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ORIGINAL STUDY

Percutaneous minimally invasive instrumentation for traumatic thoracic and lumbar fractures : A prospective analysis

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Open posterior instrumentation is still the standard procedure for unstable traumatic thoracic and lumbar fractures. There is a general tendency towards minimally invasive approaches in various surgical disciplines. The Sextant™ II Rod Insertion system is one of these. The authors prospectively studied this system in 51 patients with thoracic and lumbar fractures, between October 2007 and January 2011. Most fractures (31/51) were situated at the lumbar level. In 7 older patients the technique was combined with kyphoplasty and/or cement augmentation of the pedicle screws. The median operative time was 61 minutes (range : 26-130). The median fluoroscopy time was 132 seconds (range : 24-414). Most pedicle screws were correctly placed : 197 out of 204 screws. All fractures showed bony union after 6 weeks, but the multiaxial pedicle screws were not able to conserve the slight correction obtained peroperatively via positioning and longitudinal traction. Percutaneous minimally invasive stabilization of the spine needs further improvement.

Keywords : fractures ; thoracolumbar spine ; percutaneous ; minimally invasive ; posterior instrumentation ; Sextant ; spine surgery.

INTRODUCTION

The tendency towards smaller operative approaches is seen in various surgical specialties, also in spinal surgery, since two decades (*1,14,15*). This might minimize blood loss, risk of infection, postoperative pain, functional disturbance and prolonged hospitalization (*14,15,18*). Moreover, it might avoid fibro-fatty degeneration of the paraspinal muscles, often demonstrated by postoperative MRI. Last but not least the scar would be more acceptable (*21*). The purpose of this prospective study was to assess the results obtained with a minimally invasive system (MIS) in unstable thoracic and lumbar fractures (Sextant™ II Rod Insertion System ; Medtronic® Sofamor Danek).

MATERIALS AND METHODS

Fifty-one consecutive patients (22 females, 29 males) with unstable thoracic or lumbar fractures were operated upon between October 2007 and January 2011 (Table I). Patients with neurologic deficits were excluded (*10*). The

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Table I. — Patients' characteristics

Epidemiologic data	Number
Total population	51
males	29
females	22
ASA 1	25
ASA 2	17
ASA 3	6
ASA 4	2
ASA 5	1
Age (range)	51 y (20-84)
Duration of surgery (range)	61 min (26-130)
Fluroscopy time (range)	132 sec (24-441)
Hospitalization (range)	11 days (5-30)

Table II. — Classification of the fractures according to AO/OTA

Fracture type	Number
A . 1 . 2	2
A . 2 . 2	3
A . 2 . 3	4
A . 3 . 1	32
A . 3 . 3	8
B . 2 . 3	1
B . 3 . 2	1

median follow-up period was 14 months (range : 7-36). The median age was 51 years (range : 20-84 years). The physical fitness was assessed according to the ASA-Scoring system (*5*). Standard anterior-posterior and lateral radiographs were made. The AO classification was used (Table II). The ratio anterior vertebral height / posterior vertebral height was calculated on the lateral radiographs ; it gave an idea about the compression rate. The sagittal index was obtained as follows : the Cobb angle between the superior endplate and the inferior endplate was measured, after which the normal kyphosis (5° in the thoracic spine, 0° at the thoracolumbar junction, and minus 10° in the lumbar spine) was subtracted from this value (*1,10,23*). When necessary a CT-scan was performed to assess the individual fracture anatomy.

Surgical technique. All operations were performed by 3 experienced trauma and spine surgeons. A single shot of antibiotics (second generation cephalosporins) was administered at the induction. The patients were in the prone position, with a pad beneath breast and pelvis to increase the lordosis and to obtain partial reduction. Manual longitudinal traction was added. Four small incisions were made and the transpedicular guide-wires were inserted by means of fluoroscopy. Subsequently, the surrounding soft tissues were stripped off with dilatators, after which the cannulated pedicle screws were slid over the guide-wires. The position of the pedicle screws was controlled via fluoroscopy. These multi-axial pedicle screws, which were part of the Sextant®-system, could not be used as levers to reduce the fracture. Pedicle screw extenders were used to define the rod length, and the Sextant® rod inserter was attached. Two additional caudal incisions allowed percutaneous insertion of the rod in a curvilinear path, connecting both screw head openings on each side of the spine (Fig. 1). For detailed information about the surgical procedure : Foley and Gupta, Prokop *et al* and Schmidt *et al* (*3,16,20*). In seven older patients balloon kyphoplasty was added to address the instability of the anterior column of the spine. In this way an additional anterior approach was avoided. Their median age was 62 years (range : 51-66).

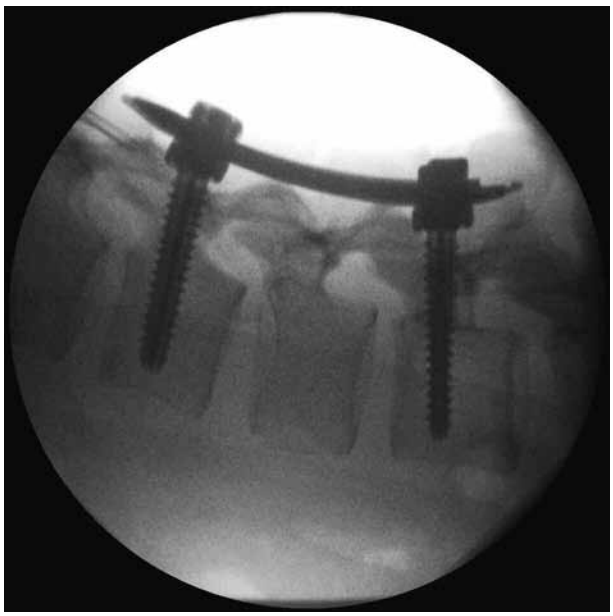

Fig. 1. — Intraoperative fluoroscopic image of an instrumented vertebra.

Postoperative treatment. A postoperative CT-scan checked the position of the pedicle screws. Early mobilization was the rule, and no complaints were noted. A clinical and radiological check-up took place after

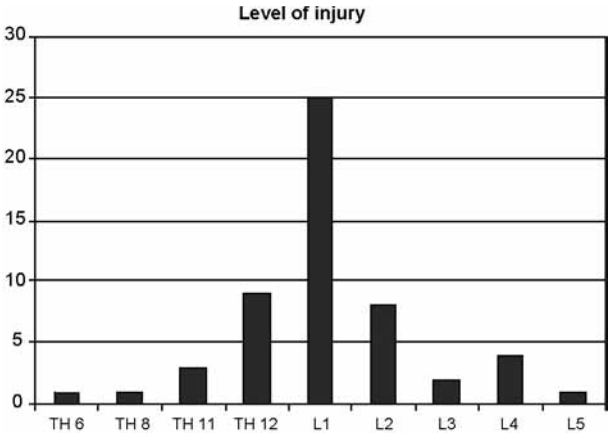

Fig. 2. — Level of spinal fractures

6 weeks and 6 months. All implants were removed after 6 months, in order to avoid loosening.

Statistical assessment. Statistical calculations were performed with SPSS 16.0 for Windows. The Kolmogorov-Smirnov test showed no normal distribution, so exclusively nonparametric statistical procedures (Wilcoxon's test and Mann-Whitney *U* test) were used for group comparisons and determination of correlations. A probability of $p < 0.05$ was accepted as significant. All data are presented as median and range.

RESULTS

Clinical results

In most patients (n = 35) the fracture resulted from a high-energy fall or jump (≥ 3 m) ; 6 had a car accident and 5 a bicycle accident ; 5 patients sustained various traumas. Forty-seven patients showed a one-level fracture, and 4 patients a 2-level fracture (T11+T12,T8+T11, L1+L2, T12+L1), totalizing 55 fractures. The lumbar spine was most often affected with 40 fractures, followed by the thoracic spine, with 15 fractures. The most injured vertebra was L1 (n = 25), followed by Th12 (n = 9) and L2 (n = 8) (Fig. 2). Most patients (n = 32) had an A.3.1 fracture, according to the AO-classification (Table II). The ASA scoring system (Table I) for physical fitness assigned 25 patients to class 1 (normal condition), 17 to class 2, 6 to class 3, 2 patients to class 4 and one patient to class 5 (*5,10*).

Operation

The median time between trauma and operative procedure was 3 days (range : 0-16 days), the median operative time was 61 minutes (range : 26-130). The median fluoroscopy time was 132 seconds (range, 24-414) with a median dose of 952cGy × cm^2 (range : 13-1430cGy × cm^2). The blood loss was estimated according to the median preoperative and postoperative haemoglobin concentration : these values were respectively 13.9 mg/dl (range, 7.9-17.1), and 11.9 mg/dl (range : 8.1-16.1), but the difference was not significant ($p > 0,05$). No blood transfusion was necessary. No neurological deficits were encountered. The median hospital stay was 11 days (range : 5-30 days). All fractures healed in 6 weeks. The implants were removed in 22 out of 51 patients (43.2%) after a median delay of 218 days (range : 140-411).

Radiological results

The median preoperative ratio anterior vertebral height/posterior vertebral height or anterior/middle column vertebral body compression ratio was 0.71. Postoperatively it improved to 0.91 (a gain of 28% ; $p > 0.05$) , but regressed to 0.86 after 6 weeks and to 0.75 (n = 22) after implant removal. The median preoperative sagittal index was 7° (range : 1-22°). It improved to 11.5° (range : 1-21°) postoperatively, but regressed to 8° (range : 1-21°) after 6 weeks, and remained at 8° (range : 1-22°) (n = 22) after implant removal.

Complications

Peroperative fluoroscopy showed twice that the pedicle screws had to be partially unscrewed in order to allow application of the rod. Asymptomatic cement embolism was seen in 2 cases, once after pedicle augmentation and once after additional kyphoplasty. The postoperative CT-scan showed correct placement of the pedicle screws in 197 out of 204 screws (96,6%). Seven screws (3.4%) penetrated the medial pedicle wall, and 4 of these 7 screws were at level L5. Revision was not

Table III. — Radiological results

Ratio ant./post. vertebral height	Preop.	Postop.	6 weeks	After implant removal (n = 22)
Median	0.71	0.91	0.86	0.75
Min.	0.41	0.73	0.46	0.56
Max.	1.11	1.23	1.14	1.41
Sagittal index	Preop.	Postop.	6 weeks	After implant removal (n = 22)
Median	7°	11.5°	8°	8°
Min.	1°	1°	1°	1°
Max.	22°	21°	21°	22°

necessary. Another patient showed loosening of the cranial screws, and revision was necessary.

DISCUSSION

Open posterior instrumentation is still the standard procedure in unstable traumatic thoracic and lumbar fractures. Primary anterior stabilization and conservative treatment are less frequently used.

Advantages of minimally invasive surgery (MIS)

MIS avoids many of the problems encountered with classic posterior midline approaches, for instance, extensive soft tissue dissection, particularly with exposure lateral to the facet joints. Furthermore, increased intramuscular pressure and ischaemia caused by the retractors, resulting in iatrogenic muscle denervation and atrophy. Indeed, MRI investigations have well documented postoperative fibro-fatty degeneration of the paraspinal muscles with consequently unsatisfactory clinical results (*21*). Irreversible electrophysiologic and histologic changes in the paraspinal muscles are reported after invasive spine surgery in human and animal studies (*8*). Other factors are prolonged hospitalization (*1,9,14,15,16*), infection and blood loss (*7,22*). Against this background, percutaneous minimally invasive spine surgery might be the right concept (*14,15,17*), but there exists no standard surgical approaches or general recommendations for spine fracture management (*1,3,14,15,16,20,21*).

The current study brought only minor complications to light, a finding confirmed by other authors (*6,19,24*). Blood loss was minimal, like in other studies (*16,19,20,24*). There was one exception : Grass *et al* (*6*) conducted a prospective study comparing open and percutaneous instrumentation, and reported a significantly ($p < 0.005$) increased peroperative blood loss in the latter. The operative time (median : 61 minutes) was in the same range as mentioned by other authors (*11,16,19,20*). Moreover, it was shorter than the time needed for conventional surgery, but not always significantly (*6,16,24*). The authors admit that the peroperative exposure to x-rays was comparable to that found with the classical approach. Moreover, a single prospective controlled trial showed that minimally invasive spinal surgery exposed the patient to significantly more radiation (*11*). The hospital stay (median 11 days) in the current study was again in the same range as in other studies (*2,6,9,15,16,19,20, 21,24*), and lower than after the classical approach (*1, 14,15,16,20*). More specifically, older patients can be mobilized much earlier, and will be less exposed to bed sores and pulmonary or thromboembolic complications (*4,12*). Therefore percutaneous spine instrumentation could be a good therapeutic option in damage control orthopaedic surgery (*4,7,9,12, 20,22*) (damage control is defined as the rapid initial control of haemorrhage and contamination, temporary closure, resuscitation to normal physiology in the Intensive Care Unit, and subsequent re-exploration and definitive repair).

The authors noted only 7 screws (3.4%), which penetrated the medial pedicle wall. In the literature misplacement rates from 2 to 16% are reported, mostly around 5%. Four of these 7 screws were at the L5 level, probably because of its specific anatomy. Surgeons should be aware of this. CT-guided

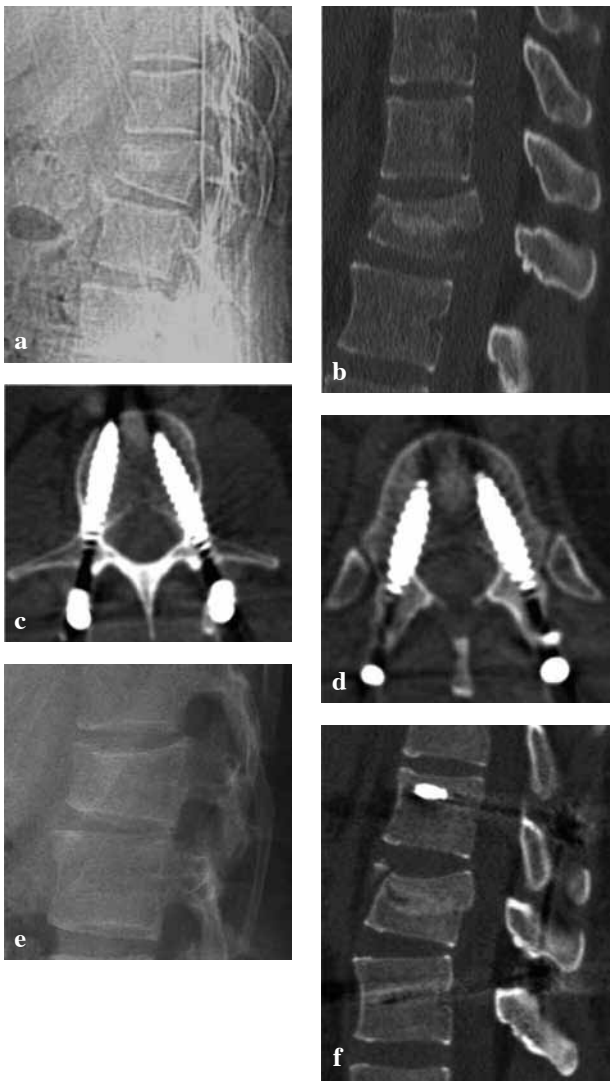

Fig. 3. — Fracture L1, AO/OTA type A.3.1. From top to bottom : typical burst fracture with retropulsion of the posterior wall ; correctly placed pedicle screws ; final correction after removal of the implant.

navigation/instrumentation is safer, but more expensive (*6,15,16,17,19,20*).

Drawbacks of minimally invasive surgery (MIS)

The multi-axial orientation of the pedicle screws does not allow reduction, distraction, lordosing or compression. Indeed, the peroperative reduction, obtained by the authors via positioning and longitudinal traction, was lost. Angle-stable subcutaneous devices should be developed. The overall reported benefits of minimally invasive surgery should not divert the surgeon from the fact that an anatomically correct reduction is the key to a successful treatment (*20*). In case of insufficient reduction one should switch to an open approach and a rigid, angle-stable stabilization system.

The system does not allow cross-linking (in very unstable fractures) (*16,20*).

The cannulated multi-axial screws are affixed to a curved 5.5 mm rod. Screw position is intrinsically limited to an arc by the structural confines of the rod passage and the local anatomy. One must await further implant developments and improvements ; they are underway (*6,16,20*).

A limitation of this study was the fact that two treatment options were mixed : instrumentation and cement augmentation. Long-term randomized studies, evaluating the medical and financial aspects of minimally invasive surgery, are necessary (*6,13, 14,15,16*).

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