Recent developments in uniportal VATS in Asia and beyond

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Contributions: (I) Conception and design: All authors; (II) Administrative support: CS Ng; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: PS Yu; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Abstract: Asian countries have been active in adopting and utilizing uniportal video-assisted thoracic surgery (VATS) for management of pulmonary and mediastinal pathologies. With accumulation of experience, the benefits of uniportal over conventional VATS are becoming more established through scientific studies. The limit in terms of safety and feasibility of uniportal VATS for more complex thoracic surgical condition continue to expand, as surgeons are more prepared to extend the applications of the approach beyond their comfort zone. Early diagnosis and treatment of small lung nodules have been facilitated by the safety of non-intubated technique and the availability of accurate localization adjuncts.

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

Received: 14 July 2018; Accepted: 17 August 2018; Published: 03 September 2018.
doi: 10.21037/jovs.2018.08.10
View this article at: http://dx.doi.org/10.21037/jovs.2018.08.10

Introduction

Uniportal video-assisted thoracic surgery (VATS) approach has been adopted by experienced thoracic surgeons in many Asian countries, and has continued to develop and flourish in this region (1). By walking through the test of time and gradually building up experience, many Asian centres have championed and pioneered techniques in uniportal VATS in the management of thoracic surgical diseases. A significant number of retrospective, as well as emerging prospective scientific investigations have been carried out to ascertain the safety profile of the technique and the post-operative outcomes achieved, demonstrating at least comparable or better outcomes to the conventional multi-portal VATS. The uniportal approach has also led to renewed interest in non-intubated procedures further reducing the operative stress to patients undergoing pulmonary resections that is safe in select patient populations. With increasing disease burden from small pulmonary lesions, various adjuncts to accurately localize small lung nodules to facilitate the early diagnosis and treatment via uniportal VATS have been proposed. The management of small pulmonary lesions will likely continue to be an important and ongoing trend for further advancements and development.

Consolidated safety and efficacy

There is increasing acceptance for the safety and potential benefits of uniportal VATS, which has been supported by scientific evidence, albeit retrospective data. Based on a number of studies and reports of early experience with uniportal VATS for anatomical lung resection (2-11), further affirmative studies have been carried out in a number of Asian thoracic centres. A recent large study gathered the experience of uniportal VATS for lobectomy and anatomical segmentectomy from 5 Asian hospitals (12). Compared to conventional multiport VATS, uniportal VATS was associated with longer operative time and more intraoperative blood loss, but resulted in shorter chest drainage duration, length of hospital stay, and post-operative pain. Another propensity-matched study by Song *et al.*, apart from echoing the comparable safety and efficacy of uniportal VATS lobectomy with the multi-portal ones, also showed that a higher number of dissected mediastinal

lymph nodes can be yielded (13). Even for anatomical segmentectomy which is technically more challenging than lobectomy, when performed via uniportal VATS can achieve similar safety profile to multi-portal VATS (14). Another conjoint study by the Taiwan and Spanish group demonstrated uniportal VATS anatomical lung resection could achieve low peri-operative mortality (~0.7%) and excellent disease-free survival over 2 years (75–92% for stage IA, 62.1% for stage 1B, 55.6% for stage 2A, and 47.1% for stage 2B) comparable to the American Joint Committee on Cancer 8th staging system data (15). These refuted the criticisms that less-invasive approach may be associated with less effective tumor clearance. Although robotic-assisted thoracoscopic surgery (RATS) might be associated with further less intraoperative blood loss and more comprehensive lymph node dissection (16), the set-up costs and cost-effectiveness might limit its applicability and maneuverability. Due to the minimally-traumatic nature, uniportal VATS has allowed the implementation of enhanced recovery program which encompassed a series of modified perioperative and intraoperative care (e.g., pre-operative training and preparation, light general anaesthesia, aggressive pain control, restrictive fluid transfusion, etc.) to reduce postoperative pain, and shorten chest drainage duration and length of hospital stay (17).

Uniportal VATS is well established for the surgical treatment of mediastinal diseases, such as thymectomy (18). Its comparable safety to multi-port VATS for mediastinal pathologies was also ascertained by Li *et al.* from China in their propensity-score matched case control study. Uniportal VATS achieved no mortality or major morbidities, while exhibited shorter operation time, less blood loss, and less postoperative pain for thymoma and other mediastinal diseases (19). Perioperative safety and prevention of recurrence remained the benchmarks for uniportal VATS for primary spontaneous pneumothorax. The benefits of uniportal VATS for major lung resection in reduction of operative time, drainage duration and hospital stay were again observed in the cases of primary pneumothorax from the Korean study (20). Their rate of recurrence requiring intervention after uniportal VATS remained comparable to conventional VATS (7.2% *vs.* 13.0%, P=0.255) over their two and a half years study period. A meta-analysis published by Yang *et al.* including 7 out of 9 Asian studies revealed shorter hospital stay, and less post-operative pain and paresthesia after uniportal VATS. While the operative time & chest drainage duration were not particularly outstanding, the similar complications rates and recurrence rates compared to conventional VATS may well justify the utilization of uniportal VATS for this benign disease (21). As the single incision created at the anterolateral chest avoided the need of a lateral port for camera and a posterior port for instrumentation, Kim *et al.* from Korea reported performing simultaneous bilateral uniportal VATS for pneumothorax in the supine position without the need of changing patient's position when preparing to perform the contralateral procedure (22).

Subxiphoid incision as an alternative to intercostal incision for thoracic surgery brings a solution to intercostal neuralgia and chronic thoracotomy pain. From the experience of Liu *et al.* and his 40 patients from Taiwan, with careful selection of patient and instruments, subxiphoid uniportal VATS could be safely performed for lung resections (23). Instrument fighting, interference by the beating heart, limited mediastinal lymph node dissection, and limited ability to handle complex conditions (such as anthracotic lymph nodes, diffuse adhesion, and major bleeding) remained some of the technical challenges. However, based on these initial experiences, its application had been extended to anatomical lung resection (24). Song *et al.* from China ascertained the advantage of subxiphoid uniportal VATS for lobectomies in terms of significantly reduced post-operative pain without compromising safety (e.g., blood loss, chest drainage output and complications, etc.) and efficacy (e.g., lymph nodes harvested, chest drain duration and hospital stay) when compared with intercostal uniportal VATS (25). Mediastinal pathologies also appeared easily approachable via subxiphoid uniportal VATS (26,27), and may be equivalent to robot-assisted thymectomy according to a study by Suda *et al.* with their 80 Japanese cohorts (28). Similar to lung resections (29), non-intubated technique could also be applied to thymectomies via single subxiphoid incision with early report by Jiang *et al.* from China (30). As the boundaries of uniportal VATS continue to expand, reports of further experiences, large-series results, and prospective studies are eagerly anticipated.

Applicability: pushing the limits

Uniportal incision does not remain the approach only for routine lung or thymus resections. In the past few years, Asian experts have pushed the safety limits of uniportal VATS. To begin with, simple wedge resections via uniportal VATS could now have intraoperative chest drain insertion avoided, which can reduce post-operative pain and shortened hospital stay (31). The single incision could be

created subareolarly to allow for a better cosmetic result and patient satisfaction, and it was similarly associated with less wound pain and chest wall paresthesia compared with two-port VATS (32). Alternatively, single incision created at the axillary fossa also allowed right upper lobectomy to be performed safely (33). While needlescopic VATS sympathectomy was already cosmetically acceptable, minimizing the number of wounds was also shown to be safe and feasible by a single incision. As reported by the authors' institution with 16 patients, instruments originally used for endoscopic vein harvesting, such as the Vasoview and Hemopro devices (Maquet Inc., Rastatt, Germany), could be used to visualize and dissect the sympathetic trunk through a single wound with satisfactory surgical results and safety profile (34). Lobectomy and segmentectomy for pulmonary sequestration were also safe and feasible via uniportal VATS (35,36). Resection of pulmonary nodules using laser (37), rib resections (38), resection of epiphrenic esophageal diverticula (39), or oesophagectomy (40,41) via uniportal VATS were just several more examples of its extended applicability in a number of Asian centres. Airway anastomosis after complex major lung resections is feasible assisted by endoscopic knot-pushers (42). Chen *et al.* from China reported their experience of 8 cases with uniportal VATS sleeve lobectomy, with reasonable safety profile and without early recurrence or bronchial anastomosis complications (43). Spontaneous ventilation avoided the interference of endoscopic anastomosis by the endotracheal tube, which makes trachea resection and anastomosis feasible via uniportal VATS (44). Vascular anastomosis via single incision was also made feasible in Asian centre (45).

The narrow safety window of lung biopsy for interstitial lung diseases can be widened by the combination of single-incision which reduces post-operative pain and lung function compromise, and spontaneous-ventilation anaesthesia which prevents airway trauma, residual neuromuscular blockade and other pulmonary complications related to intubation anaesthesia (46-50). More experience was also gathered by Hung *et al.* on 116 Taiwan patients using non-intubated uniportal VATS lung resection, showing its safety and efficacy (51). Experience gathered by Moon and his Korean colleagues identified advanced age and high body-mass index were risk factors for conversion to intubation, but overall the use of non-intubated uniportal VATS did not compromise safety in their cohort of 115 patients (52). Another series by Li *et al.* from China on younger patients with reasonable body-mass index (<25 kg/m^{-2}) completed tubeless procedures without the need of conversion to endotracheal intubation (53). Similarly, applicable to parapneumonic empyema, Hsiao *et al.* from Taiwan performed 12 non-intubated uniportal VATS decortications, and showed shortened chest drain duration, fever duration, length of stay, and lower mortality compared to tube thoracostomy alone (54). This early promising result probably justify the use of a more aggressive surgical approach for the fibrinopurulent stage of empyema due to its high efficacy and low invasiveness.

Early pathological diagnosis of small pulmonary nodules of uncertain nature in adequate clinical context is gaining acceptance due to reduced surgical trauma from the single incision, and the availability of accurate localization techniques (55). Yu *et al.* from the authors' centre described 12 (out of 32) cases of uniportal VATS wedge resection of tiny pulmonary nodules localized by hookwire insertion with real-time image guidance by cone-beam CT images in the hybrid operating theatre (56). The overall cohort achieved 100% accurate localization and clear margin of resection, with no hookwire dislodgement and a shorter 'at-risk' period of pneumothorax progression when compared to localization performed in a separate radiology room. Shi *et al.* from China also reported 13 cases of pre-op microcoil localization of small lung nodules which were successfully resected via uniportal VATS without complications or recurrence upon follow-up (57). The safety of non-intubated anaesthesia further minimized operative stress to patients. Tsai *et al.* from Taiwan performed 110 non-intubated uniportal VATS wedge resections for subcentimeter lung nodules localized by pre-op CT-guided dye marking localization (58). Clear resection margins were achieved in all cases of early-stage adenocarcinoma. Conversion rate (to multi-portal VATS or endotracheal intubation) and morbidity rates were reasonably low. Furthermore, in Hong Kong, electromagnetic navigation bronchoscopy (ENB) also became a useful adjunct for the localization of peripheral lung nodules by injection of dye agent or deployment of fiducial to the lesion through the endobronchial route (59-62). The combination of hybrid OR and ENB can further facilitates accurate localization and resection of small lung nodules via uniportal VATS.

Conclusions

Uniportal VATS development in Asia continued to be rapid, thanks to the interest and devotion of experienced VATS surgeons in the region. More evidence establishing the safety and efficacy of uniportal VATS and its advantages

over conventional VATS were made available, and the applicability of this minimally invasive technique has been extending. In leading some of the trends in uniportal VATS development, the Asian experience will continue to steer its role in management of thoracic surgical diseases.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editor (Jose Luis Danguilan) for the series "Dedicated to the 6th Asian Single-port VATS Symposium 2018" published in *Journal of Visualized Surgery*. The article has undergone external peer review.

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jovs.2018.08.10). The series "Dedicated to the 6th Asian Single-port VATS Symposium 2018" was commissioned by the editorial office without any funding or sponsorship. CN reports Consultant for Johnson & Johnson, Medtronic and Siemens Healthineer. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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doi: 10.21037/jovs.2018.08.10
Cite this article as: Yu PS, Ng CS. Recent developments in uniportal VATS in Asia and beyond. J Vis Surg 2018;4:184.

