Review Article

Single port VATS: recent developments in Asia

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Abstract: Single port video-assisted thoracic surgery (VATS) is the most recent evolution in minimally invasive thoracic surgery. With increasing global popularity, the single port VATS approach has been adopted by experienced thoracic surgeons in many Asian countries. From initial experience of single port VATS lobectomy to the more complex sleeve resection procedures now forming part of daily practice in some Asia institutes, the region has been the proving ground for single port VATS approaches' feasibility and safety. In addition, certain technical refinements in single port VATS lung resection and lymph node dissection have also sprung from Asia. Novel equipment designed to facilitate single port VATS allowing further reduce access trauma are being realized by the partnership between surgeons and the industries. Advanced thoracoscopes and staplers that are narrower and more maneuverable are particularly important in the smaller habitus of patients from Asia. These and similar new generation equipment are being applied to single port VATS in novel ways. As dedicated thoracic surgeons in the region continue to striving for excellence, innovative ideas in single incision access including subxiphoid and embryonic natural-orifice transluminal endoscopic surgery (e-NOTES) have been explored. Adjunct techniques and technology used in association with single port VATS such as non-intubated surgery, hybrid operating room image guidance and electromagnetic navigational bronchoscopy are all in rapid development in Asia.

Keywords: Asia; single port; uniportal; video-assisted thoracic surgery (VATS)

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Introduction

The early 'prototypes' of the modern video-assisted thoracic surgery (VATS) was nothing more than a rigid tube with a rudimentary light source. The technological advancements over the last three decades, in particular videothoracoscopes, linear staplers and dedicated endoscopic instruments, have rapidly allowed VATS to become in vogue, as surgeons and patients gradually acknowledge VATS's technical feasibility but also associated reduced postoperative morbidity when compared with conventional open thoracotomy approaches. In the 1990s, Asia was rapid to embrace this new technology and became pioneers and leaders in many of the VATS procedures (1). Nowadays VATS has become the first line approach for the vast majority of thoracic operations in many Asian countries.

Despite a dramatic reduction in wound size and its associated morbidity in VATS, injury to the intercostal nerves and related chronic chest wall pain and paresthesia remain problematic. Apart from taking general steps to avoid intercostal nerve injury during VATS (2), thoracic surgeons have tried to minimize access trauma by pushing the limits of ever smaller accessory port sizes by using for example 3 mm needlescopic instruments and scope. A more recent development is the introduction of single (uni)port or incision VATS which has the advantage of involving only one intercostal space and nerve for access to thoracic surgery. Single port VATS lung resection was first

reported in 2004 by Rocco for relatively simple lung wedge resections (3,4), and then advanced to, nowadays, major anatomical lung resections (5).

The technical feasibility, steep learning curve and excellent early outcomes of the 'ultra-minimally invasive' single port VATS have allowed many experienced Asian thoracic surgeons to quickly adopt this approach. Furthermore, with the meticulous skills and innovative minds of surgeons in the region, single port VATS has evolved and branched into many fascinating niches (6). This review will highlight some of the milestones and triumphs that have defined single port VATS in Asia over the recent few years.

Safety and feasibility of single port VATS for major lung resection

The feasibility and safety of a new technique is the cornerstone to its development. Single port VATS lung resection faced the same criticisms and questions as conventional VATS when it was introduced of procedural safety and oncological efficacy, which is paramount in oncological surgery. The Asian experience is particularly valuable because the patients are generally smaller with narrower rib spaces and have less instrument operating space. Furthermore, a higher proportion of patients are likely to have adhesions, some of which may be very dense due to infection such as TB, hence providing the ideal proving ground for a novel minimally invasive approach.

The safety and efficacy of conventional VATS major lung resection is well established in Asia (7,8). The Taiwan group has been one of the earliest to report their initial results for the safety and feasibility of single port VATS for major lung resection on 19 selected patients (9). Subsequently, the single port VATS technique was shown to be very adaptable and became widespread over multiple centers within the region with satisfactory early results, including other centres in Taiwan (10), Korea (11), Hong Kong (12), Singapore (13), and China (14). All of the reports showed single port VATS is safe and effective to perform, and is associated with minimal pain, low morbidity, mortality, and conversion rate (2.5–5.3%). A large-scale comparative study from China (15) showed that single port VATS was at least not inferior to conventional VATS in terms of intraoperative and postoperative outcomes. Furthermore, the Japanese study revealed that single port VATS was not only equally safe and effective compared with conventional VATS, but also reduced postoperative wound discomfort and analgesics requirement (16). In other words, experiences from Asia shows single port VATS does not seem to compromise patient safety, and can in fact improve patients' early outcomes following surgery by reducing the complications from surgical access trauma.

The other aspect of any minimally invasive surgery for oncological disease is the concern of adequate cancer clearance. Many in the past have questioned whether conventional VATS lobectomy can produce an equivalent disease free survival and long-term outcomes when compared to open thoracotomy (17). On the contrary, there is data to suggest that conventional VATS may be associated with better survival outcomes due to less postoperative immune dysfunction, and equivalent or better lymph node dissection (18,19). The limited access of single port VATS has also been criticized for limiting mediastinal lymph node dissection, which can have impact on long-term survival. A recent Taiwan study addressed this issue by demonstrating that the total number of lymph nodes dissected via single port VATS can be even higher than that from conventional VATS, suggesting that the former technique does not compromise lymph node dissection (20). Although we are still eagerly awaiting the 5-year survival data from single port VATS centres around Asia, the 2-year disease free survival rate seems equivalent to conventional VATS (12).

Technical refinements

The desire for continuous refinement in surgical techniques and to minimize access trauma has always been a high priority amongst the thoracic surgical community. Although the single port VATS access may cause less pain and further improve cosmesis, even experienced VATS surgeons can find the limited access challenging due to the cramping of instruments, and difficulty in achieving stapling angles (12). Almost from the beginning of single port VATS major lung resection, there have been initiatives to develop new techniques and instruments, above and beyond what is available for conventional VATS, to overcoming these restrictions (21). The widespread use of the single port VATS technique in Asia has also been the driving force for research into some of these advancements and refinements.

The most popular thoracoscope used in conventional VATS is the 10 mm 0° or 30° rigid rod lens system. However, in single port VATS where all the instruments share a single incisional port, significant instrument fencing can occur hindering progress. To reduce instrument fencing, surgeons have used 5 mm scopes for single port VATS to reduce the amount of space the scope occupies

within the incision despite its more limited width of vision (22-25). The advent of wide-angled rigid thoracoscope (Endocameleon, Karl Storz, Germany) (26), which has a rotating prism mechanism at the scope tip to allowed vision between 0° and 120°, can facilitate the manipulation of other instruments by reducing the need for wide movements of the scope to achieve the viewing angles. Meanwhile, the wide viewing angles can be achieved by making the scope more 'flexible' with the introduction of a 5.4-mm diameter deflectable tip thoracoscope (Olympus EndoEYE™ LTF-VP laparo-thoraco videoscope; Olympus, Tokyo, Japan). The initial experience from a group in China showed that it allowed excellent visualization of the whole hemithorax without interfering with other instruments, and moreover the scope could be held by the assistant standing opposite to the surgeon further reducing interference (27).

Endostaplers are important instruments for the division of hilar or segmental vascular and bronchial structures in VATS major lung resections. These devices were initially designed for use in general surgical laparoscopic procedures, and later adapted by thoracic surgeons for VATS. During multiport VATS the endostapler may be inserted through the different ports to obtain appropriate stapling angles. However, in single port VATS the endostapler not only occupy the single incisional port fencing with other instruments, but also has limited stapling angles through the one incision despite the flexible stapler tip. An endostapler with single port VATS in mind was developed, whereby the size of the shaft is significantly reduced minimizing the space occupied at the incision which also decrease fencing, and the angle of flexion at the tip is increased widening stapling angles. International studies as well as the experience from Hong Kong showed such new stapler design (ECHELON FLEX™ powered vascular stapler, Ethicon, Somerville, NJ, USA) was superior to conventional endostaplers in terms of ease of access, need for hilar structure dissection, precision of control, and reducing surgeons' stress (28).

Apart from the development of novel instruments for single port VATS, surgeons through their increasing operating experience have devised certain approach and techniques to facilitate surgery. Fine adjustment of the traction angle of hilar structures can be created and made easier by vertical overhanging of traction belts inside the thoracic cavity to facilitate placement of endostaplers, described by Liu's group in China (29). Along similar ideas for dealing with difficult stapling angles but for the lung parenchyma, a novel technique of lifting up the target parenchyma by a single anchoring suture which allows 2-directional traction was also described by a Korean group (22). These techniques reflect that surgical advancements do not always rely on better instruments, but can originate from creativity of experienced surgeons.

The boundaries of performing major lung resection through smaller single port VATS incision are constantly being challenged. Single port VATS surgeons who have gained considerable experience can further reduce their incision size, particularly in segmentectomy that is associated with smaller tumour sizes (30). Korean surgeons have taken up this challenge with great success first for benign lung diseases using a 2.5-cm single incision, with no conversions and satisfactory post-operative outcomes (23). Moreover, their modified approach to the anchoring and purse-string skin sutures for the drain can further improve cosmetic outcome by transpiercing the intercostal muscles 1 cm below the main transthoracic port and anchoring directly by a stitch originating from the subcutaneous suture (24). Recently, Kim's group have reported successfully performing a left upper division single port VATS segmentectomy via a 2-cm incision, further pushing the limits of minimal invasiveness in single port VATS surgery (31).

Novel approaches and future direction in Asia

The interest in single port VATS in Asia has led to many new ideas and innovative approaches from the region. The possibility of totally avoiding intercostal nerve injury and its complications was first realized by Suda's group in 2012, when they performed a thymectomy through an infrasternal approach (32). He was later able to show that this approach to thymectomy was associated with less operative duration, blood loss, and pain when compared with conventional VATS surgery (33).

Furthermore, with the high prevalence of bilateral pulmonary nodules in Asia which often require diagnostic surgical biopsy, the Japanese group reported the use of a single subxiphoid incision to access both pleural cavities for bilateral lung wedge resections (34). Such an innovative approach to avoid intercostal nerve injury was noted by Liu's group from Taiwan, who then performed the world's first subxiphoid lobectomy in 2013, providing the evidence needed that subxiphoid approach is a contender for thoracic access approach of the future (35). Interestingly, by traversing the anterior mediastinum, bilateral lung wedge resection have also been described through a unilateral single intercostal incision (36). The potential benefits of

limited access in these two approaches, and their utilization will require further studies.

In pushing the horizon for the best cosmetic outcome and least wound morbidity, Asia surgeons have been pioneering thoracic surgery that avoids skin incision and uses natural access "wounds" of the body. Recently, Zhu *et al*. from China reported the world's largest clinical experience of embryonic natural-orifice transluminal endoscopic surgery (e-NOTES) technique for bilateral thoracic sympathectomy in the treatment of hyperhidrosis (37). Using a modified gastroscope via the umbilicus transdiaphragmatic route, they showed this technique was safe, efficacious, had excellent cosmesis as well as patient satisfaction, and at the same time avoided the morbidities of chronic chest wall pain and paresthesia. In order to expand the applications of e-NOTES, a Taiwan group was able to perform transumbilical anatomic lobectomy of the lung (TUAL) in a canine model. Following surgery, the dogs survived well, demonstrating that e-NOTES's safety and feasibility may be extended to major thoracic surgical procedures (38).

Apart from pushing for further improvements in single incision access in thoracic surgery, Asia has also been at the forefront of developing pulmonary lesion localization techniques. The ability of the surgeon to palpate small pulmonary lesions is widely accepted to be impaired during VATS because of the limited access, and for the same reason, the difficulty in localization may be more significant during single port VATS. The use of preoperative localization techniques in identifying small pulmonary lesions is not new, and there are many techniques available. Use of computer tomography-guided percutaneous dye or radioisotope injection, percutaneous hookwire localization, and electromagnetic navigation bronchoscopic dye marking or placement of fiducials are only some of the available options (39). In the use of percutaneous hookwire localization in single port VATS, the appropriate placement of the wire may potentially allow reduction of incision size in single port VATS lung resection, by allowing a more ergonomic placement of endo stapler as well as intraoperative traction of lung nodule through the wire (40). In Hong Kong, we have also pioneered the use of hybrid operating theatre to perform image guided single port VATS major lung resection for small lung tumours (41). The availability of real-time DynaCT scan (Siemens Medical Solutions, Erlangen, Germany) in the hybrid theatre setting allows guided hookwire insertion and repositioning, which can be followed immediately by single port VATS lung resection in the same operating suite. The localization and surgical workflow using the hybrid set up not only reduces the risks associated with transfers and delays during which the patient may develop pneumothorax and hookwire displacement, but also, for lung lesions unable to be localized by hookwire, allowed on-table imaging to aid localization of lesion and achieve adequate margins (42). The pioneering use of imaging facilities in the hybrid theatre have also been applied to electromagnetic navigational bronchoscopy, to improve navigational accuracy of very small lesions, as well as to provide more precise and to confirmation successful marking of pulmonary lesions (43,44).

The idea of having "fast-track" recovery has recently come in vogue, and one of the important aspect of a surgical patient's journey that can be improved to boost faster recovery and discharge, is the use of lighter anaesthesia. The idea of performing conventional VATS with non-intubated anaesthesia using only regional anaesthesia and conscious sedation in experienced centres is well established (45). For the advocates of single port VATS, with only an incision over one intercostal space, the argument for and the benefit of solely regional anaesthesia should be theoretically greater compared to conventional 3-port VATS. The success and safety of this anaesthesia approach was reported in a series of 32 patients who received single port VATS for management of peripheral lung nodules in Taiwan (46). Its feasibility and application in single port VATS lobectomy was reported by Gonzalez-Rivas Diego in the same year (47). Furthermore, in selected paediatric cases, the non-intubated technique can be feasible, in this case for a 5-year old Korean girl undergoing single port VATS draining tube adjustment (48). Being associated with less side effects and complications from conventional general anaesthesia as well as the least surgical access trauma, the non-intubated single port VATS technique can be expected to extend the candidacy for major lung resection, especially for those who were judged to be at high risk for VATS under general anaesthesia due to poor lung function or other comorbidities. More extensive studies on its clinical benefits and long-term outcomes from our Asian centers are warranted.

Conclusions

Single port VATS development in Asia has been rapid. The already experienced VATS surgeons in Asia have taken the lead in many aspects of single port VATS, to improve our understanding of the new technique's safety and efficacy, and to further refine the approach through innovative

technical refinements. Although the critics will point out that not all if any of these refinements could be translated into improved clinical outcomes, on the contrary, it is such attitude to innovate and push the boundaries that has driven advances in many facets of VATS. From the Asian experience, it is foreseeable that single port VATS will continue to develop and flourish in the region.

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Footnote

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

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