Can intermuscular cleavage planes provide proper transverse screw angle? Comparison of two paraspinal approaches

Xiaofei Cheng · Bin Ni · Qi Liu · Jinshui Chen ·
Huapeng Guan

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Abstract

Purpose The goal of this study was to determine which paraspinal approach provided a better transverse screw angle (TSA) for each vertebral level in lower lumbar surgery.

Methods Axial computed tomography (CT) images of 100 patients, from L3 to S1, were used to measure the angulation parameters, including transverse pedicle angle (TPA) and transverse cleavage plane angle (TCPA) of entry from the two approaches. The difference value between TCPA and TPA, defined as difference angle (DA), was calculated. Statistical differences of DA obtained by the two approaches and the angulation parameters between sexes, and the correlation between each angulation parameter and age or body mass index (BMI) were analyzed.

Results TPA ranged from about 16° at L3 to 30° at S1. TCPA through the Wiltse's and Weaver's approach ranged from about −10° and 25° at L3 to 12° and 32° at S1, respectively. The absolute values of DA through the Weaver's approach were significantly lower than those through the Wiltse's approach at each level. The angulation parameters showed no significant difference with sex and no significant correlation with age or BMI.

Conclusions In the lower lumbar vertebrae (L3–L5) and S1, pedicle screw placement through the Weaver's approach may more easily yield the preferred TSA consistent with TPA than that through the Wiltse's approach. The reference values obtained in this paper may be applied regardless of sex, age or BMI and the descriptive statistical results may be used as references for applying the two paraspinal approaches.

Keywords Paraspinal approach · Computed tomography · Intermuscular cleavage plane · Transverse screw angle · Lumbar spine

Introduction

Pedicle screw as a fixation device is frequently used for posterior lower lumbar surgery. The posterior exposure for pedicle screw placement commonly includes the traditional midline approach and the paraspinal muscle-splitting approach. The traditional midline approach requires extensive division of the paraspinal muscles and can increase the risk of complications over both the short and long term, such as unnecessary tissue damage, blood loss and postoperative muscle atrophy and pain [1, 2]. Moreover, proper lateral-to-medial screw trajectory, which leads to stronger fixation, may be difficult for this approach in the lower lumbar vertebra (L3–L5) and first sacrum vertebra (S1) due to the obstruction of the paraspinal muscles, retractors and the prominence of the posterior iliac crest [3, 4].

In contrast, it is believed that the paraspinal approach provided a more medially oriented pedicle screw implantation and less damage of the paraspinal muscles. Wiltse et al. [5] reported a universally used paraspinal muscle-splitting approach, in which the plane between the

X. Cheng · B. Ni (✉) · Q. Liu · J. Chen · H. Guan
Department of Spine Surgery, Changzheng Hospital,
Second Military Medical University, 415 Fengyang Rd,
Huangpu District, Shanghai 200003, People's Republic of China
e-mail: nibin99@sohu.com

Present Address:

X. Cheng
Department of Orthopedics, PLA 261 Hospital, Beijing 100094,
People's Republic of China

multifidus and longissimus is separated to allow bone grafting for patients with isthmic spondylolisthesis. Later, they adapted this intermuscular plane to gain access for pedicle screw placement [6]. Weaver [7] described another paraspinal muscle-splitting approach, in which the plane between the longissimus and iliocostalis is developed for pedicle screw placement. He believed that this intermuscular plane was ideal for access to the pedicles from L3 to S2 and allowed a screw placement that was directed more medially down the pedicle. Although the two natural intermuscular planes are both considered suitable for medially oriented pedicle screw placement; to our knowledge, no study has determined which one provided a better transverse screw angle (TSA) for each vertebral level in the posterior lower lumbar surgery. To clarify this issue, we measured and compared the angulation parameters involving the pedicles and the two intermuscular cleavage planes in the same axial section from L3 to S1 using computed tomographic (CT) scan.

Materials and methods

This study was approved by our institutional review board. One hundred patients treated in our institution were randomly selected for the study. The inclusion criteria were that the patients received a CT scan including L3 to S1 vertebra, and that they were between 18 and 75 years old when scanned. The exclusion criteria included spinal deformity, trauma, infection, tumor, spondylolisthesis, sacralization, lumbarization, previous lumbar surgery or poorer quality images.

The CT images of each patient were taken using a General Electric CT scanner (GE Medical Systems, Milwaukee, WI) with an axial slice at a 3-mm interval and axial images on soft tissue window were used for measurements. Lines and angles were drawn and measured using the GE software (A.W.D 4.2 GE, Milwaukee, WI). Measurements of bilateral transverse pedicle angle (TPA), which was regarded as optimal TSA, were taken from each lower lumbar vertebra (L3–L5) and S1 in every patient separately using the methods described by Acharya et al. [8] and Arman et al. [9]. Transverse cleavage plane angle (TCPA) of entry from the Wiltse's approach and Weaver's approach were then measured bilaterally in the same image. The determination of TCPA was as follows. Lines were drawn from the intersection of the pedicle axis and the outer margin of the facet joint to the superficial-most point of the intermuscular plane between the multifidus and longissimus (line1) and between the longissimus and iliocostalis (line2). The angles from line1 and line2 to a line parallel to the vertebral midline were defined as transverse cleavage plane angle 1 (TCPA1) and transverse cleavage plane angle 2 (TCPA2), respectively (Fig. 1). The difference values

Fig. 1 Axial computed tomography (CT) scan showing the lumbar sectional anatomy at the L4 level with the paraspinal muscles labeled. Measurements were taken according to the following marked lines, midline (*thick black dash line*), the line parallel to midline (*thin black dash line*), transverse pedicle axis (*black solid line*), the line connecting the entry point (*white dot*) with the superficial-most point of the intermuscular plane between the *multifidus* and *longissimus* (*white solid line*) and between the *longissimus* and *iliocostalis* (*white dash line*). TPA transverse pedicle angle, TCPA transverse cleavage plane angle

between TCPA1 or TCPA2 and TPA were defined as difference angle 1 (DA1) or difference angle 2 (DA2).

Measurements were repeatedly made by three investigators and expressed as a mean value. The entire data were entered into a Microsoft Excel sheet and further analyzed using SPSS software version 14.0 (SPSS Inc, Chicago, IL). Results were expressed as mean $\pm$ standard deviation. All results for the left and right sides and statistical differences between DA1 and DA2 at each vertebral level were analyzed with a paired *t* test or with a nonparametric (Wilcoxon signed rank test) test. Differences of each angulation parameter, age and body mass index (BMI) between sexes were compared by independent *t* tests or by nonparametric (Mann–Whitney *U*) tests. Pearson's correlation or Spearman rank correlation was used to establish the correlation between each angulation parameter and age or BMI.

Results

Of the 100 patients, 53 were female and 47 were male. The mean age of female, male and overall was 51.7 ± 11.9 , 50.0 ± 12.6 and 50.7 ± 12.2 years, respectively. The mean BMI of female, male and overall was 23.3 ± 3.6 , 23.5 ± 3.0 kg/m² and 23.4 ± 3.3 kg/m², respectively. No significant ($P < 0.05$) difference in age or BMI was found between females and males.

There was no significant ($P < 0.05$) difference in any result between the two sides at any vertebral level from L3 to S1, and they were pooled for further analysis. Table 1 demonstrated the mean values and standard deviations for the

Table 1 Angulation parameters

	TPA (°)	TCPA1 (°)	TCPA2 (°)	DA1 (°)	DA2 (°)
Females (<i>n</i> = 53)					
L					
L3	16.44 ± 1.13	−9.51 ± 4.17	24.91 ± 2.76	−25.95 ± 4.53	8.47 ± 2.93
L4	18.87 ± 1.35	−4.06 ± 3.23	28.15 ± 4.98	−22.93 ± 3.43	9.15 ± 5.01
L5	24.99 ± 1.74	10.13 ± 5.11	31.34 ± 5.31	−14.86 ± 5.23	6.35 ± 5.85
S1	30.56 ± 2.07	11.55 ± 5.18	33.23 ± 4.34	−19.01 ± 5.49	2.66 ± 4.32
R					
L3	16.27 ± 1.32	−10.19 ± 4.20	25.34 ± 2.83	−26.46 ± 4.63	9.07 ± 3.08
L4	18.80 ± 1.42	−4.36 ± 3.28	27.43 ± 5.17	−23.16 ± 3.48	8.62 ± 5.34
L5	24.84 ± 1.76	9.19 ± 5.11	30.76 ± 5.30	−15.65 ± 5.16	5.93 ± 5.89
S1	30.34 ± 2.10	10.89 ± 5.29	33.16 ± 4.26	−19.44 ± 5.70	2.82 ± 4.17
Males (<i>n</i> = 47)					
L					
L3	16.82 ± 1.23	−9.97 ± 4.77	25.61 ± 3.04	−26.79 ± 4.59	8.80 ± 3.16
L4	18.59 ± 1.07	−3.77 ± 3.74	26.76 ± 4.26	−22.36 ± 3.80	8.31 ± 4.48
L5	25.42 ± 1.43	10.15 ± 5.49	30.73 ± 4.36	−15.27 ± 5.75	5.32 ± 4.70
S1	30.23 ± 1.62	12.79 ± 4.95	31.77 ± 3.97	−17.44 ± 5.59	1.54 ± 4.10
R					
L3	16.76 ± 1.53	−10.39 ± 4.82	25.92 ± 3.02	−27.15 ± 4.76	9.15 ± 3.29
L4	18.41 ± 1.17	−3.94 ± 3.75	25.88 ± 4.22	−22.35 ± 3.89	7.47 ± 4.43
L5	25.23 ± 1.55	9.21 ± 5.37	29.99 ± 4.48	−16.01 ± 5.73	4.76 ± 4.83
S1	29.88 ± 1.79	12.17 ± 5.00	31.58 ± 3.99	−17.70 ± 5.63	1.70 ± 4.27
Overall (<i>n</i> = 100)					
L					
L3	16.62 ± 1.19	−9.72 ± 4.47	25.24 ± 2.92	−26.34 ± 4.58	8.62 ± 3.04
L4	18.74 ± 1.23	−3.92 ± 3.49	27.50 ± 4.70	−22.66 ± 3.62	8.76 ± 4.79
L5	25.19 ± 1.62	10.14 ± 5.29	31.06 ± 4.90	−15.05 ± 5.49	5.87 ± 5.37
S1	30.41 ± 1.88	12.13 ± 5.11	32.54 ± 4.23	−18.27 ± 5.59	2.19 ± 4.31
R					
L3	16.50 ± 1.44	−10.28 ± 4.50	25.61 ± 2.93	−26.79 ± 4.70	9.11 ± 3.18
L4	18.62 ± 1.32	−4.16 ± 3.51	26.70 ± 4.81	−22.78 ± 3.70	8.08 ± 4.97
L5	25.02 ± 1.68	9.20 ± 5.24	30.40 ± 4.95	−15.82 ± 5.44	5.38 ± 5.45
S1	30.12 ± 1.97	11.49 ± 5.20	32.41 ± 4.21	−18.63 ± 5.73	2.29 ± 4.26

L left, R right, TPA transverse pedicle angle, TCPA transverse cleavage plane angle, DA difference angle

angulation parameters. The general trend in pedicle morphology was a more medially oriented direction from L3 to S1. At L3, the pedicle was usually angled at about 16° medially. With each caudal level, the medial angulation increased so that the S1 pedicle was angled about 30° medially. The orientations of line1 were anterolateral at L3 and L4, while they became anteromedial at L5 and S1. The orientations of line2 were all anteromedial from L3 to S1. Accordingly, the values of TCPA1 were negative at L3 and L4 and positive at L5 and S1. The values of TCPA2 were all positive from L3 to S1. The values of DA1 were all negative, while the values of DA2 were all positive from L3 to S1. The absolute values of DA2 were significantly ($P < 0.05$) lower than those of DA1 at each level. These were observed in each sex, as well

as in the overall group, and no significant ($P < 0.05$) difference was found between sexes. No significant ($P < 0.05$) correlation was observed between any angulation parameter and age or BMI.

Discussion

The accuracy and precision of pedicle screw placement mainly depend on two factors, proper entry point and entry orientation, which are relatively fixed at each vertebra because of the limitation of pedicle morphology [10]. Although previous studies have described different locations, it is generally agreed that the ideal entry point is

located at the junction of the transverse process and superior facet at the lower lumbar vertebra and at the inferolateral corner of the facet joint at S1 [11, 12]. When using these portals, the bilateral medially oriented screws can pass through the pedicles along their axis, which provides a more secure anchor through the triangulation effect and the insertion of screws into denser bone [13, 14]. In addition, this lateralized trajectory eliminates risk of facet joint compromise. Therefore, in the transverse section, the medial angulation of pedicle screw consistent with TPA can be regarded as optimal TSA.

In the posterior lower lumbar surgery, the ideal entry point and TSA may be impeded by several factors using the conventional midline approach, and thus the two different paraspinal approaches are used to implant the pedicle screw [15]. Anatomic studies have proved that they both allowed good visualization and direct access to the transverse process and superior facet [16]. When using the paraspinal approach, the pedicle screw is inserted at the entry point through the intermuscular plane along a line determined by the incision and entry point. As the incision orientation and the paraspinal muscle arrangement are both longitudinal, the upper or lower orientation of pedicle screw is easy to adjust in the sagittal plane. In the transverse section, on the contrary, the skin, fascias and muscles restrict the ability to alter the medially or laterally oriented angle, especially as one uses progressively smaller tubes, and thus make TCPA relatively fixed. Consequently, the more similar TCPA is with TPA, the more proper medially oriented pedicle screw implantation can be obtained.

As found in many previous studies, the present study showed that TPA depended on the vertebral level. Likewise, it revealed that TCPA also varied at the different vertebral levels. DA, namely the difference in the value of TCPA and TPA, was therefore used to evaluate the consistency of TCPA and TPA. The absolute values of DA2 were significantly lower than those of DA1 at each level from L3 to S1, indicating that TCPA through the longissimus–iliocostalis cleavage plane was more similar to TPA compared with that through the multifidus–longissimus cleavage plane. Therefore, pedicle screw placement through the Weaver's approach may more easily yield the preferred TSA, which is consistent with TPA, than that through the Wiltse's approach in these levels. According to the amount of TCPA1, pedicle screw should be adducted to about 10° to arrive at the ideal entry point through the multifidus–longissimus cleavage plane at L3 and about 4° at L4, and should be abducted by about 10° at L5 and about 12° at S1. The amount of TCPA2 displayed that pedicle screw should be abducted to about 25° to arrive at the ideal entry point through the longissimus–iliocostalis cleavage plane at L3, about 27° at L4, about 30° at L5 and about 32° at S1.

In the lower lumbar spine, TSA should be as close as possible to TPA due to the limitation of the pedicle axis diameter. If pedicle screw is inserted through the multifidus–longissimus cleavage plane, according to our results, it should be abducted to about 26° to achieve an idealized TSA at L3, 22° at L4 and 15° at L5 when touching the entry point. When the pedicle screw is inserted through the longissimus–iliocostalis cleavage plane, it should be adducted about 9° at L3, 8° at L4, and 5° at L5. The morphology of S1 pedicle is quite different from that of the lower lumbar pedicles. Optimal TSA of S1 does not mainly depend on TPA when using the anteromedial trajectory because its pedicle diameter is greater than other pedicles. Besides, S1 fixation can be obtained by the anterolateral trajectory for screw placement into the lateral vertebra. Therefore, the optional degrees of S1 screw insertion range from anteromedial 30° to anterolateral 45° [17]. Nevertheless, a majority of studies suggested that medially oriented placement of S1 screw provided greater stability and security than either straightforward or laterally oriented positions [18, 19]. The mean angle for appropriate placement of anteromedial pedicle screw was found to be about 30° in this population. To achieve this angle, the pedicle screw should be abducted to approximately 18° through the multifidus–longissimus cleavage plane or adducted to approximately 2° through the longissimus–iliocostalis cleavage plane at S1.

All measurements in this study were made from soft tissue window of CT images. It provided a good evaluation of pedicle morphology and intermuscular plane location. Although MRI provides a finer evaluation of the paraspinal muscle anatomy, it cannot precisely indicate the boundary of the bone and soft tissue, making the results inaccurate. The data analysis showed no significant correlation between angulation parameters and patient demographics, and thus the above-mentioned reference values could be applied regardless of sex, age or BMI. Our data were all obtained from Asians. Previous studies have found difference in pedicle morphology between Asians and whites [8, 20, 21], which means that the concrete values of the angulation parameters in our study may not be completely applicable to other populations. Nevertheless, the measurement methods and descriptive statistical results could be used as references for applying the two different paraspinal approaches.

Conflict of interest None.

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