Effects of minimally invasive percutaneous and trans-spatium intermuscular short-segment pedicle instrumentation on thoracolumbar mono-segmental vertebral fractures without neurological compromise

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KEYWORDS
Spinal fractures; Pedicle screws; Minimally invasive surgery; Trans-muscular spatium approach

Summary
Objective: To compare the outcomes of minimally invasive percutaneous short-segment pedicle instrumentation (SSPI) with that of trans-spatium intermuscular SSPI on thoracolumbar mono-segmental vertebral fracture without neurological compromise.

Methods: A total of 39 patients with thoracolumbar mono-segmental vertebral fracture without neurological deficit receiving treatment between January 2009 and July 2011 were enrolled. Percutaneous SSPI was performed for 18 patients (the percutaneous group), and trans-spatium intermuscular SSPI was performed for 21 patients (the trans-spatium intermuscular group). Peroperative indices, intraoperative radiation exposure time, postoperative and follow-up lumbodorsal pain, function scores, and radiological data were compared.

Results: The percutaneous group had significantly less intraoperative blood loss and less severe postoperative pains, but suffered significantly longer fluoroscopy time and higher hospitalization costs compared with the trans-spatium intermuscular group. No significant difference was observed in operating time. All patients were followed up for 17.3 ± 9.2 months (ranging from 5 to 35 months). No significant differences were observed between the two groups in terms of postoperative relative vertebral height (RVH) and regional kyphotic angle (RKA), as well as last follow-up RVH, RKA, lumbodorsal pain, and Oswestry disability index.

Conclusion: Percutaneous SSPI has the virtues of less intraoperative blood loss and less severe pains in the treatment of thoracolumbar mono-segmental vertebral fracture without neurological compromise.
Introduction

Thoracolumbar spinal fractures are a very common type of spinal injuries. Posterior short-segment pedicle instrumentation (SSPI) is one of the most widely adopted surgical procedures for such a condition nowadays, and its curative effect has been acknowledged in clinical practice for years. However, traditional SSPI requires the dissection of the paravertebral muscle and fascia tissues attached to the spinous process, vertebral lamina, and zygapophysis. This requirement consequently leads to an iatrogenic damage to the midspinal line and thus becomes one of the important factors causing spinal instability and pain. In addition, screw placement in the traditional SSPI results in an incidence of epistatic zygapophysial joint injury as high as 24% [1], which becomes an important factor causing adjacent segmental degeneration.

Therefore, minimizing the invasiveness of surgical procedures to reduce the occurrence of iatrogenic sequelae has long been an expectation of patients with thoracolumbar fractures as well as a goal that spinal surgeons are striving for. With the development of technique and surgical instruments, both percutaneous and trans-muscular spatiial SSPI have been applied in the treatment of thoracolumbar mono-segmental vertebral fracture nowadays. The trans-muscular spatiial approach was first proposed by Wiltse LL et al. in 1968 [2]. After years’ evolution, the originally designed bilateral incisions (3 cm long) along the median line have been replaced by a single incision [3]. Although reaching the screw entry point of the zygapophysial pedicle directly through the spatiial between the musculi longissimus and the multifidus still belongs to a type of open approach, the trans-muscular spatiial approach causes much less damages to the paravertebral muscles compared with the traditional one [4]; therefore, this approach protects the integrity of the paravertebral muscles sufficiently and avoids a damage to the zygapophysial joint, thereby reflecting the concept of “minimal invasiveness". In contrast, the percutaneous approach makes a further step: it minimizes incision length, only causes small damages to the paravertebral muscles and reduces intraoperative blood loss. Furthermore, screw placement in this procedure is monitored fluoroscopically, which thereby increases the accuracy of screw placement. These features endow the percutaneous approach with a real sense of “minimal invasiveness". Nowadays, the percutaneous approach has been more and more widely applied in the treatment of thoracolumbar fractures [5—7]. Its combination with transforaminal lumbar interbody fusion (ILIF) has also been applied in the treatment of lumbar vertebral degenerative diseases [8,9].

Clinical practice has shown that although percutaneous SSPI has a similar curative effect on thoracolumbar fractures compared with the traditional procedure, it does have advantages in operating time, intraoperative radiation exposure time and a higher surgery cost. To us, percutaneous SSPI has no advantage over trans-spatiial intermuscular SSPI in therapeutic outcomes.

Level of evidence: Level IV. Retrospective study.
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Subjects and methods

Subjects

The selection criteria included:

- thoracolumbar (T11-L2) mono-segmental vertebral fracture which was typed A, B1.2, or B2.3 according to AO typing;
- treatment time between January 2009 and July 2011;
- and SSPI.

Patients met any of the following criteria were excluded:

- non-passable burst bone fragments posterior to the injured vertebra, or dislocated vertebral fracture;
- thoracolumbar fracture accompanied with neurological defects or serious injuries of other spinal segments;
- thoracolumbar fracture accompanied with injuries of other associated sites which might cause severe disability or death;
- thoracolumbar fracture which had to be treated with vertebral screw placement, anterior surgery, or vertebroplasty;
- simultaneous surgery for injuries or degenerative diseases of other spinal segments;
- and thoracolumbar fracture accompanied by serious medical diseases, which might greatly affect the outcomes of the current study.

Percutaneous or trans-spatiial spatium SSPI was decided according to factors such as patients’ willingness, their ability to shoulder economically, and so on.

This study was conducted in accordance with the declaration of Helsinki and approved by the Ethics Committee of Shanghai Jiao Tong University.
A total of 39 patients with thoracolumbar mono-segmental fracture without neurological defects were finally enrolled. They were divided into two groups according to different surgical approaches: the percutaneous \((n=18)\) and trans-muscular spatium \((n=21)\) groups. Written informed consents were obtained from all participants. Radiological and surgical data were analyzed jointly by two spinal surgeons. All patients complained of thoracolumbar pains with movement disorders. Body examinations showed pressing or percussion pain of the injured segment in 37 patients \((94.8\%)\), lower lumbar paravertebral pain in 23 \((59.0\%)\), interspinous emptiness and spinous process bone friction feeling in seven \((17.9\%)\), and subcutaneous ecchymosis in four \((10.3\%)\). Their nerve functions were graded \(E\) according to Frankel’s grading. Additionally, 15 patients were observed accompanied with non-spinal associated injuries, including scalp hematoma in three patients, thoracic cage bone fractures accompanied by slight pulmonary contusion in four, and limb fractures in 12. The clinical data are summarized in Table 1.

### Surgical procedures

Both procedures were performed by the same group of surgeons, and the operations of screw placement and reposition were monitored using a C arm X-ray machine. The Sextant (Medtronic, USA) or Viper (Depuy, USA) system was utilized for the percutaneous group, and the CD Horizon Legacy (Medtronic, USA), Moss Miami SI (Depuy, USA), or SINO (WEGO, China) system was utilized for the other group. The patient was anesthetized generally and positioned proney with the abdomen suspended. In vitro repositioning was performed by appropriately pressing the thoracolumbar convex vertex ventral ward.

#### The percutaneous group (the Sextant system as the example)

The zygapophyseal joints of the injured and adjacent segments were localized fluoroscopically. An incision about 1 cm long and 1−1.5 cm lateral to the affected zygapophyseal joint was made (the incision length took allowing the surgeon’s forefinger in as the upper limit). The paravertebral muscles were dissected bluntly until to the zygapophyseal joint. The pointed end of an opening device was placed at the upper verge of the pedicle under fluoroscopic monitoring. The device was screwed into the pedicle and a guide pin was afterwards left. The opening device was withdrawn, the guide pin was tapped, and then pedicle screws were bilaterally inserted into the vertebrae adjacent to the injured one. A connective bar with an appropriate length was measured and mounted onto a locator. Another small caudal incision inferior to the original one was made for bar inserting. The bar was mounted, the screws were fastened and the locator was then withdrawn. The fascia and skin were sutured.

#### The trans-muscular spatium group (the CD Horizon Legacy system as the example)

The injured segment was treated as the centre and a median incision was made. The skin and subcutaneous tissues were cut open successively to expose the lumbodorsal fascia. The fascia was cut open 1.5 cm bilateral to the supraspinous ligament and the inner margin of the sarolemma of the musculi longissimus was sought at the medial cutting margin. The spatium between the musculi longissimus and the multifidus was dissected bluntly until to the exterior margin of the zygapophyseal joint. Pedicle screws were inserted bilaterally into the vertebrae adjacent to the injured one. A pre-bent connective bar with an appropriate length was fixed. Appropriate distraction was done according to the

### Table 1  Clinical data of the patients.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Percutaneous</th>
<th>Trans-muscular spatium</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cases</strong></td>
<td>39</td>
<td>18</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td><strong>Sex (M:F)</strong></td>
<td>25:14</td>
<td>13:5</td>
<td>12:9</td>
<td>0.341*</td>
</tr>
<tr>
<td><strong>Age (yo)</strong></td>
<td>36.3±9.2</td>
<td>37.6±11.0</td>
<td>35.1±7.4</td>
<td>0.421**</td>
</tr>
<tr>
<td><strong>Causes</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.372</td>
</tr>
<tr>
<td>Fall wound</td>
<td>15</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Traffic accident</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Weight crushing</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Others or unknown reasons</td>
<td>11</td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>AO typing</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.576</td>
</tr>
<tr>
<td>A1</td>
<td>9</td>
<td>3</td>
<td>6</td>
<td></td>
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<tr>
<td>A3</td>
<td>20</td>
<td>11</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>B1.2</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>B2.3</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Fractured segment</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.089*</td>
</tr>
<tr>
<td>T11</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>T12</td>
<td>9</td>
<td>2</td>
<td>7</td>
<td></td>
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<tr>
<td>L1</td>
<td>15</td>
<td>6</td>
<td>9</td>
<td></td>
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<tr>
<td>L2</td>
<td>12</td>
<td>7</td>
<td>5</td>
<td></td>
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</table>

* Is based on Pearson Chi² test.

** Is based on one-way ANOVA.
state of reposition, and the screws were then fastened. The incisions were washed with physiological saline. The lumbodorsal fascia, subcutaneous tissues, and skin were sutured successively.

All patients received patient control analgesia or antalgic treatment for 48 h after operation, and then radiographs in AP and lateral position were taken. Stitches were removed at 10 to 12 days after the operation. Functional training was instructed by rehabilitation physicians during their hospital stay.

Evaluations

The immobilization methods, devices, surgery receiving time, intraoperative blood loss, and fluoroscopy time were recorded. Each patient’s total cost, including hospitalization and implants, was also recorded and compared. The patients were asked for follow-up checks at 1.5, 3, 6, and 12 months after discharge from the hospital, and then they received a follow-up check every year. Their functional recovery was evaluated and instructions in rehabilitation training were then given. A radiograph was taken at each follow-up check to evaluate fracture reduction, healing, and segment fusion. A visual analogue scale (VAS) was assigned to evaluate lumbodorsal pain. The Oswestry disability index (ODI) was used to evaluate postoperative function. Preoperative, postoperative, and follow-up relative vertebral heights were measured based on pre- and postoperative radiographs, and regional kyphotic angles (RKA) were measured using the Cobb method. A vertebral reduction rate was calculated [13] and load-sharing classification was determined [14].

Statistical analysis

All measurement data were presented as mean ± standard error, and enumeration data as quantity. One-way analysis of variance (ANOVA) was performed to compare the measurement data between groups, and Pearson Chi² tests were performed to compare the enumeration data between groups. The data were analyzed using the SPSS19.0 software. \( P < 0.05 \) was considered statistically significant.

Results

The average surgery receiving time of all patients was 1.77 ± 0.87 days (ranging from 1 to 4 days) after injury. The two groups did not show any significant difference in RVH, RKA, and LSC before treatment.

A total of 156 screws were used for the patients, and no serious complication or disc, cerebrospinal fluid, peri-implants or superficial soft tissue infection occurred to them during perioperative period.

<table>
<thead>
<tr>
<th>Table 2 Surgery and follow-up data.</th>
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<tr>
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<tr>
<td>Preoperative RVH (%)</td>
</tr>
<tr>
<td>Preoperative RKA (°)</td>
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<tr>
<td>LSC (points)</td>
</tr>
<tr>
<td>Operating time (min)</td>
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<tr>
<td>Fluoroscopy time (min)</td>
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<tr>
<td>Intraoperative blood loss (ml)</td>
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<tr>
<td>Postoperative VAS</td>
</tr>
<tr>
<td>Postoperative RVH (%)</td>
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<tr>
<td>RVH correction rate (%)</td>
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<tr>
<td>Postoperative RKA (°)</td>
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<tr>
<td>RKA correction (°)</td>
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<tr>
<td>Hospitalization costs (10,000 yuan)</td>
</tr>
<tr>
<td>Follow-up (months)</td>
</tr>
<tr>
<td>Last follow-up RVH (%)</td>
</tr>
<tr>
<td>Last follow-up RKA (°)</td>
</tr>
<tr>
<td>RKA loss (°)</td>
</tr>
<tr>
<td>Last follow-up VAS</td>
</tr>
<tr>
<td>Last follow-up ODI</td>
</tr>
</tbody>
</table>

RVH: relative vertebral height; RKA: regional kyphotic angle; LSC: load-sharing classification; VAS: visual analogue scale; ODI: Oswestry disability index.

* \( P < 0.01 \) based on one-way ANOVA.
The intraoperative blood loss of the percutaneous group was noticeably less than that of the trans-muscular spatiot group, but it suffered significantly longer fluoroscopy time as well as higher hospitalization costs. No significant difference in operating time was observed between the two groups. Although the percutaneous group had less severe pains at 48 h after operation compared with the trans-muscular spatiot group, radiographs did not show significant differences between the groups in RVH and RKA.

All patients were followed up, and the average follow-up time was 17.3 ± 9.2 months (ranging from 5 to 35 months). No internal fixation failure happened. The two groups did not show significant differences in RVH, RKA, and LSC according to the last follow-ups. In both groups, lumbodorsal pains improved and good ODI scores were achieved, which did not show significant differences. The operation and follow-up associated data are summarized in Table 2.

Discussion

Both percutaneous SSPI and trans-muscular spatiot SSPI aim to minimize iatrogenic damages to the paravertebral muscles, improve surgical curative effect and reduce the risk of long-term complications by modifying the traditional approach. Percutaneous pedicle screw fixation is a minimally invasive surgical technique in a real sense, which provides a good option for the treatment of thoracolumbar spinal fractures. Most scholars hold that percutaneous SSPI can reduce the occurrence of the complications caused by screw placement and thus is a safe procedure [15,16]. In contrast, trans-muscular spatiot SSPI requires an incision similar to that in the traditional SSPI. However, this procedure allows a direct approach to the exterior margin of the zygapophysial joint through the spatiot between the multifidus and the musculi longissimus, which makes the pedicle screw entry point directly exposed without dissecting the attachment points of the paravertebral muscles. Thus, it avoids iatrogenic damages to the paravertebral muscles, joint capsules, as well as interspinous and supraspinous ligament complexes, thereby demonstrating the concept of minimal invasiveness as well. In addition, this approach combined with TLIF can also be applied in the treatment of lumbar vertebral degenerative diseases [17]. As the exposure of the vertebral lamina and zygapophysis is unnecessary in the treatment of thoracolumbar mono-segmental vertebral fracture without neurological defects, both procedures can be applied for patients with such a condition. Based on the aforementioned, the present study compared the curative effects of the two procedures on thoracolumbar mono-segmental vertebral fracture without neurological defects. In doing this, the intraoperative blood loss, radiation exposure, and hospitalization expenditures of patients treated with the two different procedures were compared.

This study shows that the percutaneous approach results in less intraoperative blood loss and less severe postoperative lumbodorsal pains, as well as brings faster recovery, compared with the trans-muscular spatiot approach. This finding is consistent with that reported in literature [18]. Loss of correction and kyphotic angle increase is an inevitable problem of the surgical treatment of thoracolumbar spinal burst fractures. Some procedures for vertebral body augmentation, such as vertebroplasty, kyphoplasty, intravertebral bone grafting or anterior surgeries, can afford extra supporting to the anterior column of spine, and consequently reducing the risks of correction loss, especially to the patients with load-sharing scores (LSC) six and above. However, patients in the current study are not that severe, and most of them were not more than six in LSC. The end results of this study show that the percutaneous and trans-muscular spatiot groups did not exhibit significant differences in curative effect and radiological measurement data, and that both approaches can achieve a good curative effect.

Although the percutaneous approach brings about less intraoperative blood loss and less severe postoperative short-term pains than the trans-muscular spatiot approach, it requires longer fluoroscopy time, as a consequence of which it cannot significantly shorten operating time. In addition, this technique has a relatively long learning curve; therefore, its early application tends to result in a higher incidence of the complications caused by screw placement [19] and increases the risk of operated zygapophysial joints injuries [20,21], which may consequently increase the risk of adjacent segment degeneration when applied for vertebral degenerative diseases [22]. But, zygapophysial joints injury is not the only reason of adjacent segment segmental degeneration. Along with the technical proficiency, the risk of injuries will be greatly reduced. Still need to say, the accuracy of screw placement in this procedure tends to be affected by factors such as patients’ bodily conformations, anatomic changes in pedicle and paraspinous muscles, and intraoperative blood loss, to which attention should therefore be given. Furthermore, another unnegligible factor is that increased intraoperative fluoroscopy time is an innate drawback of percutaneous SSPI [23], and this study shows that the average radiation exposure time of the percutaneous group was thrice longer than that of the trans-muscular spatiot group. Nevertheless, given sufficient protection, the radiation exposure time required by percutaneous SSPI is still within a safe range. Although the utilization of navigation techniques can increase the accuracy of screw placement, decreases operating time, and greatly reduce patients’ radiation exposure time (even by 98.2% sometimes) [24–27], it inevitably increases patients’ medical burdens. In most cases, the accuracy of screw placement can be effectively increased using oblique fluoroscopy during operation [28]. Despite the difficulties the percutaneous technique encounters at present, it is still reasonable to believe that with the development of percutaneous SSPI equipments as well as the proficiency in this technique, the fluoroscopy and operating time require by the percutaneous approach can be further reduced and its advantage in minimal invasiveness will turn more prominent, and that the application range of this approach will become much broader.

Trans-muscular spatiot SSPI is another procedure, which has been applied for thoracolumbar mono-segmental vertebral fracture nowadays. Compared with the traditional open surgery, this procedure greatly reduces intraoperative blood loss, and meanwhile it achieves a curative effect similar to that of percutaneous SSPI. Trans-muscular spatiot SSPI only requires common rather than specialized pedicle instrumentation; therefore, it owns a cost advantage
over percutaneous SSPI. Furthermore, the incision method involved in trans-muscular spinal SSPI is same as that in the traditional SSPI and thus is easy to master. Anatomical research has found that the space between the musculi longissimus and the multifidus is 4.04 cm away from the median line in average (ranging from 2.4 to 7 cm) [29,30]. Although this distance has nothing to do with body height, age, or body mass index, it varies from segment to segment [31]. The distance between L1 and L2 is shortest, which is only 7.9 mm; then, it increases with the downward extension of the spinal column and reaches the longest between L5 and S1 (37.8 mm); therefore, preoperative measuring of the distance is of great use for determining an incision site [32]. Some scholars assume that an incision 3 cm lateral to the median line has least influence on skin blood supply, and that bilateral incisions have shorter lengths than a median incision, because of which less subcutaneous tissues are dissected, more direct arrival at the intermuscular space is achieved and the drag force becomes less [33]. However, this study discovered that making a posterior median incision in the skin and then cutting the lumbar dorsal fascia open about 1 cm lateral to the supraspinous ligament make the intermuscular space easier to find and meanwhile do not influence the apposition suture of the lumbar dorsal fascia, since the superficial inner margin of the musculi longissimus covers the surface of the multifidus, which possesses a tendon thickening part as well as a band connected to the supraspinous ligament. This study has some limitations. First, the grouping in study was not randomized. However, considering that these two groups did not show significant differences in preoperative data, all subjects were patients with compression or stretch-induced fractures and extended positioning in combination with injured segment pressing achieved good reposition effects, this study still has certain referential value. Second, the repositioning ability of percutaneous SSPI in this study was somewhat worrying. The pedicle screws used in all percutaneous SSPI systems in this study were multiaxial, which do not possess repositioning ability. In contrast, as the trans-muscular spinal procedure can take advantage of pulling, dragging, and screw rods to assist a fracture to be repositioned, it has a theoretically better reposition effect (therefore, trans-muscular spinal SSPI is more applicable in reshaping of severe fractures). Some percutaneous mono-axial pedicle screw systems have better capability for fracture reduction and spinal realignment. Additional compare studies need to be conducted for assessing. Third, there are differences in case selection between the two procedures in clinical practice. Lastly, recent years have witnessed the emergence of some new type percutaneous SSPI systems, which allow percutaneous fracture repositioning. Therefore, more strict randomized comparative study based on the utilization of these new systems remains necessary.

Conclusion

Percutaneous SSPI has the virtues of less intraoperative blood loss and less severe pains in the treatment of thoracolumbar mono-segmental vertebral fracture without neurological defects. When compared with trans-muscular spium SSPI, it results in longer intraoperative radiation exposure time and a higher surgery cost. To us, percutaneous SSPI has no advantage over trans-muscular spinal SSPI in curative effect.

Disclosure of interest

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

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