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Use of Energy Devices in Thoracoscopy: Quantification of Lung-Sealing Capacity

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ABSTRACT

Purpose: **The use of stapling devices in pediatric thoracoscopic surgery is limited due to the decreased maneuverability of 12-mm instruments in a child's chest. The goal of this study is to quantify the ability of 5-mm energy devices to seal lung tissue in the nonsurvival swine model.**

Methods: **Nine 10-kg female swine were divided into three nonsurvival groups. Group A (n = 3): Left thoracotomy with use of a 12-mm stapler (US Surgical Corporation, Norwalk, Connecticut). Group B (n = 3): Left thoracoscopy with use of the LigaSure LS1000 (Valleylab, Boulder, Colorado) 5-mm instrument. Group C (n = 3): Left thoracoscopy with use of the Ultracision LCS-K5 (Ethicon Endo-Surgery, Cincinnati, Ohio) 5-mm instrument. Biopsy specimens of the lingula of the lung were taken. At the end of the procedure, seal burst pressures were recorded.**

Results: **Average burst pressure (mm Hg): A, staples 43.5 (43–44); B, LigaSure 44.9 (40.2–53.6); C, harmonic 37.5 (30–46.4). Average seal length (mm): A, staples 30 (30–30); B, LigaSure 27 (21.4–30); C, harmonic 26 (22–27). Average biopsy weight (g): A, staples 0.52 (0.51–0.53); B, LigaSure 1.78 (1.69–2.14); C, harmonic 1.58 (0.3–1.66). The standard deviations for the pressures were as follows: A, staples 0.5; B, LigaSure 7.54; C, harmonic 8.29. No statistically significant differences between the burst pressures were determined by the *t* test (A vs. B, $P = .78$; A vs. C, $P = .33$). There was 80% power to detect a difference in the means of 25 mm Hg for the LigaSure (A) and of 27 mm Hg for the harmonic (B).**

Conclusion: **Both the LigaSure and the harmonic scalpel can effectively seal normal lung tissue from air leaks in the nonsurvival swine model.**

INTRODUCTION

THE FIRST SIGNIFICANT USE of thoracoscopy in children was reported by Rodgers et al. in the late 1970s.[1] By the mid 1990s, thoracoscopy for the diagnosis and treatment of pediatric pulmonary diseases had become popularized by Rothenberg.[2] In infants and small children, the use of 12-mm stapling devices is

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limited by small intercostal spaces, restricted thoracic cavities, and decreased pulmonary reserve. A number of 5-mm energy devices are available that were designed to seal blood vessels, such as the LigaSure LS1000 (Valleylab, Boulder, Colorado) and the Ultracision LCS-K5 (Ethicon Endo-Surgery, Cincinnati, Ohio). These instruments potentially seal lung tissue well, but their capacity to do so has never been systematically studied.

Rothenberg described the use of the LigaSure LS1000 for completing pulmonary fissures during thoracoscopy.[3] In addition, Shigemura et al. described a case in which they excised a giant pulmonary bulla with a harmonic scalpel and then sealed the remaining lung with the LigaSure LS1000.[4] The goal of this study was to quantify the ability of 5-mm energy devices to seal lung tissue in the nonsurvival swine model.

MATERIALS AND METHODS

Experimental design

After approval had been obtained from the Institutional Animal Care and Use Committee, nine 10-kg female swine were selected as the animal model. The lingula was amputated from the left upper lobe by dividing the lung tissue with one of the three experimental devices: A, 30 mm–2.5 mm Endo-GIA Roticulator from US Surgical Corporation (Norwalk, Connecticut); B, LS1000 LigaSure Lap vessel-sealing instrument from Valleylab; C, Ultracision LCS-K5 from Ethicon Endo-Surgery.

Surgical procedures

A. 30–2.5 Endo-GIA Roticulator from US Surgical Corporation. The animal was initially anesthetized with an intramuscular injection of 25 mg of tiletamine (Telazol), 12.5 mg of ketamine, and 12.5 mg of xylazine. A stable plane of anesthesia was then maintained with the use of isoflurane titrated to effect. A left anterolateral thoracotomy through the seventh intercostal space was performed. The lingula was resected with a single firing of the 12-mm Endo-GIA stapler (US Surgical Corporation 30–2.5). The specimen was weighed. At the end of the procedure, an intravenous injection of euthanasia solution was administered. Seal burst pressure measurements were performed as described later.

B. LS1000 LigaSure Lap vessel-sealing instrument from Valleylab. The animal was anesthetized with an intramuscular injection of 25 mg of Telazol, 12.5 mg of ketamine, and 12.5 mg of xylazine. A stable plane of anesthesia was maintained with the use of isoflurane titrated to effect. Three 5-mm trocars were inserted into the fourth, seventh, and 10th intercostal spaces of the left side of the chest. The chest was insufflated to a pressure of 5 mm Hg with carbon dioxide. Under videoscopic visualization, the lingula of the left upper lobe was amputated with the use of an atraumatic grasper, the LigaSure LS1000 5-mm instrument, and endoscissors. The lung was sealed with the LigaSure and then divided with the endoscissors. The specimen was removed from the chest with the finger of a surgical glove and then weighed. The sealed lung was inspected for evidence of air leak. At the end of the procedure, a intravenous injection of euthanasia solution was administered. Seal burst pressure measurements were then performed.

C. Ultracision LCS-K5 from Ethicon Endo-Surgery. The anesthesia and surgery were performed in the same manner as in B. The only difference was that the Ultracision LCS-K5 was used both to seal and divide the lung tissue.

Burst pressure measurement

Immediately after the animal was euthanized, it was placed in the supine position. A mini clamshell incision was made at the level of the sixth intercostal space. The incision was 12 cm long, extending down both sides of the chest and centered about the sternum. Both chest cavities were entered anteriorly and filled with saline solution. A tracheostomy was performed with a 5-mm trocar, and this was tied in place with umbilical tape to create an airtight seal. The trocar was connected to the oxygen flow meter, and the lungs were inflated with oxygen flowing at 1.5 L/min. A pressure transducer was connected in line with the insufflation tubing, and the airway pressures were recorded on a chart recorder during insufflation. The burst pressure was noted when air bubbles were seen coming from the chest and confirmed by a sudden drop in the pressure recorded on the chart recorder. The side of the lung that burst (left side, experimental; right side, normal lung control) was noted by the presence of air bubbles. The Student t test was used to compare burst pressures between the experimental groups.

Specimen collection and histology

Once the burst pressures had been completed, the clamshell incision was extended for necropsy. The sealed edge of the left upper lobe was removed sharply and the seal length measured. Tissue for frozen sections was embedded in optimum cutting temperature formulation and frozen by immersion in 2-methylbutane at a temperature of −32°C. The specimens were cryosectioned into 5-μm sections, fixed by dipping in formalin alcohol, and stained with hematoxylin/eosin and Gomori trichrome stain according to standard protocols.[5–7] Additional sections were saved for fluorescence. These sections were fixed in 2% paraformaldehyde in phosphate buffered saline (PBS) for 10 minutes. The slides were rinsed three times in PBS. The slides were then pre-blocked and permeated in PBS with 3% bovine serum albumin and 0.5% saponin (PBS-BSA) for 10 minutes. One unit of Alexa 488 phallotoxin (Molecular Probes, Eugene, Oregon) was diluted into 200 μL PBS-BSA per slide. This was incubated on the slide for 30 minutes under parafilm at room temperature. The slide was rinsed with three dips in PBS-BSA. The slides were counterstained in 4′,6-diamidino-2-phenylindole (DAPI) dihydrochloride diluted to 100 ng/mL. The final rinse was a single dip in deionized water. The slides were coverslipped with Fluoromount-G and examined on a Nikon Eclipse TE-2000 microscope at 40 times magnification.

RESULTS

All nine animals underwent the procedures without complication. At the end of each procedure, the lung was observed to insufflate normally with no gross evidence of air leak before the animal was euthanized for burst pressures.

For group A (12-mm Endo-GIA stapler), all three seals were 30 mm due to the fixed size of the stapler. The average lingula biopsy specimen weight was 0.52 g. The burst pressure of all the seals failed at the staple line. Small fine bubbles were seen at the staple line in all cases. The average burst pressure for the Endo-GIA staple line was 43.5 mm Hg (Table 1).

TABLE 1. BURST PRESSURE DATA

	Burst pressure (mm Hg)	*Seal length (mm)*	*Biopsy (g)*
A. Endo-GIA	44	30	0.53
	43	30	0.52
	43.5	30	0.51
Average	43.5	30	0.52
Standard deviation	0.5	0	0.01
B. LigaSure LS1000	40.9	21.4	2.14
	40.2	30	1.51
	53.6	30	1.69
Average	44.9	27.1	1.78
Standard deviation	0.50	0.42	0.32
C. Ultracision LCS-K5	30	30	0.3
	36	22	2.8
	46.4	27	1.66
Average	37.5	26.3	1.59
Standard deviation	8.30	0.26	1.25

TABLE 2. COMPARING THE LS1000 LIGASURE WITH THE ENDO-GIA STAPLER

	Average burst pressure (mm Hg)	*Average seal length (mm)*	*Average biopsy weight (g)*
A. Endo-GIA	43.5	30	0.52
B. LigaSure	44.9	27	1.78
t test	0.779	0.423	0.021

In group B (thoracoscopy with the LigaSure LS1000), the average seal length was 27.1 mm. The average biopsy specimen weight was 1.78 g. In this group, as in the Endo-GIA group, the burst pressure reflects failure at the seal by the visualization of bubbles. The average seal burst pressure for the LigaSure group was 44.9 mm Hg (Table 1).

In group C (thoracoscopy with the Ultracision LCS-K5), the average seal length was 26.3 mm. The average biopsy specimen weight was 1.59 g. As in the other two groups, the burst pressure reflects failure at the seal by the visualization of bubbles. The average seal burst pressure for the Ultracision LCS-K5 was 37.5 mm Hg (Table 1).

When the LigaSure group was compared with the Endo-GIA group, the average burst pressure of the LigaSure group was 1.4 mm Hg higher than that of the Endo-GIA group. This difference was not statistically significant by the Student *t* test ($P = .779$). The only significant difference between the groups was for the biopsy specimen weight. The LigaSure specimens were on average 1.26 g heavier ($P = .021$) (Table 2).

When the Ultracision group was compared with the Endo-GIA group, the average burst pressure of the Ultracision group was 6 mm Hg lower than that of the Endo-GIA group. This difference was not statistically significant. No statistically significant differences in biopsy specimen weight or seal length were demonstrated between these two groups (Table 3).

Trichrome staining of the seals highlighted the integrity of the seal and made it clear where the seals had burst (Fig. 1). Phalloidin binds only to filamentous actin. When the lung tissue adjacent to the seal was labeled with phalloidin, the zone of thermal damage where actin was denatured was clearly demarcated (Fig. 2).

DISCUSSION

Advances in technology allow the surgeon to perform thoracoscopic procedures of increasing complexity. In this model, both the LigaSure LS1000 and Ultracision LCS-K5 proved to be effective devices for sealing lung tissue. Statistically, no difference was found between the strength of these seals and the seals of the Endo-GIA stapler. Histologically, the LigaSure LS1000 seal appeared to have a greater degree of organized structure (Fig. 1), and this device did have the highest mean burst pressure in the group.

Both the LigaSure LS1000 and Ultracision LC-K5 caused a small, well-demarcated area of thermal damage in the surrounding lung tissue (Fig. 2). This zone of thermal damage adjacent to the seal is where all

TABLE 3. COMPARING THE LCS-K5 ULTRACISION WITH THE ENDO-GIA STAPLER

	Average burst pressure (mm Hg)	*Average seal length (mm)*	*Average biopsy weight (g)*
A. Endo-GIA	43.5	30	0.52
B. Ultracision	37.5	26	1.59
t test	0.335	0.257	0.278

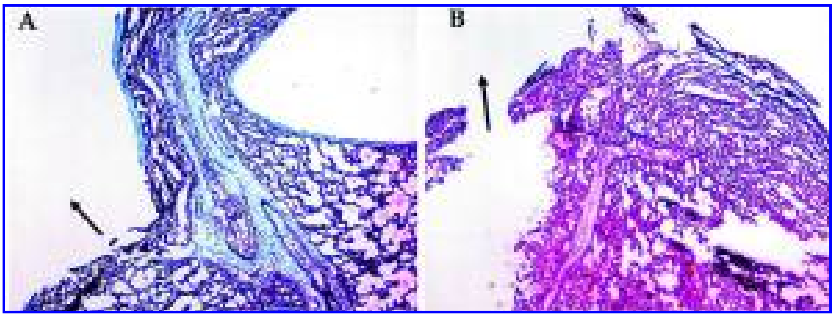

FIG. 1. Trichrome stained cryosections of the lung seals. Arrows mark the area of seal failure. Panel A is the Ligaure LS1000 seal. Panel B is the Ultracision LCS-K5 seal.

the seals failed when they were burst. Minimizing the zone of thermal damage will be important in creating devices optimized for stronger seals. Because the animals were euthanized, we do not know how the seals would have held up over time. It is possible that the zones of thermal damage could break down during the healing process.

The added dexterity and flexibility of these smaller 5-mm instruments will contribute significantly to the care of infants and children. Pediatric surgeons have started to use the LigaSure LS1000 when performing thoracoscopic lung resections in infants.[3]

In our model, we did not evaluate the thickness of tissue that could be divided with these energy devices. The study also does not address the capacity of the devices to seal diseased lung tissue. In conclusion, we have demonstrated that the capacity of the LigaSure and Ultracision is similar to that of staples for sealing normal lung tissue in the nonsurvival swine model.

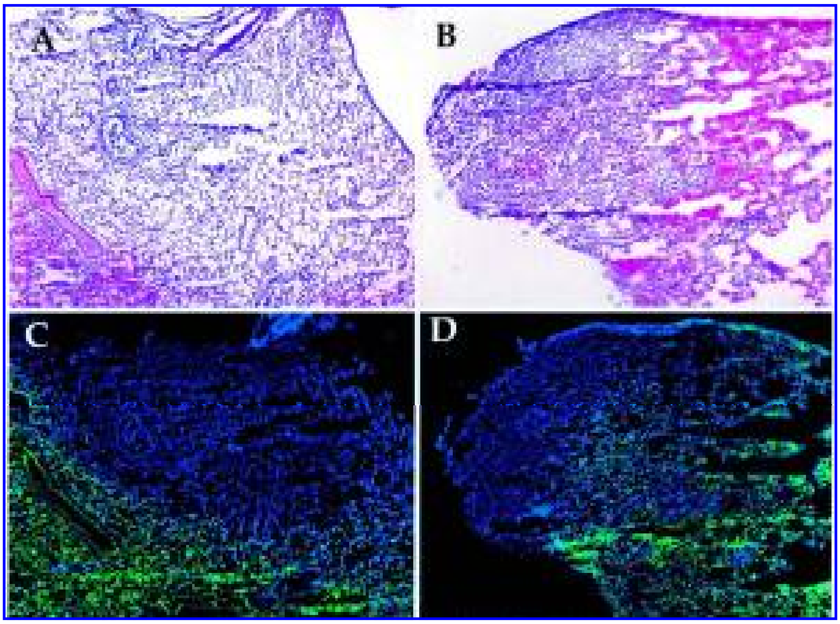

FIG. 2. Panel A H&E stained Ligasure LS1000 seal. Panel C Ligasure LS1000 seal labeled with DAPI (blue) and Phalloidin (green). Panel B H&E stained Ultracision LCS-K5 seal. Panel D Ultracision LCS-K5 seal labeled with DAPI (blue) and Phalloidin (green).

REFERENCES

1. Rodgers BM, Moazam F, Talbert JL. Thoracoscopy in children. Ann Surg 1979;189:176–180.
2. Rothenberg SS. Thoracoscopic lung resection in children. J Pediatr Surg 2000;35:271–274; discussion 274–275.
3. Rothenberg SS. Experience with thoracoscopic lobectomy in infants and children. J Pediatr Surg 2003;38:102–104.
4. Shigemura N, Akashi A, Nakagiri T. New operative method for a giant bulla: Sutureless and stapleless thoracoscopic surgery using the LigaSure system. Eur J Cardiothorac Surg 2002;22:646–648.
5. Sheehan D. Theory and Practice of Histotechnology, 2nd ed. St. Louis: Mosby, 1980, pp 137–157.
6. Luna L. Manual of Histologic Staining Methods of the AFIP, 3rd ed. New York: McGraw-Hill, 1968, p 2.
7. Thompson S. Selected Histochemical and Histopathological Methods. Springfield, IL: Charles C Thomas Publisher, Bannerstone House, 1966, p 788.

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