Feasibility of Using a Vessel Sealing System in a Human Pulmonary Lobectomy: A Retrospective Comparison of This Procedure with or without a Vessel Sealing System

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Objective: Despite recent advances in video-assisted thoracoscopic lobectomy, some technical limitations still remain. Our current study purpose was to determine if the vessel sealing system (VSS) has utility in this procedure.

Method: 112 patients who underwent an anatomic pulmonary lobectomy at our institute were evaluated retrospectively. The burst pressure of pulmonary vessels, which was divided into VSS (VSS group; n = 44) or manual ligature (ligature group; n = 53) groups, was measured experimentally in transected lungs. Perioperative clinical data was also retrospectively evaluated in patients treated with (VSS group) or without using VSS (n-VSS group).

Results: Burst pressures achieved adequate strength in both the VSS (600.0 ± 436.8 mmHg) and ligature (1057.4 ± 462.3 mmHg) groups. Compared with the n-VSS group, the VSS group patients showed lower intraoperative blood loss (115.4 ± 181.1 vs. 183.3 ± 159.1 ml), lower chest fluids by 3rd post-operative day (POD) (533.8 ± 264.8 vs. 705.3 ± 339.3 ml) and a shorter period of chest tube duration (4.1 ± 1.2 vs. 5.4 ± 2.4 days). No serious complications or perioperative (30 days) deaths occurred in either group.

Conclusion: The VSS device has the advantage in pulmonary lobectomy procedures, especially those involving video-assisted thoracic surgery (VATS).

Keywords: pulmonary lobectomy, VATS, vessel sealing system

Introduction

Vascular division is a critical procedure during an anatomic pulmonary lobectomy and manual ligation and staplers are commonly used.1,2) However, with the advent of video-assisted thoracoscopic lobectomies, manual ligation has become technically more difficult through the use of small thoracoscopic ports. As an alternative procedure, the use of a clip has been considered but this is an unreliable option for pulmonary vessels. Endostaplers are also quite feasible but are very costly and unsuitable for small vessels.

The vessel sealing system (VSS) was developed for vascular sealing. The Ligasure VSS device (Valleylab, Boulder, Colorado, USA) is a bipolar thermal vessel sealer, which uses heat energy to denature collagen, elastin and thereby achieve vessel sealing. Ligasure has proved to be a popular device for abdominal surgery, where it has been used to divide vessels, such as the short gastric of video-assisted thoracoscopic lobectomies, manual ligation has become technically more difficult through the use of small thoracoscopic ports. As an alternative procedure, the use of a clip has been considered but this is an unreliable option for pulmonary vessels. Endostaplers are also quite feasible but are very costly and unsuitable for small vessels.

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artery and splenic artery. The advantages of this instrument include low cost, good control of hemostasis, and the fact that no foreign body remains after the procedure. However, the Ligasure has not been readily adopted for thoracic surgery for which only a few cases of the use of VSS have been reported. Kennedy, et al. previously measured the burst pressure of the lung tissue in a swine model, using a fixture that progressively increased the volume in an occluded vessel segment. Albanese, et al. have reported the use of thoracoscopic lobectomy for prenatal patients, in which the main pulmonary vessels were successfully sealed using VSS.

Few clinical and experimental cases of a human anatomic pulmonary lobectomy have been reported to date. Additionally, very few comparisons of peri-operative data from VSS treatments and conventional procedures using an electrocautery device and manual ligature have been documented for human pulmonary lobectomies. The purpose of our current study was to retrospectively determine if VSS can be safely used to divide the pulmonary vasculature and provide benefits over manual ligature and electrocautery methods during an adult pulmonary lobectomy.

Methods

Patients

This study was approved by the institutional review board of Shinshu University, and informed consent was obtained from each patient.

One hundred and twelve patients who underwent anatomic pulmonary lobectomy in our institute between 2008 and 2009 were evaluated retrospectively.

Operative technique

An anatomic lobectomy (n = 112) was performed for all patients. Surgical approaches involved either a thoracotomy or VATS. A VATS approach was used in 55 cases (n = 33 in the VSS group, n = 21 in the non-VSS group). Thoracotomies were usually performed through the fourth intercostal space for an upper lobectomy and fifth center costal space for a middle or lower lobectomy. For VATS lobectomies, four ports were usually placed, one at the fourth, two at the sixth and one at the eighth intercostal space. Divisions of the larger vessel (than segmental branch) and thick pulmonary parenchyma were performed in either group using a stapler. For small vessel division and lymph node dissections, the Ligasure device was used in the VSS group, and manual ligature and/or conventional electrocautery was conducted in the non-VSS group (n-VSS). We performed a ligature at the central site even in the VSS group to provide additional assurance that the seals would not fail if contact was inadvertently made with another instrument.

Experimental phase

Acute burst pressure of the human pulmonary artery

Experiments were performed using resected lung lobes obtained by lobectomy. The diameters of each artery were measured. In the VSS group, electrical thermocoagulative fusion of the pulmonary vessels was performed using a LigasureV instrument (LS; Valleylab, USA). In the ligature group, manual ligature was performed using 3–0 vicryl. The segmental, subsegmental or small pulmonary arteries were sealed or ligated, and divided. A pulmonary vessel in a transected lung was measured for the diameter immediately, then cannulated with a plastic 20 gauge angiocatheter. The angiocatheter was attached to a digital pressure monitor to record the maximal intraluminal pressure (mmHg). To inject saline into the arterial lumen at a constant rate, the maximal burst pressure was recorded. Sealing by VSS was performed in 44 vessels and by ligature in 53 vessels. Because pulmonary vein is usually dissected by stapler for lobectomy, only pulmonary artery was estimated in this study.

Clinical phase

Fifty six consecutive lung resections using VSS for the division of the pulmonary vasculature were performed in the VSS group. VSS was used for segmental artery branch sealing and lymph node dissection at a minimum. In the n-VSS group (n = 56), manual ligature and/or conventional electrocautery was used for these procedures, as an alternative to VSS.

Hospital course

Clinical features were also evaluated. Perioperative data, operating times, amounts of bleeding, chest tube duration, and fluid levels by 3 POD were analyzed for each patient in the two groups. Chest tubes were removed when the air leaks ceased and the fluid buildup decreased to less than 200 ml/day.

Statistics

Data were statistically analyzed using ANOVA, post hoc testing, and a non-parametric Kruskal-Wallis test. Significance was assigned to P values of <0.05.
Results

Experimental phase

Acute burst pressure

The mean pulmonary artery diameter was 4.5 ± 1.2 mm (2–9 mm; n = 97) overall for both groups. It was 4.3 ± 1.8 mm in the VSS group (n = 44) and 4.7 ± 1.2 mm in the ligature group (n = 53). Table 1 presents data measurements for acute burst pressures in the pulmonary vessels. Ligated vessels provided higher burst pressure (1057.4 ± 462.3 mmHg) than those sealed by VSS (600.0 ± 436.8 mmHg). No unsuccessful seals were observed in any vessel.

Diameter

The correlation between burst pressure and the vascular diameter was evaluated (Fig. 1). In the VSS group, there was a higher tendency for intermediate arteries (700.9 ± 519.8 mmHg; 3–5 mm, n = 16) than smaller (562.8 ± 428.5 mmHg; ≤3 mm, n = 23) or thicker (535.2 ± 278.9; ≤5 mm, n = 5) vessels. In the ligature group, thick arteries (≤5 mm) tend to reveal lower pressure. But there was no significant difference in pressure between each diameter in either group. In comparison, between sealed and ligated arteries, the ligated vessels revealed higher pressure (1057.4 ± 462.3 vs. 600.0 ± 436.8 mmHg). This predominance is demonstrated in each diameter in the ligature group. However, the burst pressure in both groups achieved sufficient strength for the physical conditions.

Clinical phase

Patient characteristics

The patient characteristics are summarized in Table 2. The mean patient age was 67.0 in the VSS and 69.0 in the
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Anatomic pulmonary lobectomy was undertaken only for primary lung cancer or metastases of other organs, no inflammatory disease. There were no statistical differences between the groups in terms of sex, tumor localization (resected lobe), surgical approach and lymph node dissection. The numbers of dissected pulmonary artery without the endostapler was larger in VSS group ($n = 98$) than in n-VSS group ($n = 74$).

**Hospital course**

Peri-operative data were evaluated in both the VSS and n-VSS groups (Table 3). There were no differences in the operating times and bleeding characteristics between groups. A shorter chest tube duration (4.1 ± 2.1 days) and lower fluid by 3 POD (533.8 ± 264.8 ml) presented in the VSS group compared with the n-VSS group (5.4 ± 2.4 days, 705.3 ± 339.3 ml, respectively). No serious complications causing prolonged hospitalization occurred apart from one case of chylothorax in the n-VSS group. There were no perioperative deaths (30 days) in either group.

**Discussion**

VSS is becoming routine for vascular division in abdominal surgery and its feasibility has been particularly evident in endoscopic surgery. For pulmonary lobectomy, however, VSS has not been commonly used to divide the pulmonary artery because of concerns regarding its fragility and histological weakness, for which resulting injuries could result in life-threatening bleeding. A stapler is therefore generally used for a large pulmonary vessel in the same manner as manual ligation for a small vessel.

A VATS lobectomy is currently an accepted oncological procedure for patients with non-small cell lung cancer. During this procedure, ligation of the pulmonary artery and treatment of intraoperative accidental bleeding is often more technically challenging than during a conventional thoracotomy. For this reason, the endostapler has been the primary method adopted for a pulmonary lobectomy. However, the endostapler is costly to use and is not suitable for dividing small vessels. Usually, therefore small vessels are divided using manual ligature although this technique is relatively difficult to perform through a small incision with a TV monitor view using VATS. As an alternative technique for dividing a small pulmonary vessel, VSS is a feasible approach because of its ease of manipulation and relatively low cost.

One of several energy-fusion devices can be chosen to

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<td>Number of dissected vessels (PA) without stapler</td>
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VSS: vessel sealing system; n-VSS: without using VSS; Primary: primary lung cancer; Metastases: metastases of other organ; U: upper lobe; M: middle lobe; L: lower lobe; ND: lymph node dissection. VATS: video-assisted thoracoscopic surgery. PA: pulmonary artery. *: significant

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<th>Table 3 Peri-operative clinical data in the VSS and n-VSS groups</th>
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POD: post operative days. Data are the mean values ± SD. *P <0.05 vs. the VSS group
perform VSS including harmonic scalpels, the Biclamp VIO 300D Electrosurgical system, an Enseal PTS tissue sealing and homeostasis system, and the Ligasure devices. In our current study, we choose the Ligasure because compared with ultrasonic device, the risk of occurrence of thermal injury or cavitation is relatively low with this instrument. In addition, compared with the ultrasonic devices, the Ligasure produces consistently lower temperatures that minimize thermal spread to approximately 2–4 mm.5,8) In our present study, we observed no incomplete seals or thermal injuries among the patient cohort.

VSS is generally applied to vessels in either arteries or veins.3,9,10) Vessels up to 7 mm in diameter can be safely divided and the successful sealing of animal vessels has been reported by several authors. The levels of burst pressures have been measured above the normal physiological range in abdominal3) and pulmonary vessels.11,12) In studies in pigs and cattle, sealing devices revealed 300–350 mmHg acute burst pressure ranges. Lambertton demonstrated that using the LS device resulted in the greatest burst pressure and fastest sealing time in a bovine study.13) In a report on 12 sheep lobectomies, the vascular integrity of divided pulmonary arteries was estimated.14) That study demonstrated that the smaller arteries and veins had no vascular disruption.

These earlier studies have suggested that Ligasure can be applied safely to smaller vessels. However, there have been few previous studies that have evaluated human pulmonary vessels experimentally using this system. Tsunezuka, et al. demonstrated a burst pressure of about 600 mmHg in smaller arteries (<5 mm) in either dry or wet conditions.8) Thick arteries (>5 mm) have revealed lower burst pressures (399–447 mmHg). Our current results from measuring burst pressures showed a level of about 600 mmHg in arteries. This is lower than that in the ligature group (1054 mmHg), but is still thought to provide adequate strength to provide physiologic levels of pulmonary circulation. Resistance to pressure was found to be independent of the diameter (less than 9 mm). Albanese, et al.4) have reported a successful experience with infant pulmonary vein sealing using only VSS. Schuchert and colleagues have also reported successful anatomic lung resection in 316 cases using a Ligasure.5,6) However, there have been few reports of the perioperative advantage of VSS in comparison with conventional techniques without VSS.

The clinical features of treated patients demonstrate that VSS has clear benefits. Kovacs and colleagues analyzed the Ligasure-Atlas for wedge resection of solitary pulmonary nodules via VATS. In their series, patient data (drainage time, fluid loss, hospital stay, etc.) showed no difference between VSS and endostapler treated groups.15) Our current results seems to reveal a few more benefits, compared to these previous findings as the patients in our cohort who underwent a lobectomy in the VSS group showed less bleeding, lower fluid discharge and shorter drainage time compared with the n-VSS group. These results may reflect the advantages of VSS for lymph node dissection. Dissection with a conventional electrocautery device may not provide complete sealing for fine and invisible lymph ducts or very small vessels unlike VSS. This can be explained by the mechanical principles underlying these two techniques. In contrast to electrocautery sealing by heat coagulation only, the Ligasure device produce a permanent seal through the re-organization of elastin and collagen fibers within the vessel wall using a combination of heat and pressure.16) This sealing ability should prevent any oozing or lymph fluid discharge. In addition, the use of VSS allows technically easier and more exact divisions to be performed compared with manual ligation or the use of an electrocautery device, especially for VATS. Molnar, et al. have described a significantly shorter operating time in an animal study using VSS.17) We did not observe a reduced operation time with the use of VSS in our current retrospective study. We predict that the required time for vessel division with VSS should at least be shorter than that involving a couple of ligatures, however, the time in VSS was rather long (not significant). In VSS group, the larger number of vessels was dissected without endostapler while the large lobar branch was dissected with endostapler in n-VSS group. There is a possibility that the difference resulted in relatively long operation time in VSS group.

The efficacy of VSS in dividing the pulmonary parenchyma remains unclear. Although successful wedge resection series using VSS have been reported,11,15) there are few reports of a successful sublobar segmentectomy or division of fissures using VSS. Clarifying the potential of VSS in these types of procedures may reduce the need to use a stapler, leading to a reduction in operative costs.5) Our present results reveal that the ability of VSS sealing to maintain an adequate bursting pressure is satisfactory, as has been reported in a few previous studies. However, the long term durability of VSS remains to be clarified and is why we performed a ligature at a central site even in our patients in the VSS group. Kennedy, et al. previously reported acceptable VSS sealing durability in abdominal vessels for 20 days.3) There are, however, few reports to
date that have examined this issue. If the durability of VSS is confirmed, it may be feasible in the future to divide a pulmonary vessel by VSS alone i.e., without an additional ligature. Because our present data are retrospective, further studies are clearly required. However, our current findings provide a possibility that VSS has benefits for a pulmonary lobectomy, especially when it is performed using VATS.

**Conclusion**

Our current data and previous findings indicate that as a technically easier method for dividing vessels and for lymph node dissection that also involves less blood loss and lower fluid discharge, VSS is a safer approach to a pulmonary lobectomy. The advantages of VSS may also include a reduced length of hospital stay, less post-operative pain and lower costs.

**Disclosure Statement**

There is no financial relationship with a biotechnology manufacturer, a pharmaceutical company, or other commercial entity that has an interest in the subject matter or materials discussed in the manuscript to be disclosed, within the period of 24 months prior to the submission.

**References**