Naresh Kumar
Alexander Wild
J. K. Webb
Max Aebi

Hybrid computer-guided and minimally open surgery: anterior lumbar interbody fusion and translaminar screw fixation

Received: 20 September 1999
Accepted: 25 September 1999

N. Kumar · A. Wild · J. K. Webb (✉)
Centre of Spinal Studies and Surgery,
University Hospital,
Queen's Medical Centre,
Nottingham, NG7 2UH, UK
e-mail: 100711.2000@compuserve.com,
Tel.: +44-115-924-9924,
Fax: +44-115-951-9991

M. Aebi
McGill University,
Royal Victoria General Hospital,
687, Pine Avenue West, Montreal,
Quebec, Canada H3A 1A1

Abstract Less invasiveness is the way forward for spinal surgery. Minimal disruption of tissue, preservation of muscle function, and restoration of normal spinal alignment are still the goals of most surgical procedures. An anterior lumbar fusion technique using a less invasive procedure with the addition of translaminar screws is described. The autograft is harvested from the vertebral body, thus avoiding the morbidity associated with an iliac crest bone graft. The operative steps for the procedure are described.

Key words Less invasive surgery · Anterior/posterior lumbar fusion · Donor site morbidity · Computer assisted surgery · Cages

Introduction

Safe and cost-effective procedures which result in minimal disruption of tissue and attempt to restore the normal biomechanics and physiological characteristics of the spine, and which are not associated with short- or long-term adverse effects, should be considered in patients who are appropriate candidates for operative intervention [9]. If normal biomechanics cannot be restored, then removal of a pain source and stabilization of the segment with fusion becomes a major goal. The technique must be safe, cause minimal soft tissue damage, and guarantee a high fusion rate. Less invasive surgery allows these goals to be achieved with minimal soft tissue trauma, blood loss, and pain, and allows early discharge from the hospital.

The rationale of using a combined anterior and posterior approach is to achieve a high fusion rate as well as the removal of the disc as a potential pain source. The new technique of removal of the bone graft from the vertebral body has revolutionized the anterior technique in that it avoids the necessity of harvesting an iliac bone graft and associated morbidity.

Historical review

The use of facet screws was reported by King in 1948 [15], who immobilized the lumbosacral facet joint using a short screw which traversed the joint. The fusion rate reported with this procedure was 91%. Other authors using this procedure had a higher failure rate, and Bosworth in 1957 stated that this screw fixation did not prove to be of value compared to the difficulties encountered [29]. Boucher [2] tried to improve the bony purchase by penetrating the ipsilateral pedicle with the tip of the screw. The fusion rate increased to 100% for a single level. However, this improvement carried the potential risk of nerve root injury as the screw tip was very close to the nerve root foramen [2]. Magerl [19] in 1984 introduced the further modification of inserting the screw from the contralateral side, through the lamina, making the procedure much safer. The bony purchase was increased by the passage of the screw through the lamina and by making the screw perpendicular to the facet joint. The insertion of the screw is posterior to the neural tissue and parallel to the nerve root.

◀ **Fig. 1a–f** Technical steps for Magerl Screw insertion. **a** Incision for exposure. **b** Hohmann retractor just lateral to the facet joint and Cobb periosteal elevator being used to clear the lamina. **c** 3.2-mm AO drill bit with a sleeve is passed through a separate stab incision to drill the hole. **d** A 4.5-mm titanium screw of appropriate size is inserted. **e** Posterior view of the translaminar screws when inserted. **f** View of the translaminar screws from on top

Hodgson and Wong [11] were among the first to use combined anterior and posterior procedure in lumbar fusion operations. Originally, cortico-cancellous autograft from the iliac crest was used to replace the disc [22]. Combined anterior and posterior procedures achieve more stability than either of the two procedures performed separately [23]. The use of translaminar screws allows good biomechanical stabilization of the segment with minimal soft tissue injury. The fusion rates for isolated posterior fixation vary from 82% [7] to over 94% [12, 24, 28]. The fusion rates for the combined procedure are up to 95% [14, 17] although lower fusion rates have also been reported [4, 6]. The patient satisfaction rate in all the studies was much lower than the fusion rate. Discrepancies between fusion rates and clinical success rates are well known [25].

Postoperative morbidity, pseudarthrosis, and donor site morbidity led to the development of carbon fibre and titanium cages supplemented with cancellous bone to reduce the amount of bone graft required [26]. In 1992 O'Brien and Holte first reported the use of cancellous bone filled in a femoral ring allograft [22]. The use of a cortical ring provides immediate mechanical stability. The problem associated with this was donor site morbidity [1, 22, 27] and limitation of graft if more levels were being operated upon.

Surgical technique of 360° lumbar fusion

Translaminar screws (Fig. 1)

The anaesthetized patient is placed prone on the Montreal mattress or on rolls. The spinous process of the cranial level to be fused is localized using fluoroscopy. A midline skin incision of 2–3 cm is made over this spinous process and extended caudally over the interspinous space. A sub-fascial dissection is performed with the aid of a Cobb elevator to elevate tissue from the spinous process, lamina and facet joint. A blunt Hohmann retractor is then hooked over the facet joint to allow visualization of the lamina and the facet joint. A similar procedure is performed on the opposite side. Through a separate percutaneous stab incision, a 3.2-mm drill is used to create a hole from the base of the spinous process, into the contralateral lamina between the two tables, across the facet joint and into the base of the transverse process. The drill should be seen below the surface of lamina; this ensures that it does not penetrate the spinal canal. It is essential to use an oscillating drill in order to keep soft tissue damage to the minimum. A 4.5-mm titanium cortical screw of approximately

46- to 50-mm length is then inserted. The length of the screw can be calculated from the radiograph. The second screw is usually inserted caudal to the first one, in a similar fashion. Screw placement must be properly planned, especially in cases where there has been prior partial laminotomy, where the width of the lamina is reduced. A translaminar screw set will guide the drill and a tap is available (Stratec Medical). The facet joint can be partially disrupted with a gouge to allow fusion.

It must be noted that the screw should not be inserted in compression mode or over-tightened, due to a theoretical risk of lamina fracture. The incision made for a one-level translaminar screw is less than 4 cm in addition to the stab incisions.

Anterior lumbar interbody fusion using hybrid allograft (Fig. 2)

Next, the anaesthetized patient is turned over and positioned supine. The knees and hips are slightly flexed to relax the psoas muscles and the anterior abdominal wall. A left paramedian abdominal incision approximately 4–5 cm long is made just inferior to the umbilicus. A transverse incision is cosmetically more attractive, especially if only one level is being fused. The incision is centred over the vertebral level to be exposed with the help of an image intensifier. The anterior rectus sheath is opened and the rectus muscle is gently dissected laterally away from the posterior sheath. The transversalis fascial space is then entered below the arcuate linea. Using a retroperitoneal approach, the abdominal contents are gently reflected towards the midline then, using a soft pledget, the contents and presacral nerves are reflected across the iliac vessels. For level L5-S1 the medial sacral vessels are ligated and the disc is approached between the vessels. For L4-L5 the disc is approached by reflecting the vessels to the right of the patient; in order to give full access to the L4-L5 disc the ilio-lumbar vein may need to be ligated. A radiograph is taken to confirm the level. The Synframe (SYNTHESE) allows retraction of the abdominal contents through a small incision and is held in place by a ring attached to the operating table. Total discectomy is then carried out; the end-plates of the vertebrae are cleared of the cartilage until a firm bleeding surface is reached. A hybrid allograft or Syncage (Synthes) which is approximately sized is packed with autograft and then inserted. A femoral allograft needs to be stabilized with a buttress screw and a washer.

Harvesting bone graft from the vertebral body (Fig. 3)

After the exposure of the disc space and the adjoining vertebrae, the bone graft is harvested from either of the adjacent vertebrae. A guide pin is inserted into the centre of the vertebra and a radiograph is taken to confirm its position: it

Fig. 3a–g Technical steps for harvesting the regional bone graft from the vertebral body. **a** Instrumentation for harvesting the regional graft. **b** Guide pin in the vertebral body. **c** Drill sleeve inserted over the guide pin. **d** Diamond cutting burr placed over the sleeve to cut a dowel-shaped graft. **e** T-handle extractor used to loosen and harvest the graft. **f** Dowel of bone graft removed (*B*) with a hydroxyapatite replacement insert (*A*). **g** Hydroxyapatite dowel of similar shape but 2 mm larger inserted into the defect

must be equidistant from the end-plates. A sleeve is then slid over the guide pin. A hollow diamond cutting burr of appropriate size is mounted on a power reamer and placed over the sleeve. The dowel-shaped graft is removed with an extractor and the defect is then filled with a hydroxyapatite plug 2 mm larger in diameter than the defect.

Discussion

The success of the “hybrid allograft” or cage depends upon bone growth across the allograft/cage to allow solid

fusion. It is acknowledged that excessive movement at the bone-implant interface will lead to fibrous tissue formation [18], and reduction of movement will theoretically increase the fusion rate. It has been shown that cage implantation increases segmental stability in all directions except extension and axial rotation [18, 23]. Biomechanical data on translaminar and transfacet screw fixation suggest that it increases the flexion stiffness and to a lesser extent the extension stiffness [8]. Heggeness and Esses pointed out in their study that the functional spinal unit stiffness increased 2.4-fold in flexion-compression loading with translaminar screws [10]. Extension and axial ro-

tation loading motion is reduced by supplementary trans-laminar screws rather than by cage instrumentation alone [23]. It can be concluded that anterior hybrid graft with supplementary translaminar screw fixation reduces the movement of motion segment in all directions.

Bone density has been shown to be significantly related to the stability of the anterior/posterior construct [13, 18]. Low bone mineral density may predispose to early postoperative sinkage of the anterior implant and loss of the corrected lordosis. Collapse of the vertebral body as a consequence of removing the bone graft dowel is also a concern. It was shown in a elegant study that if hydroxyapatite of the same size and shape is used to reconstruct the bone defect so created, the physical properties of the vertebral body are not significantly altered [5]. The long-term biological effects of this procedure are yet to be evaluated, but follow-up of patients up to 18 months has shown no debilitating effect to the disc or to the end plate.

The principles of treating degenerative disc disease have gradually evolved, with significant changes in implants and instrumentation. The surgical approaches, sequence of the operation (posterior followed by anterior), patient selection, instrumentation and types of bone graft used have been developed to achieve a high rate of fusion and patient satisfaction. In recent years the combination of femoral ring allograft with autologous cancellous bone graft has demonstrated the advantage of sound structural support, with excellent fusion rates as the autograft is under compression. Normally posterior procedure needs to be done first to harvest bone graft from the iliac crest, to be used later in the anterior procedure. We have developed a technique of harvesting bone graft from the vertebral body. This technique has a major effect on the postoperative morbidity as well as resulting in a shorter hospital stay.

Computer-assisted orthopaedic surgery is being developed for its application for pedicle [16, 20, 21] or trans-laminar screws [3]. Pedicle screws now have been put in with the help of real-time intraoperative image guidance (H. Schlenzka, personal communication).

Computer-assisted surgery has been shown to be safe for pedicular screw placement. The pilot study on 30 patients revealed a 95.7% accurate placement of screws as against 85.7% by freehand technique [16]. The present problem with computer-assisted surgery is the radiation exposure necessary to procure preoperative CT scans [20]. Improvements in the acquisition of calibrated radiographic or ultrasound images and the ability to register the preoperative images with the images at the time of surgery will make it possible to insert implants percutaneously [20]. This will reduce surgical time and make the procedure less invasive. The development of a real-time image guiding system using intraoperative screening is known to reduce both radiation exposure and operative time (H. Schlenzka, personal communication). This should reduce the length of the incision and tissue dissection required for adequate exposure. Translaminar screws can be introduced percutaneously using computer-assisted surgery [3].

The ideal computer-assisted system would be the one that will not interfere with or require only slight modifications of standard surgical procedures and instrumentation. It should allow keep the surgeon to apply his surgical skills, provide sufficient accuracy, and be fast enough to allow real time instrument control and visualization.

Acknowledgement The authors acknowledge the help of Mr. Keith Bullock, Audio-Visual Department, Queen's medical Centre, Nottingham.

References

1. Banwart JC, Asher MA, Hassanein RS (1995) Iliac crest bone graft harvest donor site morbidity. A statistical evaluation. *Spine* 20:1055–1060
2. Boucher HH (1959) A method of spine fusion. *J Bone Joint Surg [Br]* 41B: 248–259
3. Bystrom S, Griessen R, Webb JK, Becker G. Percutaneous insertion of translaminar facet screws: a new technique
4. Christensen FB, Karlsmose B, Hansen ES, Bunger CE (1996) Radiological and functional outcome after anterior lumbar interbody spinal fusion. *Eur Spine J* 5: 293–298
5. Downer P, Stefan T, Aebi M (1999) Regional bone graft harvest in spine surgery. *Spine* (in press)
6. Greenhough CG, Taylor LJ, Fraser RD (1994) Anterior lumbar fusion: results, assessment techniques and prognostic factors. *Eur Spine J* 3: 225–230
7. Greenhough CG, Peterson MD, Hadlow S, Fraser RD (1998) Instrumented postero-lateral lumbar fusion. Results and comparison with anterior interbody fusion. *Spine* 23: 479–486
8. Guyer DW, Yuan HA, Werner FW, Frederickson BE, Murphy D (1987) Biomechanical comparison for seven internal fixation devices for the lumbosacral junction. *Spine* 12: 569–573
9. Hanley EN, David SM (1999) Lumbar arthrodesis for the treatment of back pain. *J Bone Joint Surg [Am]* 81A: 716–730
10. Heggeness MH, Esses SI (1991) Translaminar facet joint screw fixation for lumbar and lumbosacral fusion: a clinical and biomechanical study. *Spine* 16 (Suppl): S266–S269
11. Hodgson AR, Wong SK (1968) A description of a technique and evaluation of results in anterior spinal fusions for deranged intervertebral disk and spondylolisthesis. *Clin Orthop* 56: 133–162
12. Humke T, Grob D, Dvorak J, Mesikommer A (1998) Translaminar screw fixation of the lumbar and lumbosacral spine: a 5-year follow-up. *Spine* 23: 1180–1184

13. Jost B, Crompton PA, Lund T, Oxland TR, Lippuner K, Jaeger P, Nolte LP (1998) Compressive strength of interbody cages in the lumbar spine: the effect of cage shape, posterior instrumentation and bone density. *Eur Spine J* 7: 132–141
14. Khazim R, Sengupta DK, Mulholland RC, Webb JK (1997) Combined anterior and posterior fusion of the degenerative lumbo-sacral spine in the severely disabled patients: functional outcome. Paper presented at the 22nd Annual Meeting of the British Scoliosis Society, Birmingham, UK
15. King D (1948) Internal fixation of lumbo-sacral fusion. *J Bone Joint Surg [Am]* 30A: 560–565
16. Liane T, Schlenszka D, Makitalo K, Tallroth K, Nolte L-P, Visarius H (1997) Improved accuracy of pedicle screw insertion with computer assisted surgery. A prospective clinical trial of 30 patients. *Spine* 22: 1254–1258
17. Liljenqvist U, O'Brien JB, Renton P (1998) Simultaneous combined anterior and posterior lumbar fusion with femoral cortical allograft. *Eur Spine J* 7: 125–131
18. Lund T, Oxland TR, Jost B, Crompton P, Grassmann S, Etter C, Nolte LP (1998) Interbody cage stabilisation in the lumbar spine: biomechanical evaluation of cage design, posterior instrumentation and bone density. *J Bone Joint Surg [Br]* 80B: 351–359
19. Magerl FP (1984) Stabilisation of lower thoracic and lumbar spine with external skeletal fixation. *Clin Orthop* 189: 125–141
20. Merloz P, Tonetti J, Ahmed E, Faure c, Lavalle S, Trocazz J, Sautot P, Hamadeh A, Cinquin (1997) Computer assisted spine surgery. *Clin Orthop* 337: 86–96
21. Nolte L-P, Zamorano L, Jiang Z, Wang Q, Langlotz F, Berlemann U (1995) Image guided insertion of transpedicular screws. A laboratory set-up. *Spine* 20: 497–500
22. O'Brien JP, Holte DC (1992) Simultaneous combined anterior and posterior fusion. *Eur Spine J* 1: 2–6
23. Rathonyi GC, Oxland TR, Gerich U, Grassmann S, Nolte L-P (1998) The role of supplemental translaminar screws in anterior lumbar interbody fixation: a biomechanical study. *Eur Spine J* 7: 400–407
24. Reich SM, Kuflik P, Neuwirth M (1993) Translaminar screw fixation in lumbar spine fusion: *Spine* 18: 444–449
25. Turner JA, Ersek M, Herron L, Haselkorn J, Kent D, Ciol MA, Deyo R (1992) Patient outcome after lumbar spinal fusions. *JAMA* 268: 907–911
26. Weiner BK, Fraser RD (1998) Lumbar interbody cages. *Spine* 23: 634–640
27. Younger EM, Chapman MW (1989) Morbidity at bone graft donor sites. *J Orthop Trauma* 3: 192–195
28. Zdeblick TA (1993) A prospective, randomized study of lumbar fusion: Preliminary results. *Spine* 18: 983–991
29. Bosworth DM (1957) Surgery of the spine. *Am Acad Orthop Surgeons Instruct Lect* 14 : 39