Comparison between percutaneous and traditional fixation of lumbar spine fracture: Intraoperative radiation exposure levels and outcomes

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KEYWORDS
Radioprotection; Percutaneous spine surgery; Open spine surgery; Thoracolumbar spine fracture; Minimally invasive spine surgery

Summary
Objective: To compare radiation exposure doses and clinical and radiological outcomes between percutaneous pedicular screwing (closed reduction internal fixation [CRIF]) and classical open reduction internal fixation (ORIF) in lumbar spine fracture without neurologic deficit.

Materials and methods: Sixty patients (mean age, 42.5 years) were divided into two treatment groups: (Percutaneous) CRIF versus (traditional) ORIF. Screw position and anatomic vertebral reconstruction were checked on routine control X-ray and postoperative CT scan. Study parameters comprised: surgery time, radiation exposure time, radiation dose level for X-ray (DAP) and for CT (DLP), blood loss, length of hospital stay and postoperative pain (VAS).

Results: At a mean 25.5 months’ follow-up, there were no significant inter-group differences on the epidemiological parameters: age, gender, fracture level, fracture type on the Magerl classification, preoperative local vertebral kyphosis angle, or fracture-to-surgery interval. Effective radiation dose was 3-fold higher in CRIF than in ORIF, but 6-fold lower than for the postoperative CT scan. Postoperative pain on VAS was significantly lower after CRIF, allowing earlier gait resumption and return to work and daily activity. There were no significant differences in length of hospital stay, patient satisfaction, screw malpositioning or postoperative or end-of-follow-up kyphosis angle.

Conclusion: Percutaneous surgery provided clinical and radiological outcomes strictly comparable to those of open surgery, but with a higher effective radiation exposure dose, including for the medical team and especially for the surgeon. This higher exposure dose, however, is
Introduction

Treatment of thoracolumbar fracture remains controversial [1–3]. Open surgery is recommended in case of associated neurologic deficit or severe spinal instability, and has proved its efficacy despite a certain associated morbidity [4–6]. Percutaneous cementoplasty (vertebroplasty or kyphoplasty) can manage type A fractures in elderly patients, and may be used alone or associated to surgery to maintain vertebral kyphosis reduced by osteosynthesis [7–12].

Posterior percutaneous pedicular screwing was developed with the aim of reducing muscle trauma and blood loss [11,13–16]. Our department has been using this technique since 2004, especially in types A1, A2, A3 and B2 thoracolumbar fracture.

Keyhole surgery, however, requires more frequent peroperative X-ray control to ensure safety. Two questions thus arise: does this so-called "minimally invasive" attitude provide results comparable to classical techniques; as is it more irradiating for the patient?

The present study compared thoracolumbar fracture management by percutaneous and open surgery in terms of radiological and clinical results and per- and postoperative irradiation.

Material and method

A retrospective observational study compared two groups: 30 patients managed by percutaneous closed reduction internal fixation (CRIF) and 30 by conventional open reduction internal fixation (ORIF).

Material

Inclusion criteria
All patients admitted to the traumatology department of Nice University Hospital between June 1st, 2004 and August 15th, 2011, with traumatic fracture between levels T9 and L4, without associated neurologic disorder, and managed by internal fixation of whichever kind, were included. Ages ranged from 15 to 70 years. Data were required to be available for peroperative radiocopy time and dose.

Exclusion criteria
Cases with incomplete records as to peroperative irradiation in seconds and mGy/cm² were excluded.

The series
Sixty patients were divided into two comparable groups. There were 39 males and 21 females; mean age was 42.5 years (range, 15–66 yrs). The most frequently involved vertebra was L1 and the most frequent Magerl fracture type A3. In both CRIF and ORIF groups, assembly was based on four screws, except in two ORIF procedures with transverse devices but which required no extra radioscopic control.

Trauma was most frequently (70%) due to high fall (tree, ladder, platform, window), with road, sport and leisure accidents in second place. Twenty patients had associated lesions, mainly due to musculoskeletal trauma, and the others to craniofacial, cervical spine or pelvic trauma.

Parameters for the two groups are presented in Table 1.

Method

Peroperative irradiation measurement
All surgery was performed under two types of image intensifier, which both provided direct data on patient radiation: OEC 9800 PLUS (General Electric) and Arcadis Varic (Siemens). Data were in the form of dose-area product (DAP) in Gy/cm². The effective dose (E: dose received by the whole body) was calculated as E (mSV) = DAP × Edap, where Edap is a conversion coefficient expressed in mSV/Gy²/cm² and varying according to anatomic region: frontal thoracic spine = 0.27; lateral thoracic spine = 0.1; frontal lumbar spine = 0.21; and lateral lumbar spine = 0.13.

Depending on the surgical technique, AP and lateral control X-ray differed: ORIF usually entailed a single AP view at end of surgery plus one or two lateral peroperative views; in CRIF, an equal number of AP and lateral views were taken throughout the procedure. The effective dose should thus be calculated as E (mSV) = (DAP (lateral) × Edap) + (DAP (AP) × Edap).

Postoperative irradiation measurement
Postoperative CT used a Gems Light Speed 32 Pro scanner (Table 2) to detect screw malpositioning and the need for redo on an anterior approach.

The scanner directly provided the dose-length product (DLP), from which the effective dose could be calculated as E (mSV) = DLP × Edlp.

In CT, Edlp varies depending on anatomic region and gender: male thoracic = 0.017; female thoracic = 0.02; and abdominal-pelvic for both sexes = 0.015.

Choice of procedure
The surgical attitude depended on several criteria: CRIF in Magerl type A or B2 fracture with local vertebral kyphosis greater than 15° and reduction achieved in theater; otherwise, ORIF, including all cases with severe or definitive instability (types B1, B3, C1, C2 or C3). CRIF systematically used a four or six multiaxial screw assembly, and ORIF uniaxial screws with two median hooks at the extremities of the assembly.
Table 1  Data for overall series of 60 patients.

<table>
<thead>
<tr>
<th>Comparison parameters</th>
<th>ORIF</th>
<th>CRIF</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients, n</td>
<td>30</td>
<td>30</td>
<td>NS</td>
</tr>
<tr>
<td>Age (yrs): mean (range)</td>
<td>43.5 (15–66)</td>
<td>40.4 (15–64)</td>
<td>NS</td>
</tr>
<tr>
<td>Sex-ratio (male:female)</td>
<td>21:9</td>
<td>12:18</td>
<td>NS</td>
</tr>
<tr>
<td>Lesion level (T9-T10-T11-T12-L1-L2-L3-L4)</td>
<td>1:1:1-4-15-4-8-1</td>
<td>0-0-0-16-12-15-4-2-2</td>
<td>NS</td>
</tr>
<tr>
<td>Magerl classification (A1-A2-A3-B1-B2-B3-C1)</td>
<td>3-0-15-2-8-1-1</td>
<td>8-1-20-0-1-0-0</td>
<td>NS</td>
</tr>
<tr>
<td>Preoperative vertebra kyphosis (°): mean (range)</td>
<td>14.2 (3.8–29)</td>
<td>16.2 (3.4–25.5)</td>
<td>NS</td>
</tr>
<tr>
<td>Multiple trauma</td>
<td>12</td>
<td>8</td>
<td>NS</td>
</tr>
<tr>
<td>Assembly type (4-6-8 screws)</td>
<td>28-0-2</td>
<td>24-6-0</td>
<td>NS</td>
</tr>
<tr>
<td>Trauma circumstances (fall-road accident-other)</td>
<td>21-4-5</td>
<td>21-7-2</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS: non-significant; ORIF: open reduction internal fixation; CRIF: closed reduction internal fixation.

Table 2  Data for postoperative CT scan.

<table>
<thead>
<tr>
<th>Trot(s)</th>
<th>Voltage (U) (Kv)</th>
<th>Intensity (mA)</th>
<th>Matrix size</th>
<th>Slice thickness (mm)</th>
<th>Collimation (mm)</th>
<th>Pitch</th>
<th>Slice interval (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>120</td>
<td>Auto</td>
<td>512 × 512</td>
<td>1.25</td>
<td>40</td>
<td>0.516</td>
<td>0.625</td>
</tr>
</tbody>
</table>

Table 3  Comparison of irradiation in the two patient groups.

<table>
<thead>
<tr>
<th>Comparison parameters</th>
<th>ORIF mean (range)</th>
<th>CRIF mean (range)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radioscopy time (s)</td>
<td>29.49 (13.2–83.1)</td>
<td>139.67 (36–388.1)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>X-ray dose-area product (mGy/cm²)</td>
<td>2677.24 (583–20544)</td>
<td>8681.5 (1916–28851.8)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Radiographic effective dose (mSv)</td>
<td>0.55 (0.11–4.14)</td>
<td>1.51 (0.32–4.89)</td>
<td>0.0001*</td>
</tr>
<tr>
<td>CT dose-length product</td>
<td>0.744 (0.33–1.27)</td>
<td>0.58 (0.26–1.53)</td>
<td>NS</td>
</tr>
<tr>
<td>CT effective dose (mSv)</td>
<td>11.58 (4.43–20.53)</td>
<td>9 (4.43–23.06)</td>
<td>NS</td>
</tr>
<tr>
<td>CT/X-ray effective dose</td>
<td>21.05</td>
<td>5.96</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

ORIF: open reduction internal fixation; CRIF: closed reduction internal fixation. NS: non-significant.

*P < 0.05.

Removable corsets were used on subjective criteria, for 3 months in principle. All patients underwent immediate isometric rehabilitation, which was continued outside the department.

Deformity assessment

Vertebral deformity, and notably local vertebral kyphosis, was assessed preoperatively, immediately postoperatively and at follow-up on lateral X-ray using OsiriX imaging software (Foss, Geneva, Switzerland).

All patients underwent postoperative CT to assess implant positioning and the need for redo on an anterior approach.

Statistical analysis

All per- and postoperative variables were compared between CRIF and ORIF by Student t test on GraphPad software.

Results

The ORIF and CRIF groups differed significantly in radioscopy time, radioscopy dose (DAP) and the corresponding effective dose, surgery time, blood loss and postoperative pain; on the other hand, there were no significant differences in mean hospital stay, postoperative vertebral kyphosis, postoperative CT DLP and patient satisfaction (Tables 3 and 4).

Effective dose and radioscopy time were significantly higher in CRIF than ORIF. CT involved an effective dose 21-fold higher than the peroperative dose in ORIF and 6-fold that delivered in CRIF.

Peroperative radioscopy time varied with the experience of the surgeon, one of whom had begun using CRIF in 2004, a second in 2007 and a third in 2010 (Fig. 1): dose level fell with operator experience (Fig. 2).

Surgery time, blood loss and postoperative pain were all less in the CRIF group.

There was no significant difference in immediate postoperative kyphosis or long-term satisfaction.

Vertebral kyphosis reduction gain was the same with CFRIF and ORIF, both immediately postoperatively and at 6 months (Fig. 3).

Discussion

Thoracolumbar fracture is the most frequent spinal fracture, and treatment by percutaneous pedicular screwing remains
controversial and is still under assessment despite regular positive reports [1,3,9,13,17].

The present study recruited two small but comparable groups. Huang et al. [10] reported similar findings in two groups comparable for size, gender, age, mechanism, fracture level and vertebral kyphosis reduction.

The first studies by Chi et al. [13], followed by Pelegri et al. [11], showed CRIF to be feasible, reproducible and effective. We have used this technique since 2004, like many other teams such as those of Wang et al., Fuentes et al. and Zairi et al. [8,15,18,19], who all agree on drawing up a standard for CRIF as a primary attitude in non-neurologic thoracolumbar fracture.

Li et al. [20] demonstrated the interest of the percutaneous attitude with regard to the paraspinal muscles, and it has now become a routine procedure in traumatology, as it has been for several decades in peripheral surgery.

Despite definite advantages, this minimally invasive technique is inevitably more highly irradiating than open surgery; however, we were unable to find any studies in the literature

\[ \text{Table 4: Comparison of clinical and radiological results.} \]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>ORIF</th>
<th>CRIF</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery time: mean (range)</td>
<td>148.5 (100–225)</td>
<td>83.5 (30–180)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Blood loss (ml): mean (range)</td>
<td>318.83 (70–1000)</td>
<td>50.33 (50–60)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Pain (1–10 VAS)</td>
<td>0.63 (0–3)</td>
<td>0.17 (0–2)</td>
<td>0.0318*</td>
</tr>
<tr>
<td>Ablation of osteosynthesis material</td>
<td>0.13</td>
<td>0.5</td>
<td>0.0018*</td>
</tr>
<tr>
<td>Immediate postoperative VK: mean (range), (°)</td>
<td>3.8 (0–8.5)</td>
<td>4.6 (0–8.5)</td>
<td>–</td>
</tr>
<tr>
<td>Extrapedicular screw</td>
<td>0.03</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Sperificial skin infection</td>
<td>0.1</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Very satisfied</td>
<td>29</td>
<td>24</td>
<td>–</td>
</tr>
<tr>
<td>Satisfied</td>
<td>1</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>Disappointed</td>
<td>23.86 (0.25–43.75)</td>
<td>24.57 (1–90.50)</td>
<td>–</td>
</tr>
<tr>
<td>VK at 6 months: mean (range), (°)</td>
<td>1 (0–4)</td>
<td>1.8 (0.5–7)</td>
<td>–</td>
</tr>
<tr>
<td>Immediate reduction gain\ (preoperative–postoperative VK), (°)</td>
<td>11.2 (2.2–24.3)</td>
<td>12 (1.4–25)</td>
<td>–</td>
</tr>
<tr>
<td>Reduction gain at 6 months\ (preoperative–postoperative VK), (°)</td>
<td>13.71 (3.8–27.6)</td>
<td>14.93 (2.6–23.5)</td>
<td>–</td>
</tr>
</tbody>
</table>

VK: vertebral kyphosis; ORIF: open reduction internal fixation; CRIF: closed reduction internal fixation.

\(P<0.05\).

**Figure 1** Comparison of dose (DAP) delivered according to departmental experience. ORIF: open reduction internal fixation; CRIF: close reduction internal fixation.

**Figure 2** Evolution of dose (DAP) delivered per specialized surgeon (SS1 to SS3).

**Figure 3** Comparison of postoperative vertebral kyphosis (VK) gain (in increasing order) in the two patient groups. Surgical gain = preoperative VK – immediate postoperative VK. ORIF: open reduction internal fixation; CRIF: close reduction internal fixation.
analyzing such difference in the case of thoracolumbar fracture.

Rampersaud et al. [21] reported that spine surgeons were exposed to a 10-fold greater radiation level than orthopedic surgeons treating the limbs, due to relative tissue thickness, and advised a distance of at least 1 m from the radiation source to achieve a real reduction in irradiation.

Several physical protection methods have been assessed, for the skin, eyes and thyroid; positioning the receiver above the patient also seems to reduce irradiation of both patient and surgery team [22]. A study conducted in 2000 reported a mean of 1.4 minutes of fluoroscopy per patient per procedure, whereas the present study found 0.5 minutes in ORIF, doubtless thanks to departmental experience. Ul Haque et al. [23] advised devising methods more protective of the surgeon, recommending that spine surgeons be classified as occupationally exposed to ionizing radiation. In 2009, Wrangel et al. [24] reported that placing the receiver beside the surgeon reduced the dose by a factor of 4. In 2011, Mroz et Abdullah [25], assessing toxicity in percutaneous lumbar osteosynthesis, calculated that it would take about 5000 screws to be toxic for the eyes and nearly 6500 for the limbs of the surgeon; he reported 30 seconds’ radiography per screw, and that the procedure was safe for the surgery team. Percutaneous cementoplasty is becoming increasingly associated in elderly patients, which is liable to increase team irradiation as it too is performed under radioscopy: Mroz et al. [26] reported 4 minutes’ continuous radioscopy per vertebra in a 2-level procedure.

Image-guided navigation seems not only to increase precision in CRIF, as described by Assaker et al. [27] in 2001, but also to reduce radiation exposure time. The methods involve pre-operative CT with less peroperative controls, which may reduce the surgeon’s exposure but perhaps not that of the patient, as the CT scanner delivers 20 times the radiation of the entire surgical procedure according to the present results. In 2008, Kim et al. [28] again claimed that navigation reduced peroperative irradiation, estimating the radiation time involved in arthrodesis at 2.45 minutes for fluoroscopy versus 57 seconds for navigation. Smith et al. [29] recommended computer-assisted image guidance with no peroperative fluoroscopic control, reporting satisfactory results in terms of patient safety.

In 1999, Slomczykowski et al. [30] reported the first comparison between fluoroscopy and computer-assisted navigation in percutaneous surgery, with results favoring fluoroscopy when performed by experienced spine surgeons. He reported 4.3 minutes radiation per screw, compared to 2.3 minutes in the present CRIF group of 30 patients.

Outside of traumatology, Bindal et Glaze [31], in 2008, reported 1.69 minutes per patient in 24 percutaneous transformaminal lumbar interbody fusions (TLIF), and recommended a safety limit of 160 to 600 cases per annum, depending on the target organ.

Electromagnetic field-based image-guidance has been recommended in CRIF, as reducing patient exposure [32].

Most of these reports were of cadaver or ‘phantom bone’ studies, to achieve optimal radiation detector positioning. A search of the literature found no real-life comparative clinical studies. The sometimes long radioscropy times in the present study may be explained by the need for peroperative control of screw positioning, to enable rapid correction when need be; this is an unavoidable aspect of the learning curve. The practice of systematically taking two orthogonal views, established in limb traumatology, seems all the more essential in pediculare screwing, for which we scrupulously adhere to the radioscopy control protocol described by Foley et al. [33, 34].

From the DAP value provided by the image intensifier, the effective dose—i.e., the real dose received by the patient—could be calculated. The study found CRIF to involve greater irradiation than ORIF. Dose also depended on operator and departmental experience. University Hospital Centers provide teaching and training, and operators are continually being replaced; departmental experience follows cycles related to surgical training—whence breaks in the learning curve. The present results suggest that spine surgery should be reserved to experienced specialists. CRIF is a new technique, entailing a learning curve, as pointed out by Merom et al. [35].

CRIF involves intensive use of fluoroscopy, and this is unavoidable if safe positioning is to be ensured. Patient, surgeon and theater staff are all exposed; for the patient, this is a single exposure, delivered in his or her own interest.

Smith et al. [29] observed that the surgeon and theater staff are regularly exposed, with varying negligible consequences depending on the organ concerned. Roux et al. [36] recently showed that percutaneous pedicular screwing of the thoracolumbar spine involves the greatest radiation exposure of any percutaneous procedure in traumatology: osteosynthesis by percutaneous pedicular screwing of the thoracolumbar spine involves an effective dose equal to that of 270 anterior wrist osteosyntheses, or 44 tibial or nine femoral nailing procedures. In reality, the dose received is proportional to tissue radiosensitivity and the body area exposed. X-rays pass more easily through the wrist than laterally through the lumbar-sacral spine. In 2005, Singer estimated a hip radiograph to be equivalent to 20 lung radiographs [37]; the difference is thus more to do with the anatomic site than the surgical technique: CRIF involved a mean effective dose only three times as great as ORIF, or even less according to operator experience.

The postoperative CT scan, in contrast, involved a far higher radiation dose than surgery, whether percutaneous or open: 20-fold higher than in the ORIF group and 6-fold higher than with CRIF. CT, moreover, is often repeated at the 3rd, 6th, 12th and 18th months; it would be advisable to reduce the frequency of these postoperative controls, in order to reduce the effective dose.

The French ministerial Decree 2003-270 of March 24, 2003 implements measures to protect the surgeon, theater staff and patient against deterministic and stochastic radiation risk, in line with the European Union EURATOM directive [36]. Other measures should also be undertaken, with regard to distance, screening, equipment in lead, ECG-pulsed CT scanners with inbuilt collimators, etc. Exposed staff should undergo regular check-ups by their occupational physician, and should limit their annual dose [36].

CRIF involved shorter surgery time, lesser short-term pain and less blood loss, in agreement with the literature [15, 17]. Huang et al. [10] and Chi et al. [13], on the other hand, reported no difference between the two techniques in surgery time, which depended on operator experience. The difference found in the present study is to be explained.
by the larger surgical approach in ORIF, the associated bone graft and drainage, and the inevitably longer closure time.

Hospital stay is influenced by the severity and management of associated lesions. Pelegri et al. [11] reported that multiple trauma lengthened hospital stay. In the present study, both techniques provided the same immediate postoperative reduction in vertebral kyphosis and long-term satisfaction, in line with the literature [10,11,15].

Regular CT controls to check pedicular screw positioning in the CRIF group may account for the absence of any extra-pedicular screws in the present series; there was, in contrast, 1 such case in the ORIF group. Pelegri et al. [11] reported an intra-canal screw with neurological impact in one out of 17 patients, at the beginning of the experience with percutaneous surgery, and recommended not sparing peroperative radiology in order to optimize screw positioning. Ringel et al. [38] made the same recommendation regarding 3% of his patients, with no neurologic impairment.

In the present study, surgical technique was chosen according to fracture type and characteristics (instability). The study was retrospective, based on a decision-tree drawn up in 2004 and which entailed a recruitment bias but without impact on peroperative radiation levels. It was ensured that the two groups were comparable in characteristics and results. Palmisani et al. [14] and Yong et al. [16] performed percutaneous surgery for type-C fractures, but our department did not have this experience.

Infection rates were lower in CRIF, with an esthetically satisfactory cutaneous aspect, probably due more to underlying muscle damage in ORIF than to the skin incision as such, as previously reported [35].

Finally, osteosynthesis material obliteration at 1 year in the CRIF group was performed following the departmental protocol, and introduced a bias in long-term assessment with respect to the ORIF group; it was, however, an integral part of treatment.

Conclusion

Percutaneous fixation of thoracolumbar fracture provided the same clinical and radiological results as open surgery. Blood loss, pain, muscle damage and return to occupational and personal activity argued in favor of the percutaneous attitude.

Radiation levels in CRIF were three times those in ORIF, but six times less than for the postoperative CT scan. Patient irradiation by postoperative CT controls should be taken into account in assessing overall patient exposure.

Radioprotection for the surgeon and theater team can improve with departmental and operator experience, but peroperative radiologic controls should not be sacrificed, as screw positioning needs to be ensured.

Finally, new imaging techniques such as surgery-room CT scanners serve to enhance the technical capacities of the surgeon, but do not reduce patient radiation exposure.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


