore that "chemical pleurodesis … should only be attempted if the patient is either unwilling or unable to undergo surgery". Talc is generally considered a more powerful sclerosant than antibiotics, but even talc has been shown on meta-analysis of several trials to only yield "a success rate of 87%"[63], which is still inferior to surgical pleurodesis.

Moreover, it is arguable whether VATS in expert hands is really any more invasive than chemical pleurodesis. The well recognized complications of pain, adult respiratory distress syndrome (ARDS), and infection/empyema have all been explicitly mentioned in relation to chemical pleurodesis in the guidelines[2,13]. The British Thoracic Society guidelines conclude by predicting that the "advent of successful and well-tolerated VATS surgery will lead to less use of surgical chemical pleurodesis with talc".

Cost-effectiveness issue
It goes without saying that performing surgery will cost more than not performing surgery, simply because bringing any patient to the operating room incurs fees relating to manpower, hardware, anesthesia,

surgical consumables, and so on. However, this must be balanced against the costs of prolonged drainage, managing recurrences, and treating complications related to prolonged drainage and recurrences. Whereas with conservative treatment, prolonged leakage means an indeterminable period of waiting for the leak to stop, after any operation for pneumothorax the length of chest drainage is usually very consistent and short (1-3 d).

Schramel *et al*[64] compared 112 patients treated for first time or recurrent spontaneous pneumothorax by conservative therapy (pleural drainage or observation) with 97 similar patients treated by VATS. The authors found that VATS reduced the complication rate (29% *vs* 18%, *P* = 0.05), overall recurrence rate (27% *vs* 4%, *P* = 0.001), chest drain duration (9.4 ± 6.9 d *vs* 4.4 ± 2.6 d, *P* < 0.0001), and length of hospital stay (13 ± 10 d *vs* 11 ± 4 d, *P* = 0.03). This in turn resulted in an overall cost savings of 44% if VATS was offered primarily instead of conservative therapy. In another similar study, Torresini *et al*[65] compared patients with spontaneous pneumothorax treated by pleural drainage alone (*n* = 35) *vs* those treated by VATS (*n* = 35). They found that recurrences occurred in 22.8% of the patients in the conservative group *vs* 2.8% in the VATS group (2.8%). Mean chest drainage durations and lengths of hospital stay were 9 and 12 d respectively in the conservative group versus 4 and 6 d respectively in the VATS group. Average management costs per patient in the conservative and VATS groups were $2750.00 *vs* $1925.00 respectively. Such results suggest that offering surgery for the first episode of PSP may be cost-effective.

Inconsistency in results of VATS
Current guidelines advocating the use of VATS have nonetheless acknowledged that even after surgery there is a "recurrence rate of approximately 5%"[2]. Critics have pointed out that the results may not also be as good as reported. In some case series, the recurrence rate can be as high as 16.1% after VATS for PSP[11]. However, even in such series, the authors are quick to point out that recurrences are related to inexperience with VATS leading to overlooked blebs. With increasing experience, it is recognized that recurrence rates tend to drop[29].

In a systematic review in 2009, Chambers *et al*[66] it was noted that the available literature proved that "VATS has superior outcomes in terms of recurrence rates of pneumothorax (from 0% to 13% according to several studies for VATS *vs* 22.8% to 42% for tube thoracostomy alone), duration of chest tube drainage (CTD) (4.56 d *vs* 7.6 d) and mean hospital stay (from 2.4 to 7.8 d *vs* 6 to 12 d for CTD) with first-episode PSP compared with conservative treatment"[66]. The authors only hesitated to make a more sweeping, categorically recommendation for VATS for all first episodes of PSP because one study alone in a pediatric population showed contradictory results[58]. In that study, it was

shown that morbidity from recurrent pneumothorax was higher if VATS was performed for the first episode than if it was only performed for recurrent episodes as per traditional practice. However, closer scrutiny reveals that in that study, the recurrence rate if VATS was performed for the first episode was a staggeringly high 29%. This would nowadays be regarded as unacceptable by most thoracic surgeons, and is probably a reflection of inexperience with VATS at the time. If a more typical recurrence rate had been encountered in this study, the conclusions of the systematic review would likely have been more in favor of VATS for the first episode of PSP.

CONCLUSION

When faced with a deadly or malignant disease for which surgery is the best chance of cure, there is little hesitation on the part of clinicians or patients to accept an operation-no matter how traumatic that operation may be. PSP is altogether different because it is benign and rarely life-threatening. Therefore, the consideration of whether or not to offer surgery is one of risks *vs* benefits.

Traditionally, the risks were directly related to the fact that surgery involved open thoracotomy, and that entailed considerable post-operative morbidity. On the other hand, the benefits were not perceived to be great because the chance of recurrence after the first episode of PSP was said to be "around 30%". No reasonable person would want to have highly-traumatic surgery to prevent a benign condition that would not recur in the majority of patients.

But today, the human "cost" of surgery (morbidity) has been dramatically reduced with VATS supplanting thoracotomy as the approach of choice for PSP therapy. It promises to be even further minimized as Needlescopic VATS is being offered, and improved understanding of post-operative analgesia and chest drainage is being used to refine clinical pathways after VATS for PSP. The intimidation factor of surgery is now lower than it has ever been. On the other hand, modern clinical data is gradually prompting a realization that the natural history of PSP is not as docile as previously thought: within a few years of a first episode, around half of all patients may have recurrence. That recurrence not only involves unpleasant symptoms and a modicum of danger, but also the possibility of repeated admission and unpleasant interventions. The risk-benefit consideration is therefore swinging decidedly in favor of a more aggressive approach to first episodes of PSP.

Based on currently available evidence, technology and surgical techniques, it is becoming increasingly difficult to justify *not* offering surgery for patients with a first episode of PSP.

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