Use of energy-based coagulative fusion technology and lung sealants during anatomic lung resection

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Objectives: Energy-based tissue fusion technology is being increasingly used for vascular division in numerous intra-abdominal applications. Very few data, however, are available regarding the application of this technology in the chest during anatomic lung resection. In the present review, we evaluated the use of energy-based fusion and lung sealants during anatomic lung resection.

Methods: We performed a review of case series and published studies to evaluate the use of energy-based coagulative fusion technology and lung sealants during anatomic lung resection. We then used energy-based coagulative fusion technology during anatomic lung resection (segmentectomy or lobectomy) in 316 cases from 2008 to 2011. Two energy applications were applied to the arterial and venous branches before vessel division.

Results: In the first 12 cases, we used a device with a small curved jaw (range, 3.3–4.7 mm). Two partial venous dehiscences were noted and controlled intraoperatively. For the remaining cases, we used a larger jaw (6 mm × 22 mm) with no arterial or venous dehiscence occurring (vessels ranged from 0.4 to 1.2 cm). Autologous or synthetic tissue sealants applied to the parenchymal staple lines might reduce the severity and duration of perioperative air leaks. Suture line buttressing with pericardial or absorbable biosynthetic polyester strips might reduce the severity of air leaks in patients with severe emphysema undergoing anatomic lung resection or lung volume reduction surgery.

Conclusions: The bipolar tissue fusion system provides a safe and effective technique for the division of the pulmonary arterial and venous branches during anatomic lung resection. Surgical sealants and buttressing adjuncts might reduce perioperative air leak potential. (*J Thorac Cardiovasc Surg* 2012;144:S48–51)

ENERGY-BASED TISSUE FUSION

During the past 75 years, a remarkable evolution of surgical techniques has occurred in the management of the pulmonary vasculature during anatomic lung resection. For many decades, manual ligation by way of open thoracotomy was required for selective vascular isolation and division.¹ With the introduction of minimally invasive thoracoscopic techniques,² the endostapler has emerged as the primary method of dividing both the pulmonary parenchyma and the vasculature.^{3,4} The use of staples for control of the pulmonary vasculature has been shown to achieve secure closure of the pulmonary artery and vein comparable to that with manual surgical techniques, with minimal risk

of adverse events from the technical application or mechanical failure.⁵ In a study of 713 patients undergoing stapled vascular division of 2567 vessels, vascular complications included 5 cases of minor intimal fracture, 1 arterial avulsion, and 1 stapler misfire, with an overall adverse event rate during stapler application of 0.27%.⁶

The use of energy to accomplish vascular fusion and division is now emerging as a viable alternative to the endostapler. Energy-based coagulative and tissue fusion technology has been applied effectively and has increased in popularity and use in a wide variety of intra-abdominal procedures.⁷ Several energy-based fusion devices are currently available, including the harmonic scalpel (Ethicon Endo-Surgery, Cincinnati, Ohio), ultrasonic shears (Covidien, Mansfield, Mass), Gyrus PK Tissue Management System (Gyrus Medical, Minneapolis, Minn), BiClamp VIO300D Electrosurgical System (ERBE Elektromedizin GmbH, Tuebingen, Germany), Enseal PTS Tissue Sealing and Homeostasis System (SurgRx, Redwood City, Calif), and the Ligasure Device (Valleylab, Boulder, Colo). Currently, only the Ligasure device has been approved by the Food and Drug Administration for division of the intrathoracic vasculature.

The Ligasure system creates a vascular seal by application of bipolar electrosurgical radiofrequency energy. Vascular fusion is accomplished by the re-organization of the

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collagen and elastin fibers within the vessel wall using a combination of heat and pressure to achieve a permanent seal.⁸ The microprocessor in the generator monitors the tissue conductance properties, stops the application of energy, and allows a brief period of cooling before indicating that the seal cycle is complete. This device is fitted with a central cutting blade between the 2 coagulative surfaces of the instrument, promoting effective coagulative ligation (or sealing) and division of the pulmonary vessel or parenchyma.

Two hand-held instruments are currently available (Figure 1). The Ligasure Impact (n = 12) is 18 cm long, with a 14° curved jaw. The seal width measures 3.3 to 4.7 mm. The LigaSure Atlas is 20 cm long and applies a seal 6 mm wide by 22 mm long. The length of the shaft and the low profile of the jaws facilitate its application during thoracoscopy. An insulated layer minimizes heat transmission to the exterior jaw surfaces, minimizing thermal spread to approximately 2 mm. This device has been approved by the Food and Drug Administration for fusion and division of lymphatics, tissue bundles, and pulmonary vasculature up to 7 mm in size. Two energy applications are typically applied before vessel division. For pulmonary veins, the first-order branches are isolated and divided, instead of the main trunk, because of their thinner wall and decreased collagen content. Arterial division can be accomplished reliably in vessels up to 7 mm in diameter. For larger vessels, vascular division is recommended at the level of the

first-order branches (Figure 2). We currently do not advocate the use of the Ligasure for primary parenchymal division during anatomic lung resection.

Few published data are currently available regarding the application of this technology in the division of the pulmonary vasculature during anatomic lung resection. In preclinical swine models, the use of bipolar electrocoagulation sealing devices has been shown to achieve durable burst pressures (>300 mm Hg),⁹ with successful division of pulmonary vessels less than 5 mm in size.¹⁰ In a bovine study testing the burst pressures of 5-mm arterial vessels treated with 4 different vascular sealing devices, the Ligasure device resulted in the greatest burst pressure (385 mm Hg) and fastest sealing time (10 seconds).¹¹ Lacin and colleagues¹² studied the efficacy of energy-based fusion during lobectomy in sheep. No vascular disruption was noted for vessels less than 9 mm in size.

In humans, the data have been limited to several small case series. Although initially studied for its application during parenchymal wedge resection,¹³ its utility in anatomic lung resection was initially demonstrated in the setting of pediatric¹⁴ and robotic¹⁵ surgery without adverse events reported. Santini and associates¹⁶ reported on the use of the Ligasure device during lung resection in 36 patients, dividing vessels up to 7 mm in size without perioperative bleeding and no mortality. We have previously reported our experience with the Ligasure device in 211 patients.¹⁷ Using the Ligasure Impact hand piece (n = 12), no arterial dehiscences were encountered. However, 2 partial venous dehiscences occurred that were recognized and controlled intraoperatively. The remainder of the cases were treated with the LigaSure Atlas without vascular dehiscence. Vascular division was successfully performed on 476 arterial and 229 venous branches without the need for hemostatic adjuncts (eg, clips, staples).¹⁷ We have now used energy-based tissue fusion in 316 cases. We encountered 1 additional case of iatrogenic dehiscence involving an arterial branch that had undergone previous fusion. This patient was noted postoperatively to have a hilar hematoma that was ultimately found to be secondary to bronchial artery bleeding. While evacuating the clot, a previously sealed vessel removed from the primary site of bleeding partially dehiscenced secondary to suction trauma and requiring the placement of a clip. No postoperative complications developed that were directly attributable to the use of the Ligasure device.

The use of a single energy device to accomplish vascular division during anatomic lung resection can reduce the need to use multiple reloadable stapler cartridges, leading to a potential reduction in operative costs. The Ligasure device is priced at US\$350. Assuming the average use of 1.5 staplers per case (US\$300 each) and an average stapler cartridge cost of US\$100, the total cost savings of performing the vascular divisions during lobectomies (average, 3.5

FIGURE 1. Ligasure handpieces. A, Ligasure Impact and (B) LigaSure Atlas.

FIGURE 2. A, The Ligasure device is readily introduced through a thoracoscopic port. B, Ligasure application to the apical and anterior superior pulmonary vein. C, Vascular fusion is accomplished with 2 arteries of the left upper division. *Black arrow* denotes the divided energy applications. D, Arterial (*white arrows*) and venous (*black arrow*) stumps after fusion and division.

vessels/case) and segmentectomy (average, 2.0 vessels/case) with the Ligasure would be about US\$400 to US\$600 per case. This does not account for the multiple staple loads used to develop the fissures that would also be amenable to division with the Ligasure, potentially increasing the cost savings to as much as US\$1000 per patient.

Conclusions

Bipolar tissue fusion systems can be used safely during the division of both pulmonary arteries and veins (≤ 7 mm) during anatomic lung resection. It can be considered a valid alternative to stapling technology in this setting. Larger prospective series with long-term results and cost/benefit analyses are necessary to better define the utility of this technology during anatomic lung resection.

LUNG SEALANTS AND BUTTRESSING TECHNIQUES

Prolonged postoperative air leaks (>7 days) can occur in 15% to 18% of cases after lung resection.¹⁸ Numerous techniques have been explored to help minimize the occurrence of this difficult complication, including advances in stapling technology and the application of various fibrin and synthetic sealants. Lung sealants are most commonly applied to the surgical staple lines at the conclusion of the case prophylactically. The most extensively studied lung sealant has been fibrin glue (thrombin/fibrinogen). Mixed at application, fibrin glue creates a clot-like fibrin matrix over the staple line. It is applied in the hope of minimizing the egress of air. Studies evaluating the efficacy of fibrin

glue to date have reported mixed results. Several early prospective, randomized studies failed to show any effect on the incidence of postoperative air leak, chest tube duration, or length of stay.^{19,20} More recent studies evaluating fibrin glue and an autologous platelet-rich fibrin sealant (Vivostat A/S, Alleroed, Denmark), however, have demonstrated a reduction in the proportion of patients with postoperative air leaks.²¹

Synthetic, bioabsorbable sealants (polyethylene glycol-based) have also been applied in this setting. Several prospective, randomized trials have shown a decreased incidence of air leaks with polyethylene glycol-based sealants, with a trend toward decreased chest tube duration.²²⁻²⁴ Although several commercially available polyethylene glycol-based sealants have been shown to be efficacious in reducing postoperative air leaks after lung surgery,^{25,26} the only Food and Drug Administration–approved pleural air leak sealant in the United States is ProGEL (Neomend, Irvine, Calif), which combines a mixture of polyethylene glycol and human serum albumin. When applied, ProGEL forms a flexible hydrogel matrix that can cover and seal areas of parenchymal air leak. A prospective, randomized study has demonstrated efficacy in the sealing of intraoperative air leaks with ProGEL compared with controls and an associated shorter hospital stay.²⁷

Buttressing techniques have also been used in an attempt to minimize the occurrence of postoperative air leaks. Staple line buttressing techniques include the use of pledgets, bovine pericardium, and absorbable biosynthetic polyester to reinforce the parenchymal line of transection. Initially

used in the setting of lung reduction surgery, the use of bovine pericardial strips has demonstrated efficacy in reducing air leak severity.²⁸ In a prospective, randomized study of patients undergoing unilateral lung reduction surgery, pericardial strip buttressing was associated with a reduced duration of postoperative air leaks and earlier chest tube removal.²⁹ In another multicenter, randomized trial of patients undergoing pulmonary resection, pericardial reinforcement was associated with a reduced air leak duration.³⁰ A meta-analysis of randomized, controlled trials examining the utility of lung sealants and buttressing techniques found that the use of these adjuncts was associated with a reduced incidence of prolonged air leaks (>7 days) after lung surgery (odds ratio, 0.55; 95% confidence interval, 0.39-0.79).³¹

Conclusions

The published data regarding the use of tissue sealants and buttressing techniques during lung surgery suggest that these agents have the capacity to reduce the potential for air leaks and their duration.

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