Effects of the Ratio of Autologous Bone Graft Area in TLIF on the Fusion Rate

yunxin sun
China-Japan Union Hospital of Jilin University
liwei shao
China-Japan Union Hospital of Jilin University
xiaoyu liu
China-Japan Union Hospital of Jilin University
shihao ren
China-Japan Union Hospital of Jilin University
shihao ren
China-Japan Union Hospital of Jilin University
yifu sun (yifu@jlu.edu.cn)
China-Japan Union Hospital of Jilin University

Research Article

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Abstract

Objective

The overarching goal of our research was to investigate different autologous bone graft area ratios in transforaminal lumbar interbody fusion (TLIF) and to evaluate the effects on the interbody fusion rate to determine the optimal range of autologous bone graft area and the volume needed.

Methods

The radiological and clinical score data of 57 patients were analysed. According to the ratio (Sa/Se) of the average autologous bone graft area (Sa) to the average endplate area (Se), patients were classified into three groups: group A (Sa/Se)<19%, n=20), group B (19%≤H/Hm≤25%, n=19), and group C (Sa/Se >25%, n=18).

Results

Our data demonstrated that the intervertebral space height increased after the operation in the three groups (all P <0.05). The final intervertebral space was different between two groups (Band C) and group A. The fusion rate at six months showed significant changes between groups B and C and group A. The fusion rate at one-year showed no significant changes between three groups.The VAS and JOA scores improved markedly in all groups postoperatively.

Conclusion

In our study, an autologous bone area ratio of more than 19% achieved a better fusion prognosis, but the increase in the fusion rate did not significantly improve when the average bone area ratio of the intervertebral space exceeded 25%. After further conversion of bone volume in the study, it was concluded that the required bone graft volume ranged from 2.9 ml to 4.3 ml.

Introduction

Middle-aged and elderly people now account for an increasing proportion of the population. As the population ages, the number of patients with degenerative diseases of the lumbar spine continues to increase. Lumbar degenerative diseases (LDDs) in the middle-aged and elderly population have gradually become a socially important chronic disease.

Transforaminal lumbar interbody fusion (TLIF) is an effective method for the treatment of LDDs [1]. TLIF achieves a better decompression effect on the spinal cord and nerve through intervertebral distraction, cage implantation and local autologous bone implantation during surgery. The clinical outcomes of TLIF and PLIF have been compared in many studies. There is more evidence that the possibility of complications such as nerve injury in PLIF is higher than that in TLIF [2−4]. Compared with PLIF, TLIF is becoming more widely used in clinical treatment because of its more thorough nerve decompression and lower probability of nerve injury complications.

However, opinions on the ratio of intervertebral autogenous bone graft area in patients with single cage fusion undergoing lumbar TLIF surgery combined with intervertebral autogenous bone grafting vary. At the same time, there are few studies that analyse the ratio of intervertebral autologous bone graft in patients treated with TLIF surgery. The purpose of this study was to investigate the average area of intervertebral autograft after TLIF and its relationship with fusion satisfaction and clinical outcomes one year after surgery to provide an appropriate range of autograft area ratios in interbody fusion in clinical practice and the required amount of bone graft.

Methods

Patient sample

The present retrospective study involved 57 patients who underwent single-level TLIF in our hospital from January 2017 to February 2021. The follow-up period was at least 12 months. All the data were obtained independently by three researchers, and the mean values of multiple measurements were used in subsequent analyses.

The inclusion criteria were as follows: (1) the patients were diagnosed with LDDs that were confirmed by preoperative magnetic resonance imaging (MRI), computed tomography (CT), X-ray, and physical examination; (2) single-segment TLIF at the level of L1 ~ L5; (3) there were CT scans and plain radiographs of LDD after the operation and at the last follow-up; and (4) patients were followed up for more than 12 months.

The exclusion criteria were as follows: (1) patients with malignant tumours, severe infections, or severe osteoporosis of the lumbar spine; (2) patients with lumbar fractures or dislocations; (4) patients with two or more segmental lesions; and (5) patients with a history of lumbar surgery.

Surgical treatment

All operations were performed by experienced senior doctors from the spine surgery group of our hospital. After applying general anaesthesia, the patient's abdomen was suspended with the aid of a positioning pad to reduce abdominal pressure. With the help of preoperative imaging information and C-arm fluoroscopy, the surgical segment was positioned, and the skin was incised through the posterior median until the lamina and facet joints on both sides were exposed. During the operation, an electrocoagulation electrotome was used to stop local bleeding. Pedicle screws were placed at conventional anatomical landmarks. Then, sterile gauze was used to fill the incision, which was covered with a sterile sheet. C-arm fluoroscopy showed that the screw position was good. During the surgery, one assistant needed to remove the soft tissue from parts of the posterior bone structure of the fusion segment (part of the spinous process, lamina and facet joints). The surgeon used a nerve retractor to protect the spinal cord and spinal nerves. After the intervertebral disc was exposed, we cut the posterior longitudinal ligament and annulus fibrosus with a sharp knife and removed the nucleus pulposus tissue with nucleus pulposus forceps. Surgeons selected different types of reamers and scraped the intervertebral disc tissue further. Then, the upper and lower cartilage endplates were processed to implant the cage and autologous bone. When necessary, the surgeon used bipolar coagulation to stop bleeding during the operation. A nerve dissection probe was used to explore spinal canal and nerve root canal patency and nerve root activity. After selecting a suitable intervertebral cage, an assistant trimmed the autologous bone carefully to obtain fine granular bone, part of which was then implanted in the cage, and the remaining bone was grafted into the intervertebral space before implanting the cage. A single cage was placed obliquely into the intervertebral body through the intervertebral foramen. After placement, the internal fixation device and the cage were assessed by fluoroscopy again. After the position of the internal fixation device and the cage were satisfactory, the prebent connecting rod was installed, and the top wire was locked. After flushing, the incision was sutured, and the indwelling a drainage tube was removed. The patient returned to the intensive care unit after recovery.

Symptomatic treatment was given routinely after surgery. After the drainage tube was pulled out, postoperative adaptive activities could be performed, and protective gear had to be worn when lowering oneself to the ground.

Clinical evaluation

The JOA score was recorded preoperatively to the final follow-up, with the scale from 0 to 17 indicating worst to best, respectively. The VAS score ranged from 0 to 10 and was used to evaluate pain preoperatively, postoperatively, and at the last follow-up.

Radiographic measurement

The area of autologous bone graft and the total graft area (cage + autologous bone) were measured on each cross-section. The average of three levels was measured as the average autologous bone graft area (Sa) and the average graft (cage + autologous bone) area (St). We chose one of the levels to show the measurement method (Fig. 1).

The height of the anterior and posterior borders of the intervertebral space of the target segment was measured on lumbar X-ray. The average of the abovementioned anterior and posterior intervertebral space heights was taken as the intervertebral space height (Fig. 2).

The area of the upper endplate and the lower endplate was measured, and the average of the two was taken as the average endplate area of the target segment (Se) (Fig. 3).

The autograft area ratio (Sa/Se) was defined as the ratio of the average autograft area (Sa) to the average endplate area (Se). We used the SUK and BSF criteria to evaluate interbody fusion at 6 months and 1 year after surgery[5,6].

Conversion of auto bone volume

Corresponding to the Sa/Se obtained in the study, the average autogenous bone area was multiplied by the maximum (h = 12mm) and minimum (h = 8mm) height of the interbody fusion apparatus used to obtain the approximate range of desired autogenous bone volume.

Statistical analysis

All statistical analyses were conducted with SPSS software version 26.0 (International Business Machines Corporation, USA). The data are described as the mean ± standard deviation (x ± s), and the Shapiro–Wilk test or the normal Q-Q plot was used to verify the normality of the distribution. Intragroup differences were calculated by paired t test. One-way analysis of variance (ANOVA) was used to compare the differences among groups. A nonparametric test was used for data with a nonnormal distribution. $P < 0.05$ was considered to be statistically significant.

Results

A total of 57 patients were included in this study. We measured the ratio of the total average graft area (St) to the average endplate area (Se) of the intervertebral body. When Sy/Se reached 30%, the autologous bone graft area ratio was 19%. The autologous bone graft area ratio was 25% when the fusion rate reached a relatively stable level and was used as the grouping threshold. We divided the patients into three groups: group A, Sa/Se < 19%; group B, 19%≤ Sa/Se ≤ 25%; and group C, Sa/Se > 25%.

There were 20 patients in group A, 19 patients in group B, and 18 patients in group C. The based clinical characteristics showed no significant difference among the three groups in terms of age ($P = 0.520$), sex ($P = 0.252$), operated levels ($P = 0.350$), hypertension, diabetes and cardiopathy ($P = 0.975$), smoking ($P = 0.932$), average endplate area ($P = 0.071$) or cage height ($P = 0.453$) (Table 1).

Clinical outcomes

During the postoperative and last follow-up periods, the JOA scores in all three groups markedly improved ($P_{all}<0.05$), and the VAS scores decreased simultaneously ($P_{all}<0.05$). No significant difference was found for JOA scores or the recovery rate among the three groups ($P_{all}>0.05$). Regarding the VAS score, there was no difference

among the three groups throughout the operation ($P_{all}>0.05$) (Table 2).

Radiological features

During the postoperative and follow-up periods, the intervertebral space heights of the three groups all improved compared with the preoperative parameters ($^{*}P < 0.05$). Moreover, comparison of intervertebral space heights between groups showed that there was a significant difference between groups B and C and group A at the last follow-up ($^{a}P=0.017$). There was no difference in intervertebral space heights between the three groups preoperatively and postoperatively ($P_{preoperation}$ = 0.403, $P_{postoperation}$ = 0.717) (Table 3).

At 6 months after surgery, imaging follow-up showed that the fusion rate of the three groups was significantly different (P = 0.017). Although there was no statistically significant difference in the fusion rate between the three groups 12 months after surgery, we observed that the fusion rate of group B and group C was significantly higher than that of group A (Table 4).

During the follow-up, there was 1 incident of internal fixation failure and 1 of bone graft displacement among the 57 patients. The others experienced no infection, rejection, cage displacement, bone graft displacement or internal fixation failure (Table 5).

Discussion

Lumbar internal fixation and fusion is a standard approach for the treatment of LDDs with good efficacy and reproducibility [7]

In the early 1980s, Blume and Rojas, and Harms and Rolinger, described a modified posterior interbody fusion (PLIF) technique called transforaminal interbody fusion (TLIF), which was later described by Harms et al. [8–10]. As an alternative to PLIF, TLIF is able to achieve similar clinical outcomes and fusion rates to PLIF [11,12]. According to previous scholars reporting the comparison of the clinical results and fusion rate of TLIF with a single cage and a double cage, it has been proven that the surgical method of single cage implantation can also provide good stability and a good fusion rate [13]. Therefore, the TLIF surgical method using a single cage has become increasingly popular among clinicians because of its many advantages.

Closkey concluded that grafts with more than 30% of the intervertebral space area provided good stability [14]. However, it is worth noting that the biomaterial cage involved in intervertebral fusion does not possess the basic elements of bone formation, and it can only provide a platform for bone transplantation and stabilize the height of the intervertebral space. With the passage of postoperative intervertebral fusion time, the cage inserted into the intervertebral body may have the possibility of subsidence, displacement, and prolapse. Therefore, the available bone surface area of the intervertebral space is critical for fusion success.

In the past, domestic and foreign scholars have reported on the area of intervertebral bone and the amount of bone graft in lumbar interbody fusion. Steffen and other scholars have found that the graft accounts for 30–40% of the total endplate surface, which can effectively prevent the settling of the graft [15]. Xiao reported that successful intervertebral fusion can be achieved when the total amount of intervertebral graft bone is 2.5 times the amount of bone in the cage [13]. The study by Takeuchi scholars showed that with a certain bone graft volume, the distribution of the internal and external bone graft volume of the cage has different effects on the intervertebral fusion [16]. According to Wolff's law, the cage's larger surface area in contact with the bony endplate will not only decrease subsidence into the vertebral body but also benefit fusion[17].

Although there have been many reports on the area and amount of bone graft in posterior lumbar fusion surgery, little attention has been given to the area ratio of autologous bone graft. Therefore, the purpose of this study was to evaluate the area ratio of the autologous bone graft, which influenced the satisfaction of one-year interbody fusion and clinical outcomes.

Implantation of the intraoperative cage allowed the originally narrow intervertebral space to obtain an immediately acceptable distraction height, and the follow-up imaging data in each group showed a significant increase in the height of the intervertebral space one week after the operation. The reason why the final intervertebral space height in group A was significantly lower than that in groups B and C may be due to the low autogenous bone area ratio of the intervertebral body and insufficient effective contact with the bone graft area. force, affecting early bone growth and bone healing. When the autologous bone grafted into the intervertebral body cannot form a bone bridge with the upper and lower endplates, the free bone will be gradually absorbed, which will reduce the total area of the graft, cause the settlement of the intervertebral cage, and lead to a change in the intervertebral height. Even though the height of the intervertebral space in group A was significantly reduced during the follow-up, the height of the intervertebral space at the last follow-up was still improved compared with that before the operation. A possible explanation is that the cage plays a role in the maintenance of intervertebral height throughout the process of fusion[18].

Many studies have reported that the fusion rate of TLIF surgery is more than 90%. In our study, the fusion rate of both groups B and C reached approximately 90%. This finding indicates that an intervertebral cage combined with a local strengthening bone graft can achieve a satisfactory intervertebral healing rate after surgery.

In this study, the fusion rate of each group at 6 months after surgery was not high, which may be because the bone grafts during the operation were all obtained by decompression. Cancellous bone and bone block transplantation have a relatively long osteogenic cycle [19]. Second, in the early stage of bone fusion, autologous bone grafted into the intervertebral body undergoes a certain degree of bone resorption due to the osteolysis of osteoclasts [20]. The subjects in group A were more prone to bone nonunion after early bone resorption due to the low ratio of the average intervertebral bone area .Bone fusion can be observed from the image data of the following subjects(Figs. 4 and 5). Cases without intervertebral fusion within one year were not considered nonfusion, and there was still a possibility of intervertebral bone fusion. Studies have shown that the volume of the intervertebral bone graft increases significantly within 2–5 years after surgery, and in patients with nonunion one year after surgery, bone fusion is generally achieved during the subsequent bone fusion process [19].

Judging from the one-year postoperative fusion rate we calculated, when the average intervertebral autologous bone area was less than 19%, the fusion rate also increased significantly with increasing bone graft area, but the average intervertebral autologous bone area also increased. When it is between 19% and 25%, although the fusion rate has increased, the magnitude is significantly lower than before. When the average autologous bone area of the intervertebral body exceeds 25%, the rate of increase of the fusion rate slows down and plateaus.

Among the 57 subjects in the study, there was 1 incident of internal fixator rupture in group A. In group C, there was 1 case of displacement of local grafted bone particles.It was found that a large amount of autologous bone was implanted in the intervertebral space during the operation, and some of the grafted bone overflowed after the implantation of the cage. However, pursuing more bone grafts during surgery means that more operative time is needed to trim the autologous bone graft and deal with the intervertebral space endplate bone graft bed, which greatly increases the operative time and intraoperative blood loss, thereby increasing postoperative complications and the risk of occurrence. This is contrary to the original intention of clinical treatment.

Notably, the distribution of autologous bone at the intervertebral level was different among the groups. There are few studies describing or classifying the morphology of intervertebral bone grafts. Yao et al. divided the bone-grafted intervertebral plane into four parts: ipsilateral dorsal, ipsilateral ventral, contralateral dorsal, and contralateral ventral. the lowest side [21]. In our study, a certain degree of similarity in bone graft morphology within the same group could be observed. The distribution of bone grafts in group A was mostly irregular (Fig. 6); most of the bone grafts in groups B and C showed a certain regularity, with a “C” shape surrounding the cage (Fig. 7). Bone fusion is most likely to be observed in the lateral region of the intervertebral space during lumbar interbody fusion [22]. This means that the autologous bone transplanted around the cage can take the lead in bone fusion in the early stage, and the bone graft shape with a "C" shape distribution may be beneficial to bone fusion.

There are limiting factors in our study in terms of the small sample size, manual measurements, and short follow-up period. In addition, the surgeries of all patients were performed by three senior doctors. Further study is needed to increase the sample size and prolong the follow-up period. The relationship between the ratio of autologous bone graft and the fusion rate needs to be further studied because the specific position of cage implantation and endplate processing have a certain influence on the degree of distraction. Consequently, in the future, we plan to collect large samples of patients who were operated on by doctors of the same seniority and analyse the specific relationship by utilizing big data.

Conclusion

In TLIF, the combination of interbody fusion device implantation and interbody autologous bone grafting with extra bone provides better maintenance of intervertebral height in the early stage and alleviates the delayed bone union or bone delay caused by autologous bone resorption during early bone fusion, and it can also promote intervertebral bone fusion to a certain extent. Meanwhile, from the point of view of the position of the bone graft, the bone graft is only located on the left side of the cage; the right side or the front is not conducive to the fusion of the bone graft, and the "C" shape wraps around the cage, which is beneficial to increase the bone graft area and promote fusion. Finally, in this study, a higher fusion rate and better clinical prognosis were achieved when the area ratio of intervertebral autologous bone graft was more than 19%. However, when the area ratio of intervertebral autologous bone graft was more than 25%, there was no significant increase in the increase in the fusion rate, and excessive intervertebral grafting may cause bone graft displacement.

References

References are not available with this version

Tables

Table 1
General characteristics of the patients

	Group A	Group B	Group C	P Value
Patients	20	19	18	-
Age (years)	55.900 ± 10.627	54.895 ± 9.831	52.056 ± 11.316	0.520
Sex (male/female)	11/9	6/13	6/12	0.252
Surgical segment	2	0	0	0.343
L2-3	2	3	0	
L3-4	12	10	11	
L4-5	4	6	7	
L5-S1				
Hypertension	3	5	2	0.975
Diabetes	2	4	3	
Cardiopathy	2	2	1	
Smoking	3	7	4	0.932
Average endplate area (mm^2)	1296.622 ± 257.138	1199.589 ± 146.575	1136.721 ± 211.456	0.071
Heights of cage (mm)	10.900 ± 1.210	10.632 ± 1.342	10.333 ± 1.572	0.453

Table 2
Clinical outcomes

	Group A	Group B	Group C	P Value
VAS Scores				
Preoperation	5.250 ± 1.333	5.053 ± 1.026	5.222 ± 1.060	0.849
Postoperation	2.650 ± 0.933*	2.316 ± 0.671*	2.389 ± 0.608*	0.356
Follow-up	2.200 ± 1.056*	1.684 ± 1.108*	1.722 ± 1.275*	0.270
JOA Scores				
Preoperation	12.750 ± 1.618	12.737 ± 1.661	13.056 ± 1.697	0.804
Postoperation	16.550 ± 2.235*	17.211 ± 2.323*	17.333 ± 2.169*	0.510
Follow-up	22.300 ± 3.326*	22.842 ± 2.566*	23.111 ± 2.220*	0.654
*P < 0.05 compared with preoperative value.				

JOA scores, Japanese Orthopaedic Association Scores, on a scale from 0 to 17

VAS scores, visual analogue scale scores, on a scale from 0 to 10

Table 3
Intervertebral space height at the surgical segment

	Preoperation (mm)	Postoperation (mm)	Follow-up (mm)
Group A	8.859 ± 2.019	11.366 ± 1.172*	9.489 ± 1.977*
Group B	8.547 ± 1.774	11.719 ± 1.906*	10.883 ± 1.394*a
Group C	8.057 ± 1.822	11.334 ± 1.681*	10.862 ± 1.615*a
*P < 0.05 compared with preoperative value.			
aP < 0.05 compared with group A value			

Table 4
Fusion rate of intervertebral autologous bone grafts

Period	Fusion Rate		
	Group A (□□/□□□)	Group B (□□/□□□)	Group C (□□/□□□)
6 months postoperatively	5/20(25%)	12/19(63%)*	12/18(66%)*
12 months postoperatively	14/20(70%)	17/19(90%)	16/18(89%)

*$P < 0.05$ compared with the fusion rate of group A.

Table 5
Postoperative complications

Complication	Group A	Group B	Group C
Infection	0	0	0
Rejection	0	0	0
Bone graft displacement	0	0	1
Cage displacement	0	0	0
Internal fixation failure	1	0	0

Figures

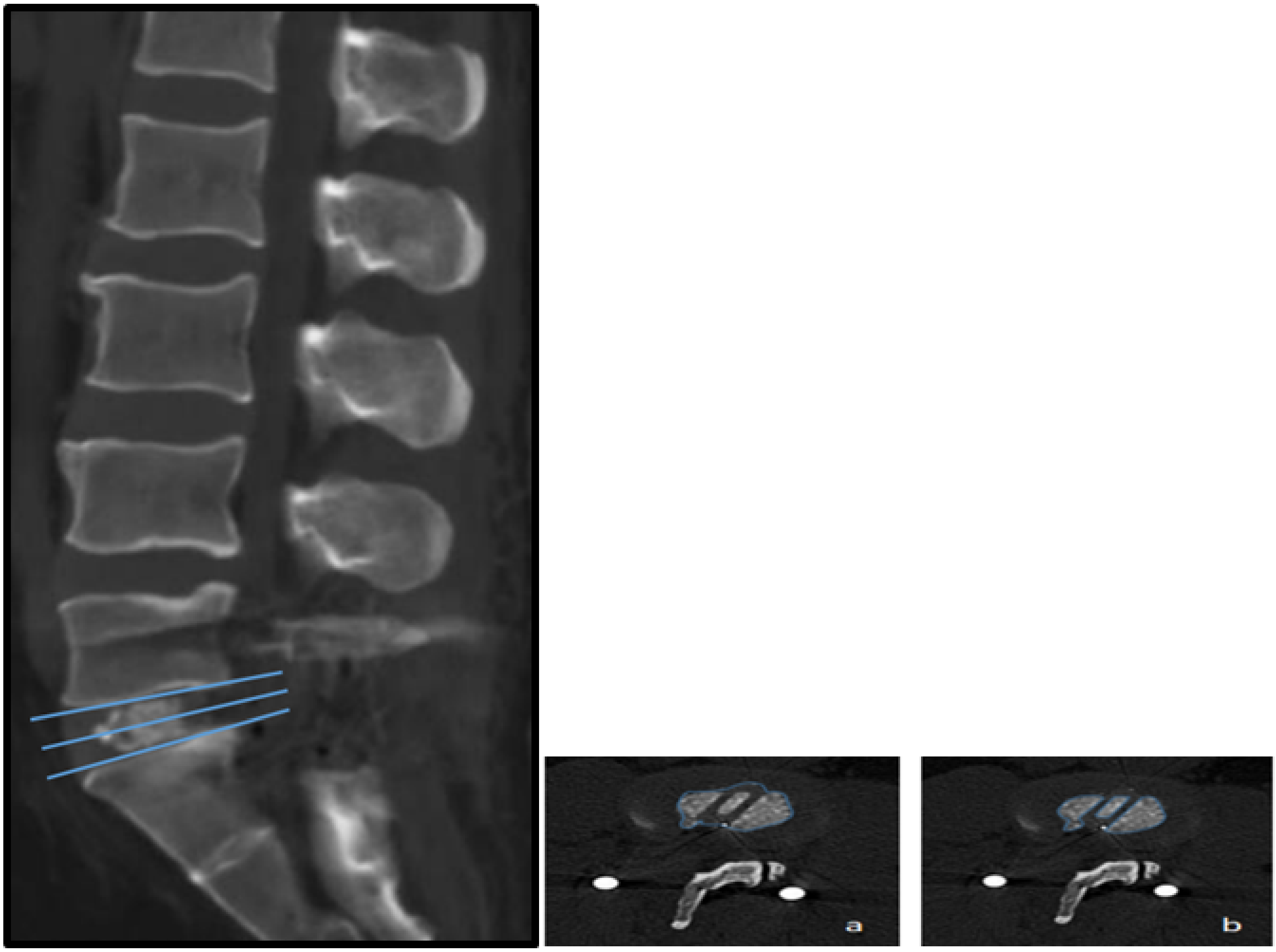

Figure 1

Measurement of three intervertebral levels and each measurement part at the median level.

a: Measurement of the total implant area. b: Measurement of the autologous area.

Figure 2

Measurement of the intervertebral space height.

Figure 3

Measurement of the endplate area.

a: Measurement of intervertebral endplate levels b: Measurement of the upper endplate area c: Measurement of the lower endplate area

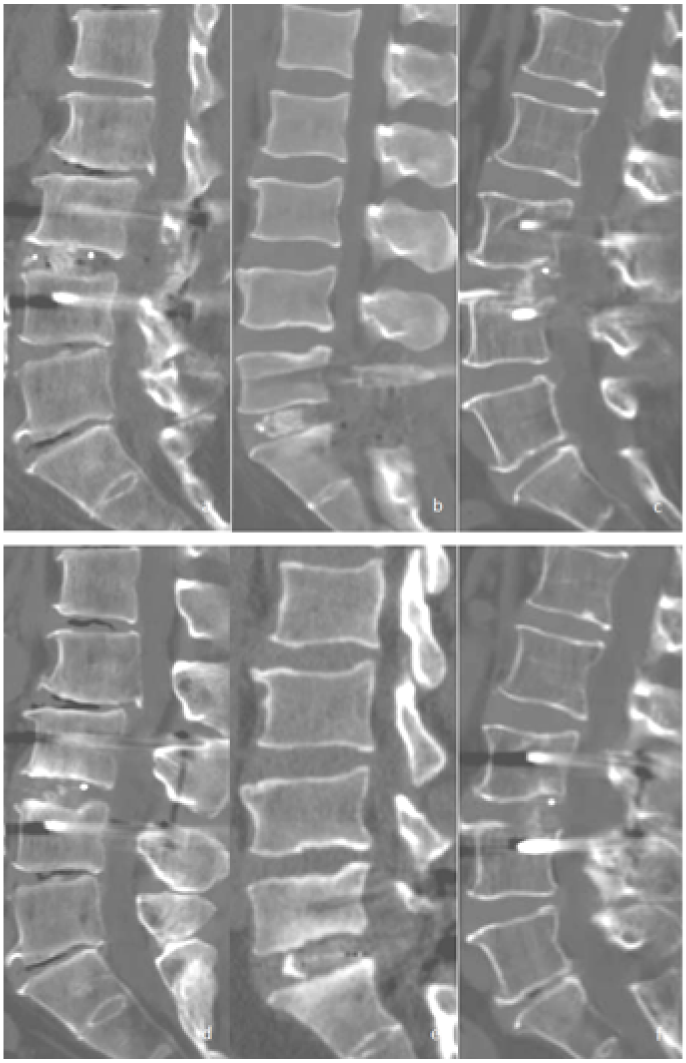

Figure 4

Imaging data of some patients with Sa/Se<19%

a-d:Postoperative sagittal image；e-h:Follow-upSagittal image showing intervertebral bone nounion and there are no continuous bone Bridges between the endplates

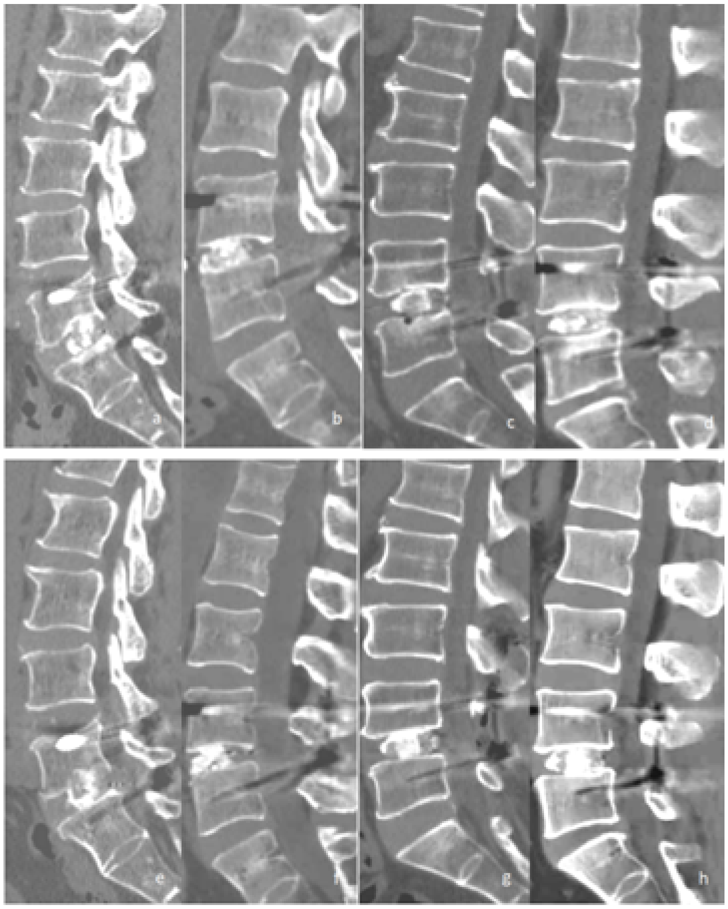

Figure 5

Imaging data of some patients with Sa/Se>19%

a-d:Postoperative sagittal image；e-h:Follow-upSagittal image showing intervertebral bone union and there are continuous bone Bridges between the endplates

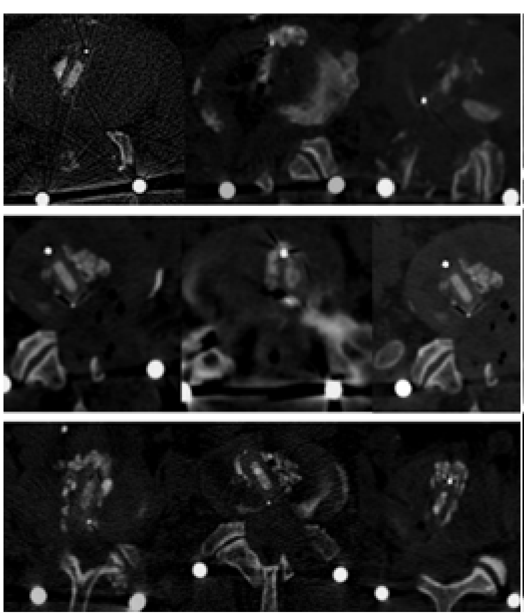

Figure 6

Group A

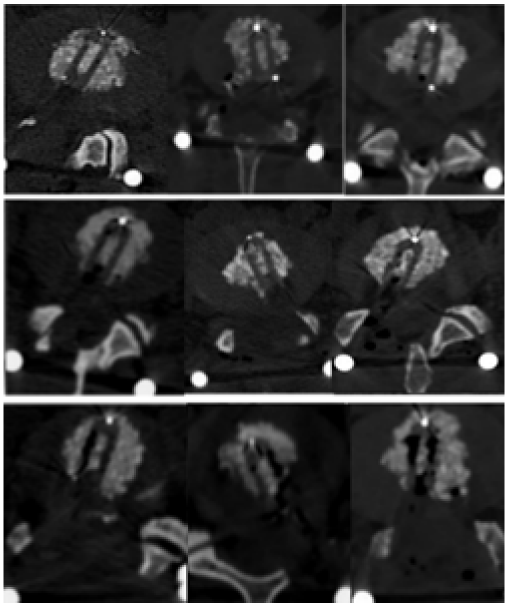

Figure 7

Groups B and C