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Spinal fusion: a combined anterior and supplementary interspinous technique

Received: 20 April 1996
Revised: 17 October 1996
Accepted: 5 November 1996

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Abstract “Standard”, noninstrumented, techniques of anterior interbody fusion are frequently followed by nonunion and collapse of the intervertebral space, probably because of persistent rocking movements, particularly in the sagittal plane. Elimination of these theoretical movements by supplementing an anterior interbody fusion with a posterior interspinous H-graft and a cerclage wire was considered to be biomechanically attractive without having the disadvantages associated with posterior instrumentation. In a

prospective study a solid fusion was obtained at 16 of 17 operated levels, with a mediocre ($\pm 50\%$) fusion as the exception. The height of the intervertebral space was increased at the majority of the fused levels. The technique is only applicable where neural arches are intact. The technique proved to be safe, simple, effective and inexpensive.

Key words Spinal fusion · Anterior fusion · Interspinous fusion

Introduction

In 1990, a patient was referred with persistent low back pain following an anterior fusion at L3–4. There was a pseudarthrosis and flexion/extension radiographs showed the operated level to open and close posteriorly, hinging on the anterior edge of the bone block. This was treated with an intertransverse and facet fusion and the flexion/extension movement was blocked with an interspinous graft and cerclage wire. The successful outcome in this patient led to the present study.

“Standard”, noninstrumented, anterior lumbar spinal fusion procedures do not always lead to a solid fusion; fusion rates average 73% [18] and range from 19% to 96% [1]. Furthermore, there is often progressive postoperative narrowing of the intervertebral space [5] caused by resorption of the graft or penetration of the graft into the vertebral bodies, and this may cause nerve root compression. Fusion rates of, or approaching, 100% can be achieved by reinforcing interbody fusion with translaminal facet screws or pedicle screw/plate instrumentation [10], or with a ceramic

interspinous block [17]. These techniques can also improve intervertebral height. However, improper screw placement can cause neurological damage; even in experienced hands, the risk related to pedicle screws is of the order of 1% [4]. Translaminal facet screws [12] are probably safer; no neurological damage was noted by Reich et al. [15] or Holte et al. [10], but the possibility remains. Instrumentation also impairs any subsequent examination by CT or MRI. Interspinous ceramic blocks do not, in theory, prevent flexion movements, and they are not always readily available.

This article describes and evaluates an implant-free, combined anterior and supplementary interspinous technique of spinal fusion, which was developed to avoid the abovementioned disadvantages while retaining the prospect of a high rate of fusion. The technique is only applicable when the neural arches are intact.

Biomechanical rationale

The situation following insertion of anterior bone grafts is shown in Fig. 1A. As with any stabilisation procedure,

Fig. 1 **A** The situation following anterior fusion. **B** Rocking over the anterior edges (*A*) of the grafts during flexion. **C** Rocking over the posterior ends (*P*) during hyperextension

Fig. 2 The tricortical wedge-shaped interbody grafts with strong broad anterior cortices (*A*) and narrow posterior bicortical ends (*P*)

Fig. 3 Anterior interbody fusion stabilised with an interspinous H bone block, to prevent hyperextension, and spinous process wiring, to prevent flexion movements

possible motion in all six degrees of freedom must be considered.

Motion in the sagittal plane

During flexion, extension and hyperextension, the vertebrae rock to and fro about the graft (Fig. 1B, C). During flexion, the anterior cortical edges of the vertebral bodies and the strong, broad cortical edges of the tricortical grafts provide a fulcrum (*A*, Figs. 1, 2) where high contact pressures are generated. During hyperextension, the narrow posterior ends of the iliac crest grafts, being wedge-shaped (Fig. 2), will generate higher contact pressures and will be even more likely to collapse or to penetrate the adjacent vertebral endplates. This continual rocking motion is probably mainly responsible for the failures of standard anterior interbody fusions and for any postoperative collapse of the intervertebral space. Rocking is a rotary movement, which is most effectively prevented by fixation as far as possible from the axis of rotation [19]. The rocking movement can therefore best be prevented by fixing the spinous processes in relation to each other with an interspinous graft, to prevent hyperextension, and spinous process wiring, to prevent flexion (Fig. 3). An intact neural arch is mandatory for this technique.

Motion in the coronal plane

By the same argument, lateral rocking movements ought to be prevented by intertransverse process stabilisation. However, there are several reasons why such additional coronal stabilisation is less important than sagittal stabilisation. The long cortical edges (*E*) probably provide more support as fulcrum during lateral bending than do the posterior ends (*P*) of the grafts during hyperextension. The distance between the most lateral cortices of the two (or three) iliac crest blocks (*EE*, Fig. 2) is greater than the depth of the blocks (*AP*, Fig. 2). The restraining effect on lateral bending of the lateral parts of the annulus is probably greater than both that of the posterior annulus on flexion and, following an anterior fusion operation, that of the remnants of the anterior annulus on hyperextension. Lateral bending occurs less frequently and is less vigorous than flexion and (hyper)-extension during normal activities. Postoperatively, lateral bending can probably be better restricted by a Scotch-cast or a plaster of Paris hip spica than can flexion/(hyper)-extension movements [7].

Motion in other planes

With the virtual elimination of rocking, the grafts remain in intimate contact with the denuded vertebral endplates. The friction hereby produced, in combination with the stabilising effect of the facet joints, should be sufficient to minimise translation and rotation. Compression forces are distributed over all the graft surfaces. The strong anterior cortices and the strong cortico-cancellous interspinous graft protect the vulnerable posterior ends of the anterior grafts (Figs. 2, 3).

Apart from the biomechanical advantages in reducing motion, the combination of appropriately sized anterior and posterior "distraction" grafts can be used to tension the annulus, increase the intervertebral height and open up the intervertebral foramina while allowing normal lumbar lordosis to be preserved or reconstituted.

Operation technique

The patient is positioned supine with the spine slightly hyperextended over the bridge of the operating table. At L4–5, an extraperitoneal approach similar to that described by Fraser and Gogan [8], but usually remaining lateral to the rectus sheath, is used. For L5–S1, a transperitoneal approach is used through a lower midline abdominal incision or, where indicated in females, a Pfannenstiel incision. Two-level fusions are carried out through the retroperitoneal approach. The anterior annulus is incised as a transverse H; the flaps are mobilised to left and right and held apart with stay sutures. The nucleus is excised along with the cartilaginous endplates to expose bleeding sub-

chondral bone. Two, or sometimes three, tricortical iliac crest autografts are inserted. The first graft is inserted while the disc space is distracted with a spinal spreader. Any remaining space following insertion of the tricortical grafts is filled with autogenous chips. The annulus flaps are approximated. A cortico-cancellous graft and some cancellous bone are removed from the anterior iliac crest for the subsequent posterior fusion.

The patient is repositioned prone. Through a midline incision, the interspinous ligament is removed. The spinous processes are separated with a small spreader inserted from the side between their bases and an appropriately fashioned H-shaped cortico-cancellous graft is tapped into place. A double, 1-mm-thick, cerclage wire is passed around the spinous processes superficial to the H-graft. The posterior halves of the facet joints are excised and grafted. Postoperatively the patient is mobilised in a lumbosacral Scotch-cast jacket with inclusion of the left thigh for 6 weeks.

All patients received routine peri- and postoperative anticoagulation therapy until they were satisfactorily mobile following removal of the Scotch-cast spica.

Patients and methods

Patients

There were 14 consecutive patients. One patient with a solid fusion unchanged after 6 and 12 months refused further radiological examination. Thirteen patients were available for study with a minimum follow-up period of 2 years: 9 females and 4 males. All patients had severe low back pain associated with degenerative intervertebral disc narrowing. There were no cases of spondylolisthesis. None required surgery within the spinal canal. Nine patients un-

derwent preoperative discography and two others underwent an MRI examination. Previous operations to remove a prolapsed intervertebral disc had been carried out once in four patients, twice in two patients and three times in one patient. The 17 levels fused were: L4-5 in three patients, L5-S1 in six patients and L4-5 + L5-S1 in four patients. The follow-up period ranged from 2 to 4 years.

Methods

The patients were examined, at least, at 3, 6, 12 and 24 or more months after surgery. Fusion was assessed on standard radiographs, in one case supplemented by CT and lateral tomography. Flexion and extension lateral radiographs were taken in all patients. The presence or absence of a sound fusion was assessed by the author and by independent radiologists. The heights of the intervertebral spaces were measured anteriorly and posteriorly, and adjusted for any differences in magnification, using 40 mm as the standard antero-posterior diameter of the middle of the body of L5.

Results and complications

Solid anterior fusions (Fig. 4) were obvious on the lateral radiographs at 16 levels. In the exception, CT evaluation was compatible with a sound fusion across one of the tricortical bone grafts, but there was partial fragmentation of the rest of the interbody graft material. Lateral tomography confirmed the bony bridging. In all cases the last two lateral radiographs, taken 6 months or more apart, showed no change apart from possible further remodelling of the fusion, and the flexion and extension lateral radiographs showed no movement at the operated levels.

The average changes in the intervertebral heights as a result of the operation are shown in Table 1. In four loca-

Fig. 4 A, B Antero-posterior and lateral radiographs showing solid fusion of the combined anterior and interspinous fusion at L4-5-S1. The posterior halves of the facet joints have also been excised and grafted. The intervertebral heights have been restored

Table 1 Intervertebral heights, in millimetres, compared with the preoperative values

	Immediately after surgery		2-4 Years after surgery	
	Anterior	Posterior	Anterior	Posterior
Average	+ 6.2	+ 3.4	+ 5.5	+ 2.8
Range	(1-11)	(0-7)	(-1-11)	(0-7)

tions, the postfusion measurements showed an increase of 1 mm over the postoperative values. This must be erroneous, and 1 mm is probably a fair estimate of the error inherent in the measurements.

During the consolidation process, intervertebral height diminished (≥ 2 mm) in six locations: 2 mm, 3 mm and 8 mm anteriorly and 2 mm, 3 mm and 5 mm posteriorly. One patient accounted for three of these: 2 mm posteriorly at L4-5 and 8 mm and 5 mm at L5-S1.

Compared to the preoperative situations, following fusion there was an increase in intervertebral height (≥ 2 mm) anteriorly at 13 levels and posteriorly at 11 levels. There were two decreases in height (1 mm) anteriorly, but none posteriorly. The remaining measurements showed either no change (three locations, all posterior) or a 1-mm increase (five locations).

In one patient there was a 6° left convex tilt at L4-5 caused by asymmetrical insertion of the anterior grafts. There were no operative infections. There was one case of transient postoperative retrograde ejaculation.

One patient developed a painful discitis at L4-5 following an L5-S1 fusion. She had previously had an L5-S1 PID (prolapsed intervertebral disc) operation. The discitis was possibly related to the pre-fusion discogram and resolved spontaneously, though with collapse of the L4-5 disc.

The subjective clinical results were good in five patients, moderate in four patients and poor (no improvement) in four patients.

Discussion

Combined anterior and posterior fusion was first carried out more than 30 years ago and the procedure has been reviewed by O'Brien and Holte [14]. Spinous process stabilisation as an adjunct to anterior interbody fixation is also not new. Several years ago Cloward mentioned that an anterior cervical pseudarthrosis could be induced to consolidate by wiring the spinous processes together, and in 1990, Tsuji et al. [17] reported the advantageous effect of an interspinous ceramic spacer to supplement lumbar interbody fusion. The present technique is a simple and inexpensive, though biomechanically more attractive, combination of these two methods. However, the basic principles of anterior spinal fusion must not be forgotten. The vertebral bodies and grafts should be of sufficient

strength and the grafted area should be as large as possible [3, 16]. With this in mind, two wide grafts from the region of the tubercle of the anterior iliac crest, or even two and a half or three grafts, are used. The grafts should be thick enough to put the remaining parts of the annulus under tension to inhibit movement, though this will have little effect on hyperextension as the majority of the anterior annulus is incised during the operation. Some improvement in resisting hyperextension could possibly be obtained by inserting a central reversed graft, with the wide cortex posteriorly, prior to two lateral grafts, but this would be superfluous in the presence of the biomechanically superior interspinous graft.

The spinal fusions were primarily evaluated on plain radiographs. Although this mode of evaluation frequently leads to erroneous assessments of postero-lateral fusions [2, 11] because of superimposition of neighbouring structures and of any internal fixation devices, an anterior interbody fusion, and particularly its anterior edge, is clearly visible on a lateral radiograph and incorporation of the graft is more easily discernible. (This point was also made recently by McCall and O'Brien [13].) The same is usually true for the interspinous part of the present fusion technique. Even so, in an attempt to improve the accuracy of assessing the fusion, rather than relying on a single film, the spine was only considered to be fused when two lateral radiographs taken at least 6 months apart showed no change apart from possible further remodelling of what had appeared to be a solid fusion. In the solitary case of doubt, the axial CT images were consistent with fusion across approximately half of the anterior interbody graft, though a pseudarthrosis in the same plane as the images, while unlikely, could have been present [9]. Fusion was confirmed by lateral tomography.

Flexion and extension lateral radiographs may provide additional information. If movement is visible, there is clearly no fusion. In the present series, there was no movement at any of the fused levels. This lack of movement is compatible with a solid fusion, but it could have been due to the mechanical effect of the supplementary interspinous stabilisation and was not, in itself, used as evidence of a successful fusion.

The rate of sound fusion with the present technique is, so far, generally better than that of interbody fusion alone, and is comparable to that obtained with supplementary rigid pedicle screw/plate fixation, translaminar facet screws or an interspinous ceramic block [10, 17]. All of these combined techniques fulfil the basic biomechanical requirement of reducing or eliminating rocking movements.

Interspinous and facet joint fusions add little to the magnitude of the anterior interbody operation, though the patient does have to be repositioned. The facet joints are fused as this removes a possible source of pain as well as adding to the fusion area. Only the posterior portions of the facet joints are excised and grafted; the remaining anterior parts continue to contribute to segmental stability

while fusion takes place. The interspinous and facet fusions require only a limited exposure with less muscle stripping than is needed for supplementary pedicle screws and plates.

An increase in intervertebral height to open up the foramina may be desirable during a spinal fusion operation. Precise comparable measurements of the intervertebral heights were not always possible due to variations in centring and angulation of the X-ray beam. Blurring of the vertebral edges caused by remodelling during consolidation was also a problem. Despite these possible inaccuracies, the overall measurements indicate that it was usually (2/3 of fused levels) possible to increase the intervertebral height and widen the foramina permanently while preserving or partially restoring the lumbar lordosis. Possibly of more importance is the fact that the posterior intervertebral height was not noticeably decreased in any patient. On average, less than 1 mm of the initial postoperative gain in intervertebral height was lost during the consolidation period. If the solitary patient with a two-level fusion and obvious postoperative collapse is excluded, then the average loss of height during consolidation was minimal (0.3 mm). This probably reflects the stability of the construction and, in particular, the virtual absence of rocking movements.

The present technique avoids any risk of damaging the neural structures as can occur with sublaminar wiring or hooks or if pedicle or translaminar facet screws are malpositioned and it eliminates any need for implant removal.

However, the technique can only be used if the neural arches, including the spinous processes, are intact.

A possible disadvantage of any combined anterior plus posterior fusion technique is that it leads to increased motion at contiguous levels, but a circumferential fusion does not appear to be worse in this respect than an anterior fusion alone [6]. A further "inconvenience" is the postoperative restriction imposed by 6 weeks in a hip spica.

The clinical results, with 9 of 13 patients (69%) having a good or moderate result, are comparable with those reported by Turner et al. [18]. However, it is not the intention of this article, nor would it be possible on the basis of 13 patients, to discuss the role of spinal fusion in the treatment of low back pain, but rather to report a technique of spinal fusion.

Conclusion

The addition of an interspinous cortico-cancellous graft and spinous process wiring to an anterior lumbar interbody fusion is a safe, simple, effective and inexpensive way of ensuring a solid fusion without the possibility of damaging the neural structures. The technique usually increases the height of the intervertebral space and the foramina.

Acknowledgements The author thanks Dr. C. de Vries for carrying out the radiological evaluation and B. Walman and H. Maeijer for the photography.

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