Risk of graft fracture after dorso-ventral thoraco-lumbar spondylodesis: is there a correlation with graft size?

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Abstract

Study design Retrospective clinical study in patients with dorso-ventral thoraco-lumbar spondylodesis.

Objective To investigate whether the ratio between graft cross sectional area and the surface area of the adjacent endplates has any effect on the midterm stability of the spondylodesis.

Summary of background data Dorso-ventral spondylodesis in the region of the thoraco-lumbar spine is one of the most frequent operations in orthopaedic surgery. Anterior stabilization with autologous iliac crest graft currently is a standard approach in many hospitals. Although numerous recommendations are given how to perform this technique, no clinical advice is available with regard to minimum graft size.

Methods Sixty-four-slice CT-scans were obtained from 82 patients 4–12 months after posterior spondylodesis with anterior implantation of iliac crest graft and stabilization with an internal fixator. The scans were analyzed using image analysis software. First, the cross sectional area of

the graft was calculated and then the surface area of the adjacent endplates. The ratio between graft cross sectional area and endplate surface area was then calculated from these two values. The grafts were then evaluated in sagittal reconstruction for signs of fracture.

Results The probability for graft fracture in autologous tricortical grafts was $>0.1\%$ ($p < 0.001$) if the graft cross sectional area exceeded 23.9% of the surface area of the adjacent endplates. Patients with lower ratio values had a higher fracture risk and below a value of 10% all grafts fractured.

Conclusion The relationship between graft cross sectional area and adjacent endplate area has an important effect on graft midterm stability in ventral spondylodesis of the thoraco-lumbar spine. In our opinion, the risk of graft fractures in dorso-ventral spondylodesis can be reduced by implantation of an appropriately sized graft without any additional procedures or instrumentation.

Keywords Graft fracture · Complication · Spinal fusion · Autologous bone graft

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Introduction

Spinal disorders play an important role in the recent western societies. Every fifth female and every seventh male in Germany suffers from chronic spinal pain [1].

In USA, 200,000 surgeries for spinal fusion with bone grafting are performed every year [2]. This high number of spine surgeries confirms the recommendation that a surgical rather than a non-surgical approach should be preferred in the cases of spinal instability since the outcomes after surgical treatment are significantly superior to non-surgical treatment [3].

Dorso-ventral spondylodesis is one method of stabilizing the spine. Fusion can be achieved with autologous, allogenic or xenogenic bone grafts which are inserted between the vertebral bodies. Other materials and systems, such as titanium cages, are becoming more and more important, whereas spondylodesis with autologous tricortical bone graft represents the current clinical standard in many hospitals [4–6].

Despite the positive characteristics of autologous bone graft in terms of osteoinduction and osteoconduction, routine clinical practice sees a small number of patients who complain of persistent symptoms in the operated spinal segment after dorso-ventral spondylodesis. This figure can rise to 33% of all the operated patients depending on the patient collective under investigation [7].

Numerous procedural guidelines and recommendations on harvesting and implantation of the graft have been published. For example, special attention should be given to the “tongue-in-groove principle” of graft implantation, i.e. optimal form-fit between the graft and graft bed [8]. According to various educational publications (textbooks and operation manuals), it is considered important that the total depth of the harvested graft should not extend beyond the median sagittal plane of the vertebral body [4].

However, detailed information on graft size is not to be found in the literature. There is only one report of an animal study in which it is suggested that there is a link between the occurrence of graft fracture and the relationship between the graft and endplate cross sections [9].

Therefore, the aim of this study was to address the question whether the relationship between the graft cross-sectional area and the surface area of the vertebral endplates had an effect on graft midterm stability in patients with dorso-ventral lumbar spondylodesis.

Materials and methods

A total of 82 computer scans were obtained (64-slice CT, Somatom Sensation, Siemens, Erlangen, Germany) from patients (31 females, age range 17–65 years, mean 39.4 years, SD 14.2 and 51 males, age range 16–77 years, mean 41.6 years, SD 15.3) and analyzed retrospectively. No specific data were available regarding bone density values of the graft. Regarding the vertebral trabecular bone architecture evaluation of the bone density was performed semi-quantitatively. An exclusion criterion for the study was non traumatic spine disease, particularly with regard to reduced bone mineral content. Technically, other exclusion criteria were motion artefacts in the CT scans, simulating fracture lines. The CT scans were acquired as part of the regular radiological follow-up assessment 4–12 months after dorso-ventral spondylodesis. The CT scans were analyzed independently by a trauma surgeon and a

radiologist, and a consensus was reached in the following discussion. The 64-slice computer tomography currently can be regarded as gold standard for evaluating the osseous integration of grafts and their intactness [10–15].

Indication for operative treatment was primary fracture in all the cases. In 86% of the fracture was type A3, type B in 12% and C in 2% according to the classification of Magerl (i.e. modified AO classification). Dorso-ventral spondylodesis was a two-stage procedure in all 82 cases. An internal fixator (Universal Spine System, USS[®], Synthes, Umkirch, Germany) was implanted for dorsal stabilization. This was followed by ventral monosegmental spondylodesis with an autologous tricortical iliac crest graft. Graft size varied due to different factors, for example, the individual patient's anatomy or the surgeon's estimation. Transplantation of the iliac crest graft was performed in graft inlay technique with both ends being inserted into the adjacent vertebral cancellous bone. During operation, the intervertebral disk tissue was removed. All surgeries were carried out in the period from April 2000 to January 2007.

As a part of study procedure, the surface areas of the endplates of the adjacent vertebra and the cross-sectional area of the bone graft were calculated from axial CT scans. The morphometric area measurements were performed with a radiology software (OsiriX Medical Imaging 3.3.2, Fig. 1a). Sagittal reconstructions of the bone grafts were examined for signs of fracture formation (Fig. 1b).

Analysis of results was performed using SPSS for Windows (version 14.0). The variable under investigation was the ratio of graft area to the area of the vertebral body. The Shapiro–Wilk test was used to test for normal distribution of the values for intact and fractured grafts. Normal distribution was assumed at $p > 0.05$. An independent t test was performed to investigate the difference between area ratios in cases with and without graft fracture.

In addition, a Gauss normal probability curve was generated to identify the area ratio value above which the probability of a fracture occurring would be $<0.1\%$ of cases (i.e. $p < 0.001$).

The relationship between graft fracture and ratio values for graft cross-sectional area and surface area of the vertebral endplates was calculated using Pearson's Chi-square test.

Influence of time between operation and follow-up investigation on fracture rate was assessed comparing the patients who were evaluated for 4–7 months with those evaluated for 8–12 months after spondylodesis.

Results

Radiological examination of the 82 human spines showed that 49 grafts were fractured and 33 were intact. Fracture

Fig. 1 **a** Axial (transverse) section of a vertebral segment showing the area of the vertebral endplate. Scale bar 5 mm. **b** Sagittal reconstruction of the same spinal motion segment. Fracture of the implanted graft is clearly visible. Scale bar 5 mm

rate slightly increased comparing the interval 4–7 months after spondylodesis (56% fracture rate) with the 8–12 month interval (66% fracture rate). In the entire patient collective, the ratio values for graft cross-sectional area and surface area of the vertebral endplates varied between 6.8 and 31%.

The Shapiro–Wilk test showed that normal distribution could be assumed for the values for intact ($p = 0.169$) and fractured bone grafts ($p = 0.859$, Fig. 2). There was a significant difference between the ratio values for graft cross-sectional area and surface area of the vertebral endplates in cases with and without fracture ($p < 0.001$).

If normal distribution is postulated and the distribution of the values, therefore, follows the Gauss normal probability curve, then the data derived from fractured grafts will

Fig. 2 Distribution of ratio values for intact and fractured grafts. The risk of graft fracture is only 0.1% ($p < 0.001$) if the graft/endplate ratio is 0.239. In the present study, the ratio values were <0.239 for 69.5% of all intact grafts

give rise to an arithmetical probability of graft fracture occurring in $<0.1\%$ of cases (i.e. $p < 0.001$) if the ratio of graft cross sectional area to vertebral endplate surface area exceeds 0.239 (Fig. 2).

In the present study, the ratio was <0.239 (23.9%) for all fractured grafts (100%, $n = 49$) (Fig. 3).

Of the 33 intact grafts, the ratio of the cross sectional graft area to that of the adjacent vertebral endplate was <0.239 in 26 (69.5%) cases, but only 8 intact grafts had a ratio of <0.2 . None of the intact grafts yielded a ratio <0.1 (Fig. 4) whereas all grafts with a ratio of <0.1 fractured (Fig. 3).

Osseous integration of the graft ends into the cancellous bone of the adjacent vertebral body was confirmed for all

Fig. 3 Distribution diagram of fractured grafts. It becomes obvious that all fractured grafts lie below the 23.9% ratio mark

Fig. 4 Distribution diagram of intact grafts. It becomes obvious that the majority of intact grafts lie above the 20% ratio mark but none are below the 10% ratio mark

grafts in the study and there were no cases of bone fracture at the level of the graft bed. All grafts were fractured in the middle at the level of the intervertebral disk space.

The relationship between graft fracture and ratio value yielded a highly significant relationship ($p < 0.001$) between the variables in Pearson's Chi-square test.

Discussion

Current literature includes numerous publications on dorso-ventral fusion and its dependence on the implants used [16, 17]. Likewise, the advantages and disadvantages of tricortical iliac crest grafts and their biomechanical properties have been adequately discussed [18, 19]. However, despite the introduction of alternative materials with promising fusion rates, such as PEEK-cages or even different cages filled with cancellous bone, autologous tricortical iliac crest graft still remains a standard for spinal fusion.

The aim of this study was to investigate the question of whether the size of the intended graft or, more specifically,

the ratio of the graft cross-sectional area to the area of the adjacent endplates had an effect on the incorporation and/or midterm stability of dorso-ventral spondylodesis. This question has not been discussed in the literature with reference to patients. Only one animal experiment addressing a possible relationship between the two parameters has been reported [9].

The results of the retrospective clinical investigation show that there is a specific relationship between graft cross-sectional area and surface area of the vertebral endplates which has an influence on the observed incidence of autologous graft fractures. The autologous iliac crest grafts in our patient collective fractured if the ratio of graft cross sectional area to the area of the adjacent endplates was below 0.239 and arithmetic extrapolation showed that the statistical probability in that situation would predict fracture in $<0.1\%$ of cases if a higher value could be achieved during operation.

However, it has to be stated, that various causes of graft failure must be considered in addition to inappropriate graft size. For example, Jones et al. [20] reported weakening of the graft due to incorrect harvesting technique or

inappropriate harvesting tools. Important factors in this regard are given as heat necrosis during harvesting and the locally and inter-individually varying mechanical property of the bone tissue itself.

The anatomical region of the pelvis, where the bone graft is harvested should also be considered, particularly with regard to the iliac tubercle, since this is the part of the pelvis with the maximum thickness [21].

In the literature on clinical practice, graft incorporation rates of 70 and 100% have been reported after spinal fusion [4, 22–25]. Reported data on the incidence of graft fractures (e.g. 23% fracture rate [21]) are lower than what we have observed in our patient collective. However, these data must be viewed critically since the rate probably was far higher but many fractures could not be detected with the diagnostic methods available at that time [26]. This statement still applies even if it is assumed that clinical CT resolution is constantly improved and represents the commonly accepted gold standard for the diagnosis of osseous integration [15]. In addition, so far no correlation between graft fracture and clinical outcome have been published so far [22].

Summary

With regard to graft fracture rate after dorso-ventral spondylodesis of the thoraco-lumbar spine our results show that the fracture rate is strongly related to the ratio between the cross-sectional area of the graft and the surface area of the adjacent endplates. If this ratio is reaching a value of <0.239 , the risk of fracture increases distinctly (i.e. statistically is higher than 0.1%). If it is <0.1 , the graft fracture rate can be 100% as was in our investigation. To be less abstract, this would mean, if an endplate of a vertebra, which width is 45 mm and ap diameter 30 mm, the minimum size of the graft should be for example 18 mm in width by 18 mm in thickness to reduce the risk of a potential graft failure.

We think that these reference values, if taken into account, can reduce the risk of potential graft fractures in dorso-ventral spondylodesis simply by implantation of an appropriately sized graft without any additional procedures or instrumentation.

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Conflict of interest None.

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