Original Research

Video-Assisted Thoracic Diskectomy and Anterior Release: A Biomechanical Analysis of an Endoscopic Technique

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Abstract

This study evaluates the residual biomechanical stability of the spine following multilevel anterior diskectomies and anterior longitudinal ligament release using video-assisted thoracoscopic surgery (VATS). Eighteen domestic pigs were randomly divided into three groups of six pigs. Group 1 underwent thoracic anterior release from T4-T9 using a left-sided VATS approach, group 2 underwent thoracic anterior release from T4-T9 via a traditional left thoracotomy (open), and group 3 did not undergo surgery and served as a control. After surgery, the animals were euthanized, and the thoracic spinal columns were harvested for biomechanical testing. Nondestructive testing was performed on all specimens in pure compression, flexion, extension, right lateral bending, and torsion. Specimens from group 1 had significantly lower stiffness values (P < .05) than the control group for all five test modes. These data demonstrate that adequate anterior release of the thoracic spine can be obtained with the VATS technique. Further prospective clinical studies on VATS are required before the widespread application of this technique.

The role of anterior thoracic diskectomy and anterior longitudinal ligament release in the treatment of severe thoracic spinal deformity is known. Recent studies on thoracic surgery suggest that patients benefit when thoracoscopy is elected over traditional thoracotomy in selected procedures. Although some authors have demonstrated the possible clinical applications of this evolving technique in the surgical treatment of spinal deformity, the required comparative biomechanical studies remain undone.

This study evaluates the residual biomechanical stability of the spine following multilevel anterior diskectomies and release using video-assisted thoracoscopic surgery (VATS).

Materials and Methods

Eighteen domestic pigs (50-60 kg) were randomly divided into three groups of six specimens per group. Group 1 underwent thoracic anterior release from T4-T9 using a left-sided VATS approach, group 2 underwent thoracic anterior release from T4-T9 via a traditional left thoracotomy (open), and group 3 did not undergo surgery and served as a control group.

After surgery, the animals were euthanized, and the thoracic spinal columns were harvested for biomechanical testing. All aspects of animal care and manipulation were performed in accordance with the guidelines set forth in the Animal Welfare Act and the NIH-PhS Guide for the Care and Use of Laboratory Animals.

Surgical Technique. Animals were anesthetized and prepared for surgery in a routine fashion. Anesthesia was induced using a combination of xylazine, zolazepam, and tiletamine. Following anesthetic induction, an endotracheal tube was placed and anesthesia was maintained using isoflurane vaporized in oxygen.

For the thoracoscopic procedures, the
endotracheal tube was advanced into the right mainstem bronchus for single lung ventilation. This selective intubation allowed intraoperative collapse of the left lung to facilitate thoracoscopic exposure of the left hemithorax.

All animals were positioned in right lateral recumbency, and the left hemithorax was approached for surgical manipulation. In groups 1 and 2, all surgeries were performed by a team consisting of an experienced spine surgeon (group 1: P.J.C. and group 2: E.W. and R.K.) and an experienced veterinary surgeon.

For the open cases, a thoracotomy was performed, with removal of a portion of the sixth rib leaving the costovertebral joint intact. This allowed access for disectomy and release at the levels of T4-T5 to T8-T9.

For thoracoscopy, the initial trocar was placed at the level of the xiphoid (sixth intercostal space) along the midaxillary line. Three additional access portals were placed along the midaxillary line from the 4th-10th intercostal space. The access ports consisted of two 12-mm rigid thoracic trocars and one 20-mm flexible thoracic trocar.

For both groups, the pleura overlying the 4th-10th thoracic vertebral bodies was opened lateral and parallel to the hemiazygous vein. The left segmental intercostal arteries and veins arising over these vertebral segments were isolated and divided using monopolar electrocautery or hemostatic clips and sharp dissection. A gauze sponge was used to pack the aorta and hemiazygous vein away from the site of disectomy and anterior release.

The anterior ligament was released at each interspace, and disk removal was continued to expose the posterior longitudinal ligament. The costovertebral joints were left intact. Venous sinus bleeding was managed by packing with gauze or an absorbable hemostatic material. The surgery was considered completed when the surgeon decided that an adequate release had been obtained.

The animals were euthanized by intravenous administration of a saturated solution of potassium chloride while still under general anesthesia. The thoracic vertebral column was harvested, including approximately 9 cm of rib on each lateral side, and frozen (−30°C) for subsequent biomechanical testing. The thoracic cavities were inspected for any evidence of damage associated with the surgical procedures.

**Biomechanical Testing.** Specimens were thawed and cleaned of musculature. Additional dissection was performed to create consistent thoracic spine specimens from T3-T10 with approximately 5 cm of rib on each side. T3-T4 and T9-T10 were fixed with 5-cm screws to limit movement to the surgical site and provide a means to anchor the specimens during biomechanical testing. The specimens were then potted in body filler and frozen until testing. Anterior and lateral radiographs (Fig 1) were taken to determine consistent load application points for testing.

Nondestructive testing was performed on all specimens in pure compression, flexion, extension, right lateral bending, and torsion on a biaxial MTS 858 materials testing machine (MTS Systems Corp, Eden Prairie, Minn). A 100-N ramp load with a 20-second period was applied for 15 cycles (10 cycles of conditioning and 5 cycles of data collection) for the pure compression, flexion, and extension test modes. The test fixtures were locked for pure compression to limit displacement to the axial direction only. For flexion and extension, the load was applied either 3.5 cm anteriorly (flexion) or posteriorly (extension) from the midline of the vertebral bodies.

The test fixtures were pinned above and below the test specimen in the coronal plane to constrain motion to the sagittal plane. A 50-N ramp load with a 20-second period was used for right lateral bending with a 3.5 cm lateral offset. The fixtures were pinned in the sagittal plane to constrain motion to the coronal plane. Torsion was tested with 50-N of compression plus 35° of ramp rotation with a 20-second period. Motion for torsion was constrained to axial rotation. Load, displacement, and rotational data were collected for the five cycles and analyzed using an algo-

| TABLE 1 |
|----------------|-----------|
| **Stiffness value ranges for each loading mode** |            |
| **Loading Mode** | **Range**  |
| Pure compression (N) | 80-100    |
| Flexion (Nm)         | 2.8-3.5   |
| Extension (Nm)       | 2.8-3.5   |
| Right lateral bend (Nm) | 1.25-1.75 |
| Torsion (degrees)    | 30-35     |
algorithm developed in LabView (National Instruments, Austin, Tex).

Load-displacement plots were created for pure compression, and moment-angle plots were created for flexion, extension, right lateral bending, and torsion. Stiffness was calculated from the linear portion of each plot using linear regression. The ranges used to calculate the stiffness values for each loading mode are listed in Table 1. The stiffness values from the last three data cycles were used in the statistical analysis. Statistical analyses were performed with an ANOVA comparison and a Games-Howell post hoc test to determine significance between groups.

**RESULTS**

The average operative time for the VATS discectomies and release of T4-T9 was 80 minutes (range: 65-95 minutes), while the average time for the open discectomies and release was 50 minutes (range: 45-65 minutes). Operative times do not include wound closure, which was not performed in either group. There were no intraoperative complications in either group.

The blood loss recorded for each of the 12 animals was <300 cc (group 1 average: 208 cc [range: 150-300 cc] and group 2 average: 204 cc [range: 200-225 cc]). The post-procedure inspection of the thoracic cavities in all 12 animals revealed no evidence of injury that would be considered a complication associated with the surgical procedure.

The stiffness values from the load-displacement plots (N/mm) for pure compression are shown in Figure 2. The stiffness values for group 1 (VATS) and group 2 (open) were significantly less than the control group (P<.05). In addition, the stiffness values for group 1 were significantly less than for group 2 (P<.05).

The stiffness values from the moment-angle plots (Nmm/degree) for flexion, extension, right lateral bending, and torsion are shown in Figure 3. Again, the stiffness values for groups 1 and 2 were significantly less than the control group and significantly different from each other (P<.05) for all loading modes except right lateral bending (Table 2). For right lateral bending, the stiffness value for group 1 was significantly less than for the control group (P<.05). Although the mean stiffness values for group 1 were less for group 2, and groups 1 and 2 were less than group 3, no other significant differences were noted for this loading mode.

**DISCUSSION**

This study evaluates the stiffness in the porcine thoracic spine following multilevel thoracic discectomies and anterior longitudinal ligament release. Two different surgical techniques were used to perform multilevel thoracic discectomies and anterior longitudinal ligament release from T4-T9. All surgeries in group 1 (VATS) were performed by one surgeon. All surgeries in group 2 (open) were performed by a different surgeon. Adequacy of release was determined at the time of surgery by the operative surgeon.

Although the thoracic spine of the pig is small in size in relation to other animals and to the human thoracic spine, age-matched and weight-matched domestic pigs were used for this study. The homogeneity between specimens and surgical availability that this model provided was important for biomechanical testing.

All spines were tested biomechanically at a separate facility without any knowledge of the surgical technique used for release. The porcine thoracic spine with multilevel discectomies and
anterior release and partial rib removal was unstable. Although this instability alone might account for some differences among the specimens in the surgical release groups, it did not affect the significant difference between the control group (intact spine and partial rib removal) and the surgical release groups (groups 1 and 2).

The study was intended to eliminate the operating surgeon's potential bias of one technique over another in performing discectomies and release. A different spinal surgeon performed the discectomies and release in each group. Unfortunately, our study did not standardize the subjective differences between surgeons in regard to what is an adequate release.12

The purpose of this study was to evaluate the technique of VATS in performing thoracic discectomies and release from T4-T9. Our data demonstrate a significant decrease in stiffness in the VATS group compared with both the control and open surgery groups. Our study was not designed nor was intended to determine which surgical technique, VATS or open, provides a better release. The surgical reasons for these differences are not entirely clear and indeed may be related to the subjective opinion of the operative surgeon regarding "adequate release." Therefore we are not suggesting that VATS is a better technique for anterior thoracic spinal release.

CONCLUSION

The potential benefits of VATS over open thoracotomy have been documented in the thoracic surgical literature.13 Recent preliminary reports suggest a possible role for the VATS technique in thoracic spine surgery.4-10 This study demonstrated that multilevel thoracic discectomies and anterior release can be performed in a porcine animal model using VATS. Our study does not address the safety, fusion capabilities, or cost effectiveness of this technique. Further laboratory and prospective clinical studies are required before the widespread application of this technique.

REFERENCES


EDITORIAL DISCUSSION

ORTHOEDICS: What were the spine inspected to determine the relative amount of disk material removed in the open versus the VATS groups?

Connolly et al: The animals were euthanized by intravenous administration of a saturated solution of potassium chloride while under general anesthesia. Once this was done, the thoracic vertebral columns were harvested, and each disk space was inspected prior to being placed in packing equipment to be frozen and then shipped for subsequent biomechanical testing. Because there is no accurate way to measure the amount of disk material removed for each disk space in comparing the open versus endoscopic techniques, our comparison of the two groups was by visual inspection. We did not note any significant difference in the relative amount of disk material removed in the two groups.