Traumatic spinal fractures the fall and rise

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CHAPTER 5

THREE-DIMENSIONAL THORACOSCOPIC SURGERY FOR SPINE FRACTURES: A TECHNICAL REPORT WITH FIRST RESULTS AND EXPERIENCES

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Abstract

Background

Conventional 2 dimensional (2D) video assisted thoracoscopy (VATS) is a technical procedure mainly performed by experienced surgeons. The technique may however come with difficulties in hand-eye coordination and estimation of depth. 3D-thoracoscopy can help overcome these difficulties by providing a stereoscopic 3D view. The objective of this study is to report the first experience and results with 3D thoracoscopy for spine surgery in trauma patients.

Methods

The first four patients treated with anterior stabilization for traumatic spine fractures using 3D-thoracoscopy in an academic hospital are described. Baseline characteristics, operative time and blood loss were retrospectively collected. These data are compared to a cohort of patients treated in the same center with the conventional 2D technique. Additionally the treating surgeons' and residents' experience with the technique is described. Surgical equipment consists of 3D compatible video monitors, a videoscope with two cameras and special glasses to be worn by the personnel.

Results

Four patients were successfully treated using 3D thoracoscopy. Operative time was comparable to that of the conventional 2D technique and less blood loss occurred. No per- or postoperative complications or problems occurred. Per-operative views were of very high quality and provided improved depth perception. Surgeons and residents deemed the technique helpful, especially during technically demanding aspects of the procedure.

Conclusions

While a shorter learning curve, decreased surgery time and blood loss have to be proven in future prospective studies, the first experience with 3D-VATS for spine surgery is positive and future use in minimally invasive spine surgery seems feasible.

Introduction

Severe traumatic thoracolumbar spine fractures that lack anterior stability are indicated for anterior stabilization, generally secondary to posterior fixation. One possible anterior stabilization method is minimally invasive thoracoscopic placement of a distractable cage after partial corpectomy of the fractured vertebra[1, 2]. The thoracoscopic approach can however be complex and technically demanding. Spatial 3D orientation represented on a 2D monitor provides surgical difficulties and lacks depth vision, which could be overcome by 3 dimensional (3D) visualization during the procedure.

3D-endoscopy was first applied in laparoscopic abdominal surgery[3, 4] and soon followed by thoracoscopic pulmonary surgery[5]. While the first studies in 3D endoscopy did not show superiority over 2D[3, 4], the introduction of high-definition imaging and technical improvements led to improved surgical performance in abdominal[6-9] and pulmonary surgery. The main advantage of 3D-video assisted thoracoscopy (VATS) over 2D-VATS is reported as decreased surgical time[10-12]. The use of 3D thoracoscopy for the treatment of thoracolumbar fractures or post-traumatic deformities might provide these advantages as well.

The use of 3D-thoracoscopy has not yet been reported in spine surgery. We describe the technique, feasibility, experience and results of the first four patients treated with 3D thoracoscopic anterior spine stabilization after thoracolumbar fractures.

Methods

Data collection

All patients treated with 3D-thoracoscopy for traumatic spine fractures in one academic medical center were reviewed. Baseline and per-operative surgical data of the first four patients treated with 3D-thoracoscopy were collected from the hospital information system. Operative time and blood loss of the three patients treated with only anterior stabilization were compared to the mean of the last ten patients that underwent only anterior stabilization for traumatic spine fractures with conventional 2D thoracoscopy in the same academic medical center. The indication for anterior stabilization in these patients was the same as the indication used for patients treated with the 3D technique and is described under Indications. Surgeons and residents that performed the surgery were asked for experienced (dis)advantages with the technique and their opinion compared to conventional thoracoscopy. The institutional ethics committee METc VUmc approved this study under number 2017.414.

Operation room set-up and 3D image conception

Operating room set-up and positioning of 3D-thoracoscopy is the same as traditional 2D-thoracoscopy. The standard monitors are replaced by 3D compatible monitors which can be switched back and forth to normal 2D view per-operative without changing the video scope. The 3D view is created by two video sensors on the video scope that alternately transmit an image to the high definition monitors. A videoscope with flexible camera tip was used. The monitor synchronizes with the respective signals from the video sensors and transmits a right and left polarized signal. The surgeons wear special glasses (Fig 1) with respectively a right and left circular polarized lens. The right and left eye then only receive a right- or left image specific signal which are then composed to a stereoscopic 3D image in the brain. Everybody in the room participating or observing the procedure wears the glasses. Although they slightly dim the light intensity, the glasses do not distort normal view and can therefore be worn during the whole procedure, even when the 3D monitors are not used.

Fig 1. Per-operative setting with surgeons wearing 3D glasses

Surgical technique

The thoracoscopic surgical technique according to which the procedure was performed was the same as in previously performed 2D-thoracoscopy and comparable to the method described by Beisse et al. and Khoo et al.[1, 2] As in the 2D surgical technique, the patient is positioned in lateral decubitus position and single lung ventilation is performed. Thoracoscopic partial corpectomy of the fractured vertebra with discectomy is performed with maintenance of the posterior vertebral wall. After this, an expandable titanium cage (Obelisc, Ulrich medical, Ulm, Germany) is thoracoscopically implanted in the resulting cavity and secondly the adjacent intact vertebrae are connected using anterolateral plating (MACS-TL,Braun, Melsungen, Germany). Finally the cage is surrounded with corpectomy bone augmented with bone graft from the corpectomy to stimulate bony fusion.

Port placement in 3D-thoracoscopy is the same as in 2D-thoracoscopy and dependent on fracture level. In the reported patients, two types of surgical procedures were performed; 'standard' anterior stabilization for fresh spinal fractures and anterior stabilization for post-traumatic kyphosis correction. The anterior thoracoscopic approach was similar for both procedures, however in posttraumatic kyphosis correction this was combined with posterior instrumentation during the same procedure (which consequently increases operative time and blood loss). Posttraumatic kyphosis correction is a three staged procedure, first thoracoscopic anterior decompression and corpectomy is performed in lateral decubitus position. Then the patient is switched to prone position and dorsal short segment fixation and lordosis are applied. The patient is then switched back to the lateral decubitus position and the expandable cage and anterolateral plate are thoracoscopically implanted. The cell saver is always available during this procedure because of the high risk of large blood loss. The 'standard' anterior stabilization for fresh spinal fractures is a one stage procedure usually performed one to two weeks after posterior instrumentation and is therefore without the need of repositioning the patient during the procedure. Lumbar fractures treated with a thoracoscopic approach usually require the crus of the diaphragm to be opened[2] and this causes 20-30 minutes of extra time.

Indications

The patients that were treated with 3D thoracoscopy for acute spinal fractures had an unstable anterior column. This is usually defined by a load sharing classification[13] ≥ 7. In the acute phase these patients are first posteriorly stabilized based on an unstable fracture (ligamentous injury; AO type B or C type, neurologic injury or severe deformity (depression > 50% or kyphosis > 30˚). If the anterior column is not deemed stable (usually AO type A2 or A4), often a CT scan is made after one week to evaluate the fracture. It is then decided based on kyphosis, comminution and fusion to perform additional anterior stabilization.

Results

Patients

Four patients were operated on using 3D-thoracoscopy between September 2016 and May 2017, all were female with a mean age of 46 years. Traumatic spine fractures were located at T10, T11 and L1. Three patients underwent a solely anterior approach, two shortly after primary posterior fixation due to an anterior column deficiency and one primary anterior treatment without posterior fixation in a pincer AO type A2 fracture. Three patients had a LSC of ≥ 7 and AO fracture types A4. One patient had a LSC of 5 but suffered a pincer AO type A2 fracture with large comminution, which created an unstable anterior column. One patient underwent a (three staged) posttraumatic kyphosis correction due to pain and a severe pre-operative kyphosis (33,4°). Further patient details are described in Table 1 and 2. The control group consisted of the last 10 patients treated with anterior stabilization for fresh traumatic spine fractures. The group consisted of six males and four females with a mean age of 40 ± 16 yrs, there were six T12 fractures and four L1 fractures.

Table 1. Patient characteristics

Pt	M/F	Age	Cause	ISS	Post – Ant (days)
1	F	44	Kitesurf accident	19	20
2	F	50	Fall horse	9	-
3	F	49	Fall stairs	9	15
4	F	39	Fall height	29	0

Surgery

All four patients underwent anterior two-segment (one vertebra below and above the fractured vertebra) stabilization. Mean operative time for the 3D standard anterior-only stabilization (patients 1-3, table 1 and 2) was 168 ± 42 minutes , which was comparable to the mean of 170 ± 52 minutes for the last ten patients treated with conventional 2D thoracoscopy. Blood loss was considerably less for 3D thoracoscopy with a mean of 383 ± 104 mL compared to a mean of 704 ± 595 mL for conventional thoracoscopy. The three staged procedure (posttraumatic kyphosis correction), applied in one patient, took 481 minutes (including two times repositioning) and resulted in 2200 mL blood loss. These results were comparable to previous three-stage procedures using conventional techniques. The radiographic results of the patients (Fig 2) were comparable to those of patients treated with the conventional technique. No per- or postoperative complications occurred in all patients.

Table 2. Fracture and surgery characteristics

Pt	Indication	Surgery	Fracture	LSC	AO fract	CA pre	CA post	Post. fix	Ant. fix	Operative Time (min)	Surg. Blood loss (mL)
1	Sec tr	A	T10	7	A4 – B1	26,1	19,6	T7-T9-T11	T9-T11	204	350
2	Tr	A	T11	5	A2 – B2	12,2	11,4	-	T10-12	178	500
3	Sec tr	A	T10	9	A4 – B1	15,7	12,5	T8-T12	T9-T11	122	300
4	PTKC	AP	L1	8	A4	33,4	5,50	T12-L2	T12-L2	481	2200

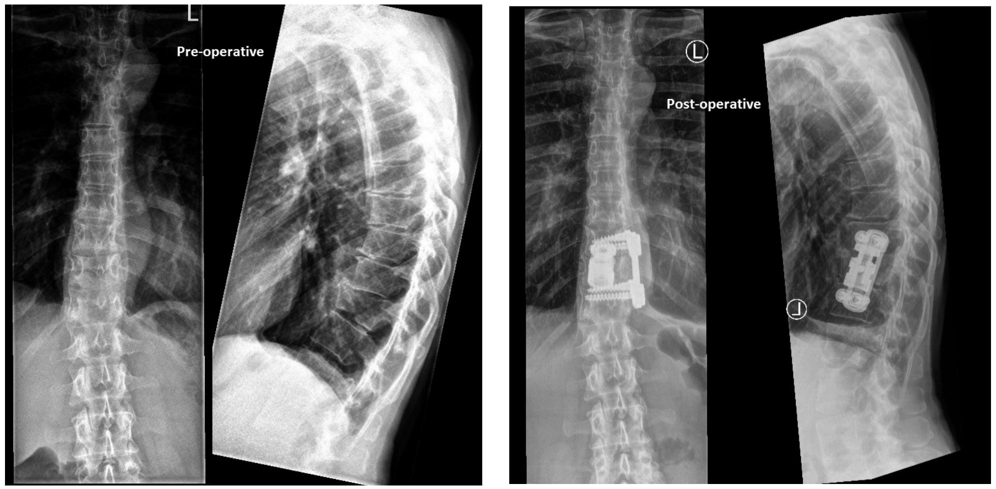
Pt; patient. Sec tr; anterior fixation secondary to posterior fixation for traumatic fracture. Tr; direct anterior fixation for fresh traumatic fracture. PTKC; post traumatic kyphosis correction. A; anterior. AP; anterior and posterior (three-stage). LSC: Load Sharing Classification. AO fract; AO fracture classification. CA pre; Cobb Angle pre-operative. CA post; Cobb angle post-operative.

Surgeon's experience

The treating surgeons (FB and JD) are experienced in the surgical treatment of traumatic spine fractures and very familiar with the thoracoscopic anterior approach as this is the only center in the country where this surgical technique is performed. They were very satisfied with the 3D image quality and stereoscopic views. The 3D view facilitated a fluent surgery process. The main advantage was improved depth estimation compared to 2D thoracoscopy which especially facilitated identification of vital structures and the partial corpectomy. If one of the cameras of the video portal gets blurred due to, for example blood spots, one is looking through the glasses at the monitor, the surgeon will only have 2D vison. Cleaning the video portal solves this problem, and this is not different from the 2D-thoracoscopy procedure where there is no vision if one lens is blurred.

Residents that participated in the procedures also reported improved depth estimation which especially aided in connecting instrumentation such as screws, bolts and plates that have to be attached. Because this procedure is not frequently performed and residents rotate between hospitals, they could not compare 3D thoracoscopy to the conventional 2D technique. Although the residents were not familiar with 3D thoracoscopy nor laparoscopy, no side effects such as nausea, dizziness or eye strain due to the stereoscopic view occurred.

Fig 2. Radiographic result of a patient treated using 3D-thoracoscopy, with lateral and antero-posterior X-ray pre-operatively and one month post-operatively.



Discussion

While the use of 3D-endoscopy is already implemented and increasingly used for lung surgery[5, 10-12] and abdominal surgery[3, 4], there is no literature on the use of this technique in spine surgery. Studies on 3D-thoracoscopy for lung surgery have mainly shown improvement in operative time[10-12]. The results of and experience with the treatment of our first four patients showed benefits of the 3D-images over conventional 2D-images in spinal surgery. It provided better depth estimation and a safer procedure due to clear visibility of vital structures that surround the surgical area (aorta and segmental vessels, spinal cord, exiting nerve roots). Presumably, this resulted in less blood loss compared to previous operations with conventional 2D thoracoscopy. Blood loss was also less compared to the average blood loss (650mL) of 150 patients treated in a center with high expertise[1]. It has to be noted though that blood loss is very dependent on individual patient characteristics such as anticoagulative medication, fracture complexity and anatomic variations.

Based on the first four patients we are therefore cautious to draw definitive conclusions on improved blood loss, but the results show potential.

Operative time of the first four 3D procedures was comparable to that of the conventional 2D procedure in this center. However, as reported for 3D-VATS, 3D thoracoscopy for anterior spinal stabilization has the potential to improve operative time, especially due to a faster and more precise corpectomy. Furthermore, residents reported to have better understanding of the surgical procedure, which might enhance a steeper learning curve. While results are promising, definitive conclusions can obviously only be drawn with results of more patients that are treated using this 3D technique. Additionally, the current results have to be interpreted in the light of the retrospective design and consequent possible selection bias. We expect that 3D thoracoscopy provides benefits comparable to those of 3D-VATS and 3D-laparoscopy[8, 9].

In our university hospital center, 3D equipment was already available as being used for lung and abdominal surgery and could directly be used by our spine surgeons to perform a 3D-thoracoscopic spine procedure. No additional training for the treating surgeons for 3D compared to 2D was needed. The surgeons had not used 3D-thoracoscopy before which proves that the concept can be easily adapted by surgeons already familiar with the conventional thoracoscopy technique. Higher costs due to the 3D technique are inevitable when using this expensive technique. However, especially in an academic teaching hospital the costs might provide good value because the technique is associated with steeper learning curves[14, 15]. Residents might learn faster and perform with less complications. The residents involved in this study had not seen the procedure before but were able to assist successfully. Beside residents, the technique might also be beneficial to junior surgeons not familiar with conventional thoracoscopy, due to improved spatial orientation which might shorten the learning curve[14, 15]. However this has still to be proven for spine surgery. If future studies demonstrate advantages such as shorter operative times, less blood loss and possibly less complications, the technique might be worth the additional costs.

Because the incision for the working and video portal are made in direct alignment with the designated vertebra, a rigid (20 degrees) camera is probably sufficient to visualize the work area. However, a flexible camera tip is available if needed, and has its main advantage in providing a complete overview of the working area with its surrounding vital structures.

The described technique is not intended to replace previous techniques such as image guided navigation[16] but merely to aid in precisely estimating and placing fixation material. Furthermore, 3D-thoracoscopy could possibly be combined with image guided navigation for pedicle screw insertion to have the advantages of both techniques. Other developments might also be combined with 3D-thoracoscopy for spine surgery, such as uniportal 3D-thoracoscopy to even further minimize surgical damage[17-19]. In addition glasses-free 3D-thoracoscopy is readily available and provides even more ease of use, however this comes at a much higher cost.

Conclusion

We have shown feasibility and a positive first experience with 3D-thoracoscopy for spine surgery mainly due to improved depth estimation. Experienced thoracoscopic spine surgeons with access to 3D compatible instrumentation, can readily experience the advantages of the technique without additional training. Operative and patient specific advantages such as reduced operative time and blood loss are promising but have to be proven in future studies comparing conventional and 3D-thoracoscopy for spine surgery.

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