Review Article

Surgical outcomes for single-port VATS for pneumothorax: a narrative review

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Background and Objective: Although the recurrence rate is higher than that of thoracotomy, video-assisted thoracic surgery (VATS) has now become the standard treatment method for spontaneous pneumothorax (SP) because of superior perioperative outcomes such as pain, paresthesia, hospital stay and cosmesis. Many thoracic surgeons are adopting single-port VATS as a less invasive method for treating SP. However, the safety and efficacy of single-portal VATS has not yet been established compared to conventional three-port VATS for SP.

Methods: We performed a review of randomized and non-randomized studies of surgical results of single-portal VATS. We searched the PubMed/MEDLINE from its inception to September 2022 to compare single-port VATS and multi-port VATS for SP. The perioperative outcomes including pain, paresthesia, and recurrence were analyzed in the searched 17 literatures.

Key Content and Findings: Operative time was slightly longer in single-port VATS in two articles but it was related to the learning curve period. There was no significant difference in two meta-analysis studies. Chest tube drainage durations were also not different or in both single and three-port VATS in most studies. However, the meta-analysis demonstrated a shorter hospital stay in single-port VATS. Acute pain score and paresthesia were better in single-port VATS in most of the articles which we reviewed. Patients who underwent single-port VATS had higher satisfaction levels than those who underwent three-port VATS. There was no significant difference in the recurrence rate in both minimally invasive methods.

Conclusions: In many studies, postoperative outcomes were feasible in single-port VATS. Pain, paresthesia and satisfaction were better in single-port VATS compared to three-port VATS. The safety and feasibility of single-port VATS for SP were not inferior to conventional three-port VATS.

Keywords: Spontaneous pneumothorax (SP); video-assisted thoracic surgery (VATS); single-port; pain; paresthesia; recurrence

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Introduction

Spontaneous pneumothorax (SP) is defined as air collection in the pleural cavity, with or without primary lung lesions. The management goals of SP are to evacuate air from the pleural space and to prevent its recurrence. The incidence of primary spontaneous pneumothorax (PSP) is 7.4 to 18 cases per 100,000 population per year among men and 1.2 to 6 cases per 100,000 population per year among women (1).

There are various treatment options for SP, including simple aspiration, thoracic tube drainage and chemical pleurodesis, pleurectomy, pleural abrasion, conventional thoracotomy surgery, and thoracoscopic surgery. Chest tube drainage can effectively relieve symptoms in a first episode of SP but is not a definitive treatment method for the complete resection of causative bullous pulmonary lesions. A high recurrence rate of over 30% after closed thoracostomy drainage was reported (1). Surgical procedure is mandatory to reduce recurrence and return the patient to daily life. Daemen *et al.* demonstrated favor results of Video-assisted thoracic surgery (VATS) of significantly reduced ipsilateral recurrence rates and length of hospitalization compared to chest tube drainage for the treatment of first episode of primary SP (2). Surgical treatment should be considered if a patient meets the following indications: (I) second ipsilateral pneumothorax; (II) first contralateral pneumothorax; (III) synchronous bilateral SP; (IV) persistent air leak (despite 5 to 7 days of chest tube drainage); (V) failure of lung re-expansion; (VI) spontaneous hemothorax; (VII) professions at risk (e.g., pilots, divers); and (VIII) pregnancy (3).

Traditionally, open thoracotomy and surgical pleurectomy have been adopted as standard treatments for uncontrolled SP until the early 2000s (3). The conventional procedure with a long skin incision and spreading of the intercostal space is related to extensive injuries of the chest wall muscle and intercostal nerve. Sustained post thoracotomy pain increases the required dosage of analgesics and limits physical movement, which eventually results in a delay of the patient's return to work (4).

Many surgeons desire to overcome the drawbacks of open thoracotomy by decreasing its invasiveness. VATS became popular since 1990s and increasing numbers of thoracic surgeons have conducted minimally invasive thoracic surgery on various pulmonary diseases. However, with the development of the thoracoscope and other instruments, the stability and feasibility has been improved and open thoracotomy has been gradually replaced with VATS. Waller *et al.* (5) showed that VATS results in fewer postoperative analgesic requirements, shorter hospital stays, and less reduction of forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) than open thoracotomy. Inderbitzi *et al.* (6) proved the safety and feasibility of VATS for SP by demonstrating good results with a recurrence-free rate of 93.8% and a postoperative complication rate of 5.1%. Mouroux *et al.* (7) demonstrated VATS as a valid alternative to open thoracotomy for the treatment of SP by demonstrating acceptable results with a recurrence rate of 3%. Lim *et al.* (8) conducted a parallel-group multicenter randomized trial to compare outcomes of early-stage lung cancer between VATS and open resection recently. They demonstrated significantly better physical functioning at 5 weeks in VATS group (8).

Conventional VATS for SP consists of three ports for a camera, grasper, and endo-stapler. The minimally invasive surgical procedure has developed in the direction of reducing the number of ports to decrease its invasiveness. Yamamoto *et al.* (9) reported successful wedge resection of pneumothorax with a flexible scope through a single 2.0-cm skin incision in 1998. Rocco *et al.* (10) announced the first cases of single-port VATS for the treatment of SP using a 5 mm thoracoscope 0° and articulating instruments without any recurrence. Since then, single-port VATS has attracted attention in many pneumothorax centers for the treatment of SP.

Single-port VATS is considered a less invasive procedure in regard to incision numbers. However, an overarching theme of surgical operation for SP is to achieve a good perioperative outcome and a low recurrence rate. Jutley *et al.* (11) demonstrated comparable safety and feasibility of single-port VATS with no recurrence and a better postoperative maximum pain score compared to three-port VATS. In a meta-analysis, single-incision thoracoscopic surgery (SITS) was associated with lower postoperative pain at 24 and 72 hours (12). In the study, the postoperative paresthesia rate was significantly lower in the SIST group than in the three-port VATS group (12). These favorable results have led to increased interest in single-port VATS. However, the vast majority of surgeons hesitate to adapt this surgical procedure of the treatment for SP. The biggest reason for not applying the method is the discomfort of instrument collision and the difficulty of ensuring sufficient visibility.

This review intends to confirm the safety and feasibility of single-port VATS by providing an overview of the post-operative outcomes including pain, paresthesia and

Table 1 Literature search strategy summary

Items	Specification
Date of search	September 2022
Databases and other sources searched	PubMed/MEDLINE
Search terms used	Uniport, single port, single incision, multi port, two port, video-assisted thoracic surgery and spontaneous pneumothorax
Timeframe	No date restriction
Inclusion criteria	Comparison of the VATS method for SP data including one of these outcomes
	English language
Exclusion criteria	Studies of other thoracic surgery, not SP
	Other languages, not English
Selection process	Authors reviewed selected studies

VATS, video-assisted thoracic surgery; SP, spontaneous pneumothorax.

recurrence after the surgical procedure by analyzing published articles. We present the following article in accordance with the Narrative Review reporting checklist (available at https://vats.amegroups.com/article/view/10.21037/vats-22-37/rc).

Methods

We performed a review of randomized and nonrandomized studies of the surgical results of single-port VATS. We searched PubMed/MEDLINE from inception to September 2022 to compare uniport VATS and multiport VATS for SP (*Table 1*). The search keywords included "uniport", "single port", "single incision", "multi port", "two port", "video-assisted thoracic surgery" and "spontaneous pneumothorax". Eligible studies were selected by the following criteria: (I) comparison of the VATS method for SP; (II) data including one of these outcomes [complication, postoperative stay, operative time, length of postoperative drainage, paresthesia, visual analogue scale (VAS), patient satisfaction scale (PSS), recurrence]; and (III) published in English. The exclusion criteria were defined as follows: (I) studies of other thoracic surgery, not SP; (II) studies published in other languages, not English; (III) studies duplicated, case reports, letters; and (IV) studies in which the necessary data were not provided. The authors reviewed the entire manuscript of potentially relevant articles more closely to confirm the papers were all eligible. We analyzed eligible 17 articles (11,13-28) to evaluate the safety and feasibility of single-port VATS for SP (*Table 2*).

Operative time, chest tube drainage duration, hospital stay

Single-port VATS is a procedure in which all endoscopic instruments including a camera, grasper and endo-stapler are used through a small single hole sized between 2.0 to 3.5 cm (11,14,22). There are a number of surgical considerations to overcome in the single-port VATS. Compared to three-port VATS, in which the operative instruments can be applied at the operative field with a rhombus geometric configuration to obtain sufficient surgical field, single-port VATS needs angled thoracoscope and roculating instruments much more to address the target lesion (10). For these reasons, some thoracic surgeons consider single-port VATS to be an ergonomically uncomfortable method due to collision of instruments and a limitation of the visual field and they think the surgery will take long time. Careful dissection to avoid injuring the vessels at the muscle layer and intercostal space is mandatory to prevent bleeding. Bleeding can smudge the camera lens and result in poor visibility and difficult operation. Many thoracic surgeons adopt wound protector to protect the intercostal nerve as well as to secure a clean operative window for single-port VATS (13,14,22,29). This simple device allows single-port VATS to be a more acceptable surgical procedure. The reproducibility and efficacy of the surgical procedure could be analyzed with operative time indirectly.

We reviewed 16 studies (13-28) to evaluate the operative time of single-port VATS. Only two of the reviewed studies

Table 2 Comparative outcomes of analyzed studies

Studies	Year	No. of patients single-port/multi-port	Operation time	Chest tube drain duration	Hospital stay	Pain	Paresthesia	Recurrence	Satisfaction
Jutley (11)	2005	16/19	–	NS	NS	S	S	NS	–
Salati (15)	2008	28/23	NS	NS	S	NS	S	NS	–
Chen (16)	2011	10/20	NS	NS	NS	S	–	NS	S
Chen (17)	2012	36/26	NS	–	S	S	–	NS	–
Yang (18)	2013	27/13	NS	–	NS	NS	S	NS	S
Tamura (19)	2013	19/18	NS	NS	NS	S	–	–	NS
Kang (20)	2014	33/19	NS	S	S	S	S	–	–
Igai (13)	2014	31/72	M	NS	–	–	–	–	–
Ocakcioglu (21)	2015	37/69/40*	NS	S	NS	S	–	S	–
Song (22)	2015	37/23	NS	NS	NS	S	–	NS	–
Tsuboshima (23)	2015	34/35	NS	NS	NS	–	–	NS	–
Jeon (24)	2016	40/46	NS	S	S	NS	S	NS	–
Kutluk (25)	2018	45/45/45*	NS	NS	NS	S	–	NS	S
Nachira (26)	2018	65/39	NS	S	S	S	S	NS	S
Fiorelli (27)	2021	21/22	NS	NS	NS	S	S	–	S
Yoshikawa (14)	2021	161/71	M	NS	NS	–	–	NS	–
Wang (28)	2022	56/48	NS	NS	NS	S	S	NS	S

*, single-port/two-port/three-port. NS, no significance; S, favor result in single-port VATS; M, favor result in multi-port VATS.

reported the operative time was longer in single-port VATS. Igai *et al.* (13) reported a longer operation time in the SITS group than in the 3-port group (55.2±15.5, 35.9±14.0 min, P<0.0001). They evaluated the long operation time of the SIST group is related to interference of each instrument and emphasized the use of multi-degrees of freedom forceps to overcome the interference. Yoshikawa *et al.* (14) reported a significantly longer operation time in the U-VATS group than in the 3P-VATS group (46.7±15.0 and 38.1±17.5 min, P<0.001), but the difference gradually decreased as the number of surgeries increased. In the late period, there was no significant difference compared to the 3P-VATS group. Tsuboshima *et al.* (23) showed no significant difference in operative time between the single-port group and three-port group (67±19.4 *vs.* 62.5±15.4 min). In a meta-analysis, there was no difference in operative time between the SITS and 3P-VATS groups (12). The other twelve studies showed that the operative time of single-port VATS is comparable to that of three-port VATS for SP. Although there are small obstacles in the surgical practical aspect such as confliction of instruments, limitation of visibility the single-port VATS can be performed with less difficulty by using of a 30° camera and a roculating instrument.

Chest tube drainage duration and hospital stay are indicators of recovery after surgery. Post-operative complications such as prolonged air leak, bleeding and pneumonia are related to the chest tube drainage duration. The advantages of VATS compared to open thoracotomy are early recovery and fewer complications (30). For this reason, the surgical operation for SP replaced open thoracotomy with VATS. These perioperative outcomes are closely related to the feasibility and safety of single-port VATS for SP.

We reviewed 17 studies (11,13-28) to evaluate chest tube drainage duration and hospital stay in single-port VATS for SP. Chest tube drainage duration and hospital stay are significantly shorter in single-port VATS in four studies (20,21,24,26) and five studies (15,17,20,24,26) respectively. Ocakcioglu *et al.* (21) demonstrated no significant difference in either chest tube drainage duration or hospital stay

between the single-port, 2-port and 3-port groups. Igai *et al.* (13) reported that there was no significant difference in the duration of postoperative drainage and postoperative hospital stay. Salati *et al.* (15) reported a better outcome of postoperative stay (3.8 *vs.* 4.9 days, P=0.03) in the single-port VATS group. They explained that the reason for rapid discharge in the single-port VATS group was less postoperative pain and faster recovery. A meta-analysis by Yang demonstrated no significant difference in the mean duration of chest tube drainage, but the hospital stay was significantly shorter in SITS (12). There is no study that chest tube drainage duration and hospital stay is significantly longer in single-port VATS in the articles we reviewed. In the evaluation, there is no difference in the duration of chest tube drainage between the procedures. Compared to three-port VATS, the postoperative hospital stay of single-port VATS is reported to be similar or slightly shorter.

Pain

Post-operative pain after treatment for SP is a very important factor in the recovery process. Severe pain can cause postoperative hypoxemia, which is associated with complications such as myocardial insufficiency and pulmonary complications, delirium, delayed wound healing and prolonged convalescence (31). The pain intensity is related to the degree of chest wall injury that occurred during the surgical procedure. During open thoracotomy, chest wall damage is related to a long incision in the chest wall muscles, including the serratus anterior, latissimus dorsi and intercostal muscles. The operation field is secured by spreading the intercostal space in the large incisional thoracotomy. Spreading stretches the anterior and posterior chest wall structures and may compress and injure the intercostal nerves (32). These mechanisms cause the postoperative pain of open thoracotomy. On the other hand, there are small wounds in the chest wall without any spreading during the VATS procedure. Theoretically, VATS is related to less postoperative pain because it is less invasive than open thoracotomy. Intercostal nerve injury is related to leverage movement during manipulation of the thoracoscope and instruments against the adjacent neurovascular bundle in VATS (33). Landreneau *et al.* (34) reported a superior result of pain-related morbidity in the VATS group compared to open thoracotomy of pulmonary wedge resection for peripheral lung lesions. It has been confirmed in many studies that conventional VATS has less postoperative pain than open thoracotomy or small incision surgery (35,36). Many thoracic surgeons have chosen VATS as a method of SP surgery because it has the advantage of reducing postoperative pain. Single-port VATS is a less invasive procedure than conventional three-port VATS in terms of the number of ports. A number of surgeons think that patients who receive single-port VATS for SP complain less about postoperative pain for this reason.

We reviewed the postoperative pain intensity of single-port VATS for SP compared to conventional three-port VATS in 14 articles (11,15-22,24-28). Eleven studies out of the studies showed better pain score in single-port VATS compared to multi-port VATS (11,16,17,19,20-22,25-28). Chen *et al.* (17) reported a lower VAS score at 72 hours after surgery in the single-port group than in the three-port group (2.5 *vs.* 2.9, P<0.008). Kang *et al.* (20) found a significantly lower VAS score at 24 hours after the surgical operation in the single-port group. Ocakcioglu *et al.* (21) demonstrated that the VAS scores at postoperative hours 24, 48, and 72 were 3.42±0.94, 2.46±0.81, and 1.96±0.59, respectively, in the single-port group, which were significantly lower than those in the other two- or three-port groups. Kutluk *et al.* (25) reported prospective randomized controlled trial data of wedge resection of the bullous parenchyma and partial pleurectomy with a comparison of single-, two- and three-port VATS. Single-incision patients had significantly less pain at 4, 24, and 72 hours (25). Yang *et al.* (18) reported single-incision thoracoscopic surgery (SITS) using a SILS port compared to conventional three-port surgery. There was no difference in postoperative pain scores. However, there was a non-statistically significant trend toward less frequent use of IV analgesics in the single-port group (2.8±1.0 *vs.* 3.5±2.5; P=0.23). Jeon *et al.* (24) showed that the VAS score was significantly lower in the single-port group. However, they found that the chest tube was removed earlier in the single-port group (12 patients in the single port, 1 patient in the three-port VATS), and the VAS score was not significantly different at POD 1 after exclusion of these patients (P=0.176). They cautiously suggested that early chest tube removal is the most important factor for pain reduction, not single port VATS (24). In a meta-analysis, Qin *et al.* (37) concluded that single-port VATS groups were significantly associated with lower VAS at 24 and 72 h when compared to the three-port VATS groups (VAS at 24 h: SMD =−0.87; 95% CI: −1.07 to −0.68; P<0.00001; VAS at 72 h: SMD =−0.49; 95% CI: −0.68 to −0.30; P<0.00001). There was no significant difference in the VAS at 48 h between the two VATS groups (SMD

=–0.40; 95% CI: –1.47 to 0.67; P=0.46) (37). There was no study that three-port or two-port VATS is less painful than single-port VATS for the treatment of SP in the studies we reviewed.

Single-port VATS is completely different from conventional three-port VATS in the number of ports. The increased pain in the three-port VATS group can be explained by the large area of the injured intercostal space. However, there is more torqueing of the intercostal nerve in single-port VATS, with all of the instruments and the thoracoscope occupying the same small space. Therefore, it is important to release the levering force in the intercostal space to minimize postoperative pain in single-port VATS. Several thoracic surgeons suggested the use of articulating instruments, specially designed ports and methods to replace the grasper to improve postoperative pain in single-port VATS (13,18,23,24,29). A specialized port or a wound retractor is effective to protect the intercostal nerve and articulatory instruments secure the diamond angle of resection. Yang *et al.* (18) demonstrated a comparative outcome in an SIST group using a single-incision laparoscopic surgery (SILS) port (Covidien SILS PT12; Tyco Health care, Norwalk, CT, USA) and articulating instruments. Wound protector (11/17 reviewed studies) was used mainly in the single-port VATS to protect of intercostal nerve and vascular bundles and secure operative field in this review. Tsuboshima *et al.* (23) proposed a surgical method featuring a chest wall pulley. Son *et al.* (29) described anchoring sutures instead of a grasper to resect a bleb lesion. They emphasized that the skin incision can be decreased and the compression at the intercostal nerve would be relieved with that method (29). These efforts made single-port VATS possible with smaller wound and less intercostal nerve injury in the treatment for SP.

Paresthesia

Chronic post-thoracotomy pain (CPP) is defined as pain that persists over 2 months after thoracotomy surgery. CPP was first reported in 1945 by Blades with a note of chronic intercostal pain in a patient who had a thoracotomy for chest trauma during the Second World War (38). The etiology of CPP is explained by nerve injury resulting in neuropathic pain and dysesthesia, such as numbness, hyperalgesia, and somatic pain, for a long time. So, the paresthesia described by patients may be a component of CPP after thoracic surgery (39). The characteristics of paresthesia are mild pain that is non-debilitating and refractory to conventional analgesic treatments (39). The incidence of paresthesia was estimated at 11–80% (34). Paresthesia can persist for several years after surgery. Sihoe *et al.* (39) found that 21.0% of patients who received VATS for primary SP had paresthesia at 12 months after VATS pleurodesis. The primary goal of VATS is improvements in acute and chronic postoperative pain. In some comparative reports, there was no significant difference in paresthesia development between multi-port VATS and open thoracotomy (40,41). Landreneau *et al.* (42) reported that VATS is associated with less acute postoperative pain and analgesic requirements than thoracotomy, but there was no significant difference in CPP occurrence.

There are several strategies to reduce paresthesia by reducing torque in the wounds, preemptive local analgesia, intercostal nerve block, and early aggressive postoperative pain control in VATS (39). Bolotin *et al.* (43) demonstrated that the intercostal nerve block group required a significant decrease in the postoperative analgesic requirement (20±18 *vs.* 50±21 mg of pethidine) for patients who underwent VATS bilateral sympathectomy (43). In 1995, Yim (44) proposed five measures to minimize chest wall trauma in VATS. (I) Flex the operating table to drop the hip so that it will not interfere with the maneuvering of the thoracoscope. (II) Avoid torquing of the thoracoscope. A 30° lens is helpful (III) and does not require a rigid port for instruments. Instruments are introduced directly through the wound (IV), and smaller telescopes (5 mm) are used for simpler procedures (V) to deliver specimens through the anterior port because the anterior intercostal spaces are wider (44). Katz *et al.* (45) reported that early postoperative pain was the only factor that significantly predicted long-term pain.

It is difficult to evaluate paresthesia objectively because of the subjective assessment by patients in the heterogeneity of chronic pain descriptions, such as ‘pins and needles’, ‘numbness’, and ‘swelling’. In general, many thoracic surgeons think that single-port VATS have fewer nerve injuries than three-port VATS, so the paresthesia will be less.

We reviewed paresthesia in eight studies (11,15,18,20,24,26-28), which demonstrated favor result in single-port VATS. Jutley *et al.* (11) reported that 86% of patients in the single-port group had no residual neurological symptoms. However, 58% of the patients in the three-port groups complained of symptoms such as ‘pins and needles’ and ‘numbness’ of varying severity (11). Yang *et al.* (18) demonstrated a lower rate of paresthesia in the single-port group compared to the three-port group (33.3% *vs.* 76.9%, respectively; P=0.01). Masmoudi

et al. (46) evaluated three hundred fifty one patients who received single-port VATS for SP and reported at the 30-day postoperative examination that 29.3% of patients described homolateral parietal disorders (discomfort and paresthesia), and 10.6% had chronic pain. In a meta-analysis by Qin *et al.* (37), the rates of paresthesia in the single-port and three-port VATS groups were 19.04% and 58.77%, respectively. The meta-analysis suggested that the single-port VATS groups were significantly associated with a lower rate of paresthesia than the three-port VATS groups (OR =0.13; 95% CI: 0.07 to 0.24; P<0.00001) (36). Another meta-analysis that evaluated 4 studies reported that the postoperative paresthesia rate was significantly lower in the SIST group than in the 3P-VATS group (12). In the eight reviewed articles paresthesia rate was significantly lower in single-port VATS.

Recurrence

The goal of surgical treatment for SP is to prevent recurrence. The recurrence rate of primary SP is as high as 30% after conservative treatment including simple aspiration and closed thoracostomy for the treatment of the first episode (3). Surgical wedge resection is required to reduce the high recurrence rate. Historically, open thoracotomy and surgical pleurectomy have been the standard treatments for recurrent primary SP with a good result in the recurrence (3). The recurrence rate after open thoracotomy and surgical pleurectomy was superior to that after VATS in some studies (35,36,47). Barker *et al.* (30) demonstrated the relative risk (RR) of recurrence in patients undergoing three-port VATS compared to open surgery in a meta-analysis. In the study, the overall RR of both nonrandomized and randomized studies was 4.731 (95% CI: 2.699–8.291; P<0.0001). This result means that three-port VATS is related to a recurrence rate as much as four times that of open surgery. Pagès *et al.* (48) conducted a large propensity score analysis of recurrence after surgical operations of VATS versus thoracotomy for SP with 7,396 enrolled patients from the national database. They found the recurrence rate was higher in the VATS group (3.8%) than the thoracotomy group (1.8%) (48). However, in a recently published meta-analysis with an analysis of seven randomized controlled trials, post-operative recurrence rate was lower in the VATS group compared to the thoracotomy or small incision groups (49). Although VATS has a higher recurrence rate compared to open thoracotomy, VATS is replacing the surgical treatment for SP because the other perioperative outcomes are better (30,35,36).

Bullectomy alone is associated with a high post-operative recurrence rate of between 9.5% and 24.5% (50,51). Additional procedures including mechanical pleurodesis and coverage techniques to get pleural symphysis or visceral pleura thickening have been conducted simultaneously to reduce the recurrence rate. Historically, mechanical pleurodesis has been considered a reasonable treatment for the prevention of recurrence. Pleural abrasion is slightly less effective compared to pleurectomy to get pleural symphysis but there are few good comparative case-controlled studies (3). Mechanical pleurodesis is more frequently conducted through open thoracotomy than VATS (30). This fact could be one of the causes of the better recurrence rate in thoracotomy (30). However, there are some disadvantages including greater blood loss, increased post-operative pain and a longer hospital stay in mechanical pleurodesis with thoracotomy (30). Lee *et al.* (51) conducted a randomized controlled comparative study of staple line coverage with absorbable cellulose mesh and fibrin glue after bullectomy in VATS for PSP. A total of 1,414 patients in 11 hospitals were enrolled in the study. They found the overall recurrence rate was 13.8% in the coverage group and 14.2% in the mechanical pleurodesis group (51). They showed that the coverage technique was not inferior to mechanical pleurodesis (51). These additional methods have been applied more effectively in the VATS for SP to improve surgical outcomes. Three-port VATS gradually replaced open thoracotomy for the persuasive reasons of better cosmesis, less pain, and better perioperative outcomes. Recently, the VATS procedure became the standard of treatment for SP. In the reviewed studies (17 studies), mechanical pleurectomy was conducted in 3 studies, mechanical abrasion in 8 studies, coverage methods in 5 studies and talc pleurodesis in a study. As the demand for less invasiveness increased, single-port VATS increased in the field of treatment for SP.

We reviewed 13 studies to evaluate the recurrence rate after single-port VATS compared to three-port VATS (11,14-18,21-26,28). Jutley *et al.* (11) reported that there was no recurrence after single-port VATS and only one case after three-port VATS. They suggested that single-port VATS allows for good exposure and adequate resection of affected areas of the lung. Song *et al.* (22) reported two recurrences in the SITS group (n=37). However, there was no recurrence in the three-port VATS group (n=23). Salati *et al.* (15) found that the single-port approach did not increase the risk of recurrence of pneumothorax (10%

single-port *vs.* 13% three-port). Tsuboshima *et al.* (23) demonstrated comparative postoperative recurrence rates of SIST and three-port (11.8% *vs.* 14.2%, respectively). Yoshikawa *et al.* (14) reported that the differences in the recurrence rate between the U-VATS and 3P-VATS groups were not significant during the first 2 years postoperatively (2.5% and 4.2%, respectively, P=0.44). Chen *et al.* (17) reported a higher recurrence rate in the three-port group than in the single-port group (7.7% *vs.* 2.8%, respectively). However, the follow-up period was longer in the three-port group (30 *vs.* 16.3 months), so they explained that if the follow-up periods were similar, the difference between the two procedures would be smaller (17). A prospective randomized trial showed that there was no significant difference in the recurrence rates (5%) between the three groups (single-, two-, and three-port VATS) (P=0.769) (25). Jeon *et al.* (24) reported two recurrences after single-port VATS (5%) and four recurrences after three-port VATS (8.7%) without a difference (0.681) in the mean follow-up period of 27±6 months. In a meta-analysis, there was no significant difference in recurrence rate of single-port VATS compared to multi-port VATS in all reviewed studies (12).

Satisfaction

We reviewed 7 articles (16,18,19,25-28) to evaluate satisfaction with single-port VATS for SP. In the six studies satisfaction score was better in single-port VATS. Yang *et al.* (18) reported that the single-port group was associated with a higher satisfaction rate regarding wound scarring (70.4% *vs.* 30.7%; P=0.03). Ocakcioglu *et al.* (21) showed a significantly better score in the satisfaction scale scores of patients in the single-port group at the 24th and 48th hours after surgery (P=0.038, P=0.046). Wang *et al.* (28) demonstrated that the single-port group was related to significantly better scores on the patient satisfaction scale at 24 hours postoperatively than the two-port group. As seen in this review, patients who received single-port VATS for SP were more satisfied with the treatment than the multi-port VATS groups. A good satisfaction score is related to less pain, early recovery and better cosmesis.

Conclusions

VATS has been the main surgical procedure for SP since the 2000s because it is less invasive than open thoracotomy. VATS is related to a better perioperative outcome, better cosmesis, less postoperative pain and better satisfaction, although the recurrence rate is slightly higher than that of open thoracotomy. There is a steady demand to reduce the number of ports to achieve the least invasiveness. In this review, although single-port VATS has its practical drawbacks of confliction of instruments and visual field limitation, there is no evidence for inferiority of single-port VATS in the parameters of operative time, chest tube drainage, hospital stay compared to conventional multiport VATS. In majority of the reviewed studies which analyzed postoperative pain, paresthesia, these parameters were better in single-port VATS. There is some limitation to objectively evaluate the operative outcomes of single-port VATS for SP because this study is not systemic review with enough evidence of randomized controlled trials. However, single-port VATS is not inferior in terms of postoperative outcomes compared with multiport VATS, and it is a safe, feasible and reproducible surgical procedure for SP.

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