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Comparison of retraction pressure between novel and conventional retractor systems—a cadaver study

Laboratory investigation

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Object. Sore throat, dysphagia, and dysphonia are very common after anterior cervical surgery; clinical studies show an incidence of up to 60% or more. Neural, mucosal, or muscular injuries during dissection or retraction are regularly discussed, but investigations are few. Retraction pressure causing ischemia might explain these complications. A new anterior cervical retractor system (Seex retractor) using novel principles has been introduced to surgical practice. There are isolated reported investigations comparing different anterior cervical retractors. Therefore, the purpose of this study was to measure retraction pressure on the aerodigestive tract in cadavers during the anterior surgical approach for cervical spine operations performed using either the conventional (Cloward) retractor system or the Seex retractor system. The goal was to find the significance of the shape of the retraction blades (flat vs curved) in retraction pressures.

Methods. In cadavers, the anterior cervical spine was approached surgically at the C3/4, C4/5, C5/6, and C6/7 levels. A simulated anterior discectomy procedure was performed using a Cloward retractor with curved blade, a Seex retractor with curved blade, and a Seex retractor with flat blade at each level. For each retractor application, an online pressure transducer (Tekscan pressure measurement system) is applied between the rear side of the medial retractor blade and medial soft-tissue complex. Retraction pressures are recorded twice for both retractors at each level. Average retraction pressure (ARP), average peak retraction pressure (APRP), pressure distribution along the area of retraction, pressure difference at the edge and surface of the retractor blades, pressure variation with flat and curved blades, and so on were determined and compared. One-way ANOVA and Tukey honestly significant difference tests were used for statistical evaluation.

Results. Forty sets of pressure recordings were made in 5 cadavers. The Cloward retractor system showed higher average contact pressure than the Seex retractor system in 36 sets. In 32 sets, the Cloward retractor system showed higher peak retraction pressure than the Seex retractor system. None of the recordings showed uniform pressure distribution over the retracted area. With the Seex retractor itself, the flat blade generated more peak retraction pressure than the curved blades in 28 sets of measurements; it was the reverse in 3 sets; and in 9 sets the peak pressure was almost the same. Higher retraction pressure was noted along the edges of retractor blades in general, and along the convexity of a curved blade. Those parallel bands corresponded to the edges of the retractor blades. The Seex retractor with a curved blade generated the lowest average retraction pressure and average peak retraction pressure ($p < 0.01$, ANOVA).

Conclusions. Retraction pressure was found not to be uniform all over the retracted surface. Higher retraction pressure was noted along the edges of retractor blades in general, and along the convexity of a curved blade. The conventional retractor system with a curved blade generated significantly higher retraction pressures than the novel Seex retractor with a curved blade. *(DOI: 10.3171/2009.11.SPINE0956)*

Key Words • **anterior cervical surgery** • **retractor** • **dysphagia** • **hoarseness**

The anterior approach is widely used for surgical exposure of the cervical spine. This approach is associated with postoperative problems like sore throat, dysphagia, and dysphonia. These problems are usually temporary, but they are very common—occurring in up to 60% or more of cases.[19,24,27] Most patients experience these symptoms as very uncomfortable. The causes are commonly cited as neuronal,[1] muscular,[17,22] and mucosal[22] damage of the aerodigestive pathway during dissection, retraction, or insertion or inflation of the endotracheal tube. During retraction, these instruments exert pressure on the underlying tissue.[4] Retraction pressure–induced ischemic damage might explain most of the soft-tissue complications following the anterior cervical approach.[10]

Abbreviations used in this paper: APRP = average peak retraction pressure; ARP = average retraction pressure; CRC = Cloward retractor with curved blade; ETCP = endotracheal tube cuff pressure; HSD = honestly significant difference; RLN = recurrent laryngeal nerve; SRC = Seex retractor with curved blade; SRF = Seex retractor with flat blade.

A new novel anterior cervical retractor system (Seex retractor; patent holder Dr. K. Seex, No. PCT/AU05/001205) has been introduced. The fundamental principle of the new system is that bone fixation can be used to provide the retractor blade with an axis of rotation inside the wound. This gives improved retractor blade stability, with the mechanical advantage of a lever. The stable rotation thus produced allows adjustable retraction and tissue relaxation without compromise in stability. This configuration is quite different from that of the conventional soft-tissue-mounted retractor systems. In this study we assessed whether this difference in principle affects retraction pressure on the medial soft-tissue structures during anterior cervical surgery in cadavers. We also investigated the effect of the shape of the retraction blades (flat vs curved) in retraction pressure generation. This is the first investigation of retraction pressures performed using any 2 different retractor systems for anterior cervical spine surgery.

Methods

The study was conducted in 5 fresh, intubated cadavers, which were positioned for a standard anterior cervical surgical approach. A right-sided anterolateral approach was used. Prevertebral space was approached through a plane between larynx, trachea, and esophagus medially, and between sternocleidomastoid muscle and carotid sheath laterally. An exposure adequate to complete standard discectomy was done. Anterior cervical discectomy was performed at the C3/4, C4/5, C5/6, and C6/7 level in each cadaver. At each level, a CRC (conventional retractor: Cloward Cervical Large Retractor Set No. C50–1380, Cloward Instrument Corp.), an SRC, and an SRF were used one after another for retraction. The Tekscan (I-Scan) pressure monitoring system (a "Tactile Sensor System") was used for recording retraction pressure on the tracheo-esophageal complex. The sensor (model 4201) was placed between the medial retractor blade and the soft tissue behind it. The sensor was positioned in such a way that the pressure readings were obtained from the flat of the blade as well as the edge. Pressure recordings were made in millimeters of mercury continuously for a 2-minute period at a rate of 2 readings per second. Thus, 120 pressure readings were made for each recording. At each level, the order of retractor chosen for the pressure recording was changed from the previous level. This was done to avoid error due to initial or subsequent application of a particular retractor system in pressure recording.

In each cadaver for each level, 3 primary pressure readings were made; 1 for each retractor system. After finishing primary pressure recordings at 4 levels, the study was repeated in the same cadaver at the same 4 levels for repeat pressure recordings. Thus, for each cadaver, 4 sets of primary recordings and 4 sets of repeat recordings were obtained.

There are 276 sensels (pressure-picking points) in the sensor we used. At any given point in time, 1 pressure recording (1 frame) consists of 276 pressure readings obtained in a 2D plane, corresponding to the retracted area. The pressure variation within the area of retraction was correlated to the shape of the retractor blade, and the data were used to compare curved and flat blades. Pressure recordings were made at a rate of 2/second. Two minutes (120 seconds) of retraction gave 240 frames of recordings. Because there were 276 pressure readings for each frame, a 2-minute-long retraction gave 240 × 276 pressure readings. The ARP was defined and calculated as the arithmetic mean of the retraction pressure recorded during the entire 2-minute period (240 × 276 readings). Peak retraction pressure was the highest-pressure reading within the area of retraction at a particular point in time (within a frame). Thus, from each recording, 240 peak retraction pressure values were noted and averaged to obtain the APRP. The ARP and APRP were used to compare the magnitude of pressure generated by the retractors. The mean ± SD of ARP and APRP of the CRC, SRC, and SRF devices were calculated for the entire study group and compared. One-way ANOVA and Tukey HSD tests were used for statistical evaluation, and p values were set at 0.01 for the significance of their results.

Results

Forty sets of pressure recordings were made from 5 cadavers at 4 levels by using 3 retractors. Of the 40 sets, 20 were primary recordings and the remaining were repeat recordings. Each of the pressure recordings were 2 minutes in duration, with a rate of 2 readings per second. The area of retraction was clearly represented in Tekscan-generated 2D pictures of pressure readings in color code (Figs. 1 and 2). The flat blades generated high-pressure readings as parallel bands corresponding to the edges of the retractor blades (Fig. 1), but with curved blades higher-pressure readings were noted from the center convex area of the blade (Fig. 2) and from the edges.

Forty sets of ARP and APRP values were calculated for each of the retractor systems; these findings are graphically represented and compared in Figs. 3–8. The mean of 40 ARP values of the SRC was 19.75 ± 10.57 mm Hg (range 9–50 mm Hg), that of the SRF was 25.125 ± 14.46 mm Hg (range 10–74 mm Hg), and that of the CRC was 33.4 ± 13.42 mm Hg (range 16–66 mm Hg). These results from the retraction pressure data were found to be statistically significant with 1-way ANOVA for 3 samples (F = 83.81 and $p < 0.0001$) and with the Tukey HSD test (HSD at alpha level 0.05 = 2.54; HSD at alpha level 0.01 = 3.19; $p < 0.01$ for M_1 vs M_2, for M_1 vs M_3, and for M_2 vs M_3 [M_1 is the mean ARP of SRC, M_2 is the mean ARP of SRF, and M_3 is that of CRC]).

The mean of the 40 APRP values of the SRC was 68.72 ± 68.05 mm Hg (range 14–254 mm Hg), that of the SRF was 94.4 ± 73.74 mm Hg (range 18–255 mm Hg), and that of the CRC was 124.46 ± 55.72 mm Hg (range 37–255 mm Hg). The ANOVA evaluation of APRP revealed its statistical significance (F = 7.91 and $p < 0.0006$), whereas results for the Tukey HSD test showed no significance in two of the comparisons (HSD at alpha level 0.05 = 33.92; HSD at alpha level 0.01 = 42.35; not significant for m_1 vs m_2, $p < 0.01$ for m_1 vs m_3, and not significant for m_2 vs m_3 [m_1 is the mean APRP of SRC, m_2 is the mean APRP of SRF, and m_3 is that of CRC]).

Fig. 1. Pressure recording with flat-blade retractor showing the edges generating high-pressure areas (*red* and *yellow*).

Fig. 2. Pressure recording with curved-blade retractor showing convexity and edges generating high-pressure areas (*red* and *yellow*).

Of the 40 sets of recordings at 1 level (Cadaver 4; repeat C5/6 level), ARP was the same for all 3 retractors. At another level (Cadaver 1; repeat C3/4), ARP was the same for CRC and SRF. At 2 other levels, SRF showed higher ARPs than the other retractors. At 36 levels, CRC showed the highest ARP. The SRC never showed a higher ARP than CRC at any level. The SRC showed the highest APRP at only 1 level (Cadaver 1; C4/5), and at 6 levels the APRP was highest with the SRF. In Cadaver 3, repeat C6/7 recording showed the same APRP with CRC and SRF; this was higher than that of the SRC. In the remaining 32 levels, the CRC generated the highest APRP.

With the Seex retractor, the flat blade generated more APRP than curved blades in 31 levels; it was the reverse in 3 levels and the same in 6 levels. Only at 1 level did the curved blade generate higher ARPs than the flat blade. At 11 levels that pressure was the same for both, and at 28 levels, higher values were noted with the flat-bladed device.

Discussion

Retraction-Related Complications

Sore Throat. A prospective study noted an incidence of up to 40% for postoperative sore throat following elective tracheal intubation for various procedures.[3] Following anterior cervical spine surgery with uncontrolled ETCP, the incidence of postoperative sore throat can go up to 74%.[19] One of the reasons for postoperative sore throat is ischemic damage of the oropharyngeal and tracheal mucosa.[5,15] Ischemic mucosal damage increases with higher ETCP,[20] and in patients undergoing anterior cervical spine surgery, ETCPs have been found to increase during retraction.[23] Thus, retraction-induced high ETCP might explain the increased incidence of postoperative sore throat following anterior cervical spine surgery.

Dysphonia. The reported incidence of dysphonia

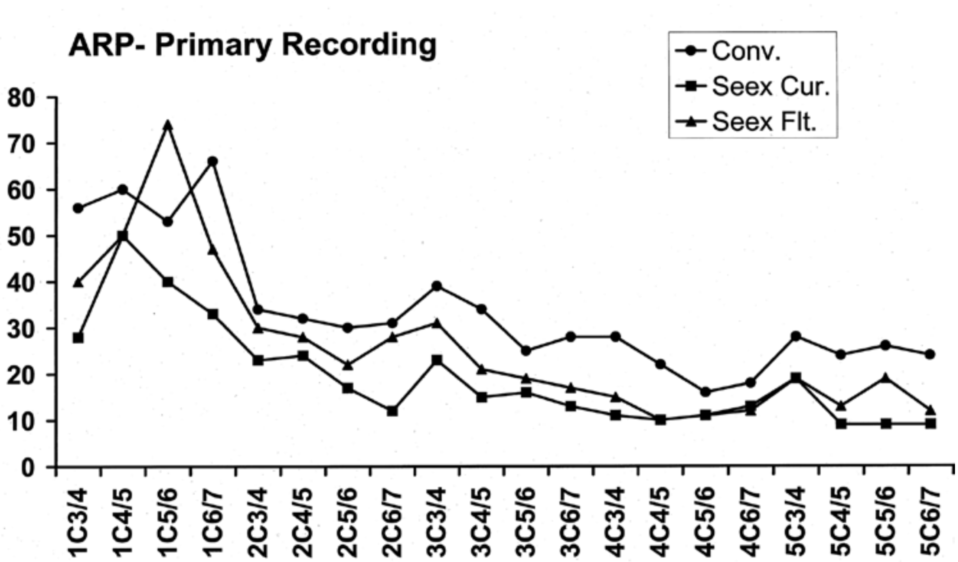

Fig. 3. Primary ARP recordings from 5 cadavers (numbered 1–5 on the x axis, with cervical levels also given; the values on the y axis denote pressure in mm Hg). Conv. = conventional; Cur. = curved; Flt. = flat.

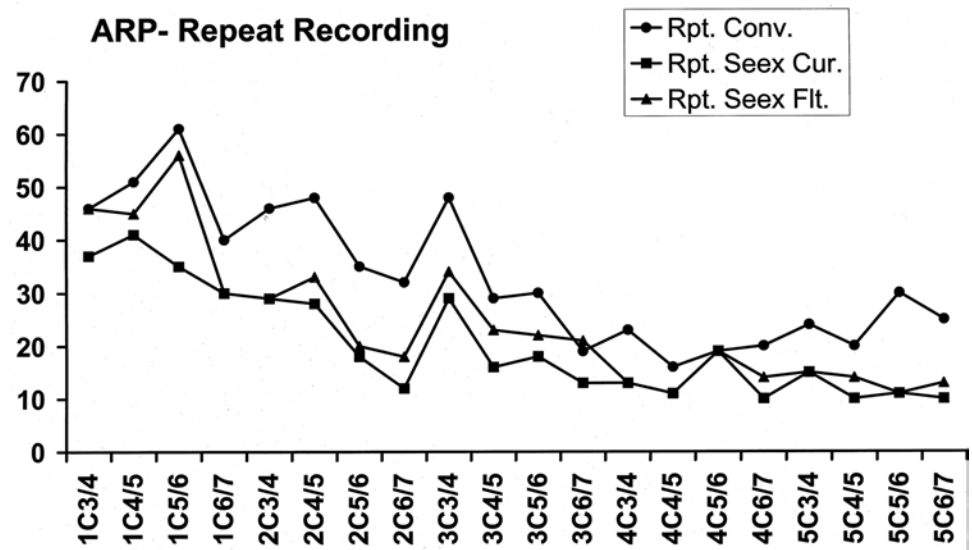

Fig. 4. Repeat (Rpt.) ARP recordings from 5 cadavers.

in recent studies has been up to 60%.[24] The mechanical changes happening to the tissues during retraction involve stretching and compression. Stretch-[26] and/or pressure-induced[14] ischemic damage of the RLN is one of the described causes of dysphonia after cervical spine surgery. This may occur anywhere along the course of the nerve. The reported incidence of RLN palsy varies between 0.07 and 11%.[2] A recently published study found increased levels of recurrent laryngeal irritation (on intraoperative electromyography studies) with self-retained retractors compared with hand-held retractors with periodic soft-tissue release.[7] Dysphonia may also be caused by laryngeal damage due to its compression onto the unyielding shaft of the endotracheal tube, which is fixed distally by the balloon cuff and proximally by tape at the mouth.[13] This happens with the laryngeal displacement that occurs with retraction. Another reason for dysphonia is tracheal mucosal edema caused by ischemic damage at the level of the endotracheal tube cuff.[21] Ischemic damage may occur more with tracheal retraction, because this has been shown to cause a significant increase in cuff pressure.[12] Because the trachea usually commences at the C-6 level, operations below this level require tracheal retraction, which may place them at higher risk for mucosal damage.

Dysphagia. Postoperative dysphagia is a well-known complication of anterior cervical spine surgery; the reported incidence reaches 60–70%.[24,27] Potential causes during anterior cervical spine surgery include injury to the glossopharyngeal and hypoglossal nerves (in exposure

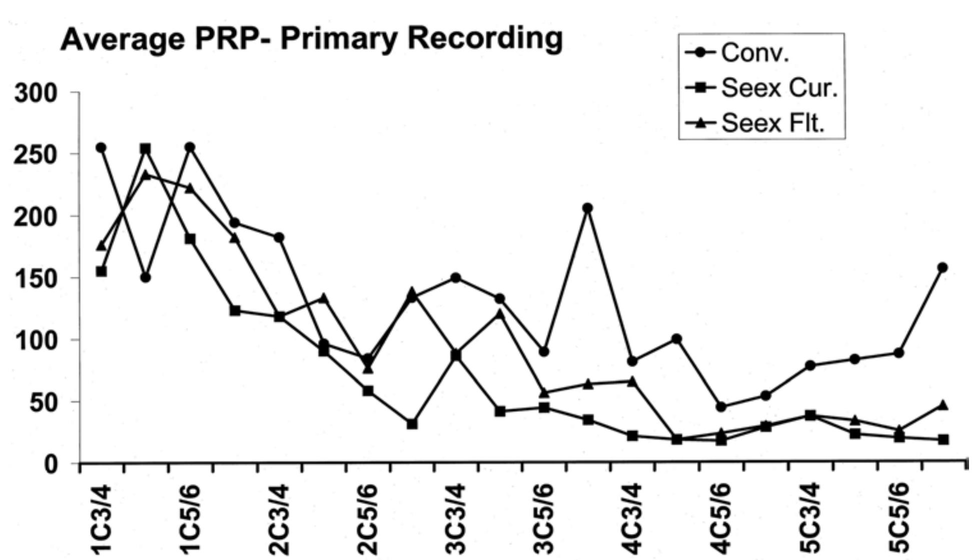

Fig. 5. Primary APRP recordings from 5 cadavers.

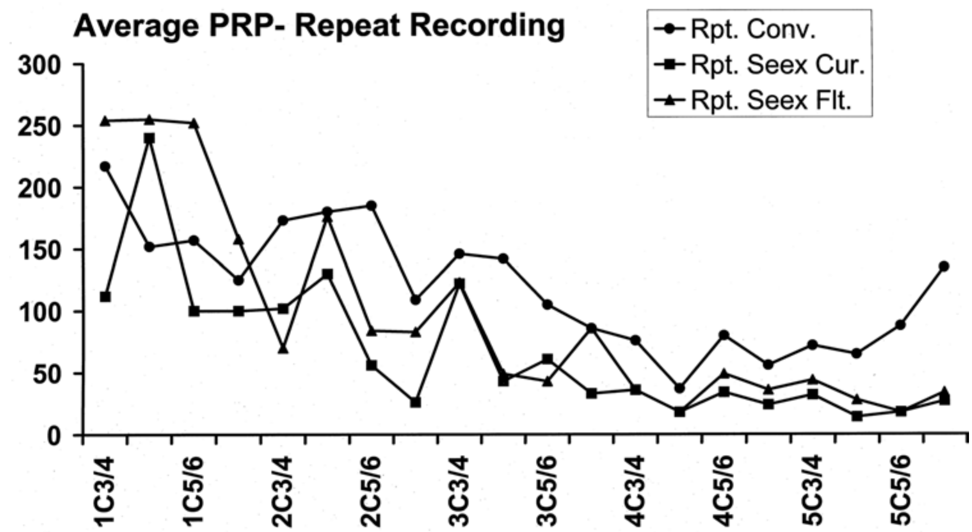

Fig. 6. Repeat APRP recordings from 5 cadavers.

of C-3 or above), superior laryngeal nerve (at C3–4 levels), and RLN (at C-6 or below).[16] Direct damage during dissection or indirect damage to these neural structures[8] or to the mucosal wall by retraction may result in dysphagia. Prevertebral soft-tissue swelling is another reason for temporary dysphagia following cervical spine operations,[8] for which retraction injury is an obvious cause.[16]

Retraction Pressure

Retractors may injure tissues directly, with their sharp teeth causing bruising or laceration, or as a result of pressure, causing ischemia.[11] Studies in the lumbar spine have shown reduced muscle injury and postoperative pain with intermittent release of retractors,[6,9,13] indicating that ischemic damage due to retraction pressure may explain some of the postoperative symptoms. Direct measurement of ischemic tissue damage would be ideal, but we believe it is reasonable to consider measuring retraction pressure as a more practical alternative to the investigation of soft-tissue injury caused by retractors. There have been other studies on retraction pressure during anterior cervical surgery, both in cadavers and in patients,[18,25] that support this.

This study was conducted with a 48 × 23–mm^2 area sensor. That enabled us to record pressure variations over a wider area than in other studies conducted with point-pressure recording methods. Pressure mapping in this study clearly demonstrates that pressure is not uniform throughout the area of retraction (Figs. 1 and 2), which is the rationale for using parameters like ARP and APRP for comparing the retractors. This is the first study to demonstrate variations in pressure over the retracted surface. Within the retracted area, a consistent pattern of pressure variation was noted. There were 2 areas of higher-pressure readings: 1) from the area corresponding to the edges of the retraction blade (more so in the case of flat blades); and 2) the area over the convexity of the curved blade. This can be explained in terms of displacement of the retracted tissue (maximum at the convexity), and in terms of change of direction of the vector force along the retracted tissue (corresponding to the border of the blade). In the comparison of curved versus flat blade with the Seex retractor itself, the curved blade (that is, the SRC) generated less ARP (19.75 vs 25.125) and APRP (68.72 vs 94.4) than the flat one (the SRF). Statistical significance of this finding is demonstrated only with ARP; however, it is reasonable to conclude that curved blades cause less pressure on retraction than the flat blades, based on the raw data (Figs. 7 and 8).

Comparing the Seex retractor and a conventional retractor with curved blade, the CRC showed higher ARP and APRP at 39 of 40 levels; at one level both recorded the same ARP, and only at one level did the SRC generate a higher APRP. Considering the mean of ARP of the whole study group, SRC (19.75 mm Hg) generated less retraction pressure than CRC (33.4 mm Hg.). This was found to be statistically significant with 1-way ANOVA ($p < 0.0001$) and Tukey HSD tests ($p < 0.01$). The mean APRP of the whole study group with SRC (68.72 mm Hg) was also found to be less than that of CRC (124.46 mm Hg). This was also found to be statistically significant with 1-way ANOVA ($p < 0.0006$) and Tukey HSD tests ($p < 0.01$). (These mean values are found with relatively higher SDs, for which an explanation is given along with limitations of our study.) We suggest 2 explanations for this finding. 1) The conventional or Cloward retractor system (CRC) blades are designed to rely on the soft-tissue (longus colli muscle) counterpressure for stability. These blades provide a static vertical channel of retraction for the operation. In the Seex system, the blades are attached to a metal frame, and that frame is mounted onto the vertebral bodies. The attachment of the blade to the frame acts as a hinge and gives freedom to the blade for rotation in the transverse direction. This allows an oblique channel of retraction. The displacement of the medial soft tissues is less with the oblique channel (Fig. 9). 2) The other

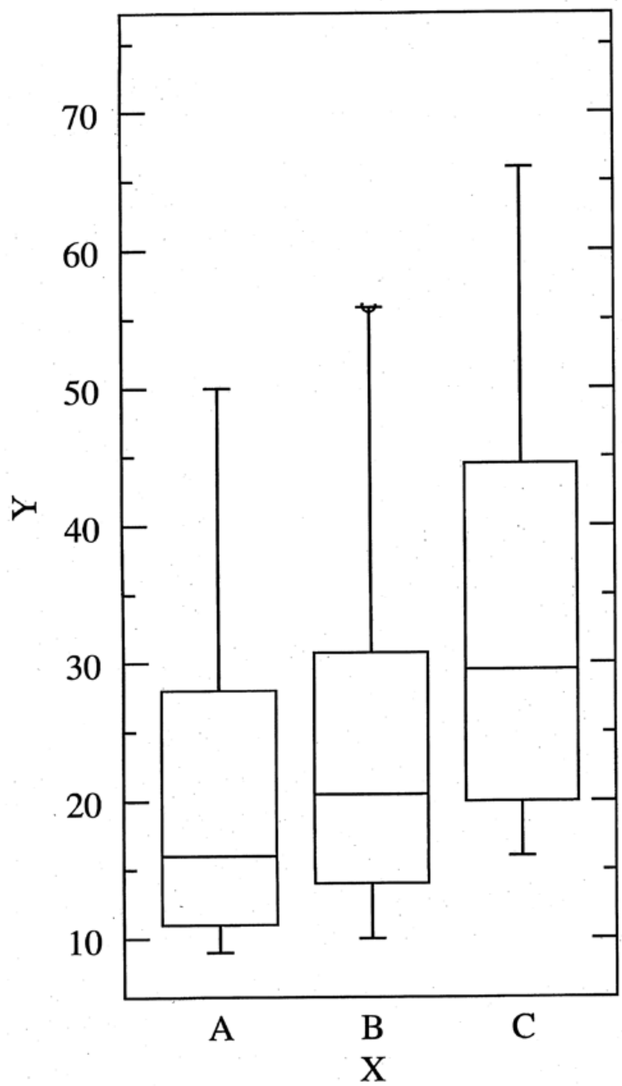

Fig. 7. Boxplot showing ARP group means with 95% CIs *(whiskers)*. The SRC group is represented by A, SRF by B, and CRC by C. Values on the y axis denote pressure (mm Hg).

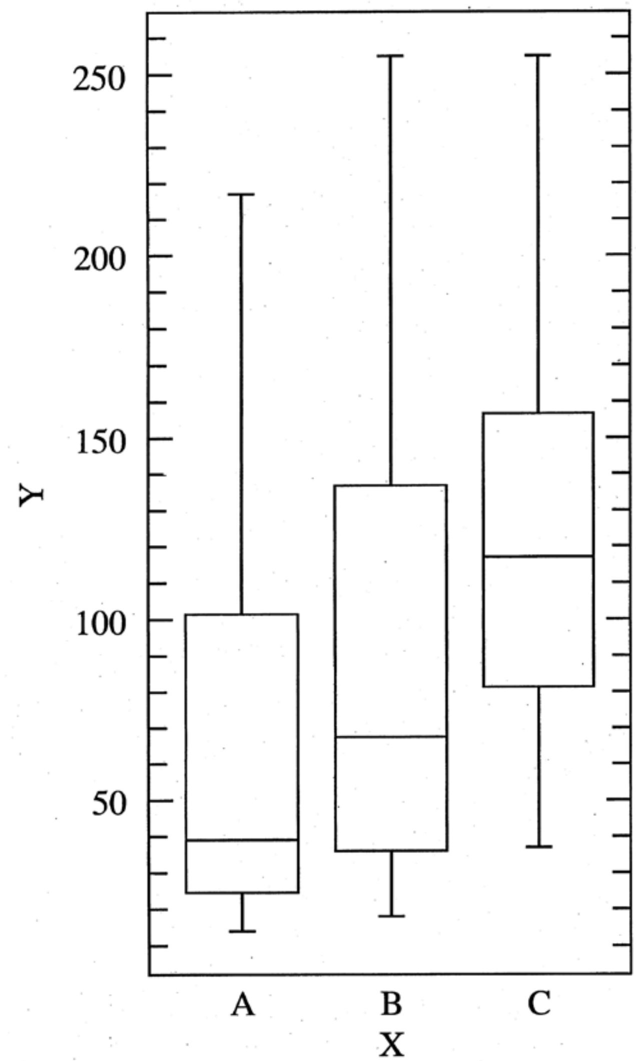

Fig. 8. Boxplot showing APRP group means with 95% CIs *(whiskers)*. The SRC group is represented by A, SRF by B, and CRC by C. Values on the y axis denote pressure (mm Hg).

explanation is that a conventional retractor may require a wider opening of the blades to achieve stability under soft tissues.

In this experiment we chose to ignore the extent of tissue separation and instead to measure the pressure generated during simulated discectomy using whatever separation was required to perform the operation. There are 2 reasons. 1) Although it is possible with conventional retractors to measure the extent of tissue retraction at any point in time because the retractors produce a trough with vertical sides, it is, however, unusual for conventional retractors to remain static for the duration of an operation. This is because the longus colli muscle stretches, the retractors move sideways, and the retractors often have to be further separated to maintain stability. Also, the retractors frequently tilt. 2) With the Seex retractor the degree of separation is fixed only at the base. The system is designed so that one or both blades can rotate to create an oblique channel for the surgery. The rotation means that the retraction of the trachea/esophagus can be either significantly less or more with the Seex retractor than with a conventional device set to produce the same 20-mm exposure of the disc space. It is a feature of the design and suggested function that the degree of rotation and thus retraction need not, and indeed should not, be held constant during the entire procedure.

The one theoretical advantage for the Cloward device is that it allows the blade to rotate around a vertical axis along its length, conforming to the tissue pressure. The 2 Seex blades rotate only around a horizontal axis in the wound.

There are many limitations in this study. The physical properties of cadaver tissue are different from live human tissue. To limit errors due to tissue changes with prolonged storage, we used fresh frozen cadavers (the

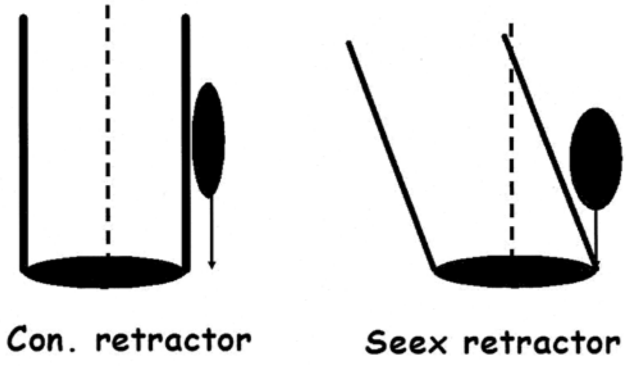

Fig. 9. Diagrammatic representations of intraoperative axial view. The Seex retractor provides an oblique surgical channel, thereby causing less retraction on medial structures. For the same exposure, the conventional (Con.) system uses a vertical channel and causes more retraction.

maximum storage period was 3 weeks). In our study there are significant pressure differences noted between the cadavers. That is reflected in our statistical evaluation as relatively higher SDs for the calculated mean values of all retractor systems. The pressure variation between cadavers is due to the difference in physical properties of the cadavers, but importantly, readings with all 3 retractors (SRC, SRF, and CRC) fluctuated in parallel with different cadavers (Figs. 3 and 5). The "repeat" data also showed similar changes (Figs. 4 and 6). Thus, although physical properties of the cadavers affected the absolute pressure readings, the relative difference between the retractors remained unaffected. The duration was clearly much shorter than for real surgery. In live surgery one expects a reduction in pressure with time, due to tissue stretch or adjustments. This should affect both systems equally. There are different retractor systems used in clinical practice, like Caspar, Cloward, Trimline, Shadowline, Koros, Blackbelt, and so on. In this study we compared the Seex retractor against the Cloward retractor system. Because the working principles of the Cloward retractor and other systems are all the same, we believe it is reasonable to infer that the conclusions of this study are applicable to all such retractor systems. What (if any) clinical significance these differences in retraction pressure have in live surgery and choice of retractors will require further study with independent outcome assessments. Such a study is currently underway (Australian New Zealand Clinical Trials Registry No. 12608000430336; http://www.ANZCTR.org.au/ACTRN12608000430336.aspx).

Conclusions

In this cadaver study there were 3 noteworthy findings. 1) Retraction pressure was found not to be uniform all over the retracted surface; this has relevance for future studies and methodologies. 2) Higher retraction pressure was noted along the edges of retractor blades in general, and along the convexity of the curved blade. 3) The conventional retractor system with the curved blade generated significantly higher retraction pressures than the novel Seex retractor with the curved blade. This last finding justifies an in vivo study to assess any potential clinical significance by comparing the Cloward style with the Seex using curved blades.

Disclosure

The authors have not received any financial support to conduct this study. Dr. Seex has patents pending in regard to the device and its principles.

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