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Trans-vertebral Trans-sacral strut grafting for high-grade isthmic spondylolisthesis L5-S1 with fibular allograft

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Abstract

Symptomatic high-grade isthmic spondylolisthesis serves as a challenging clinical problem. Traditional treatment by in situ posterolateral arthrodesis has been associated with pseudarthrosis rates up to 50%. Even with successful posterolateral fusion, the graft is in an unfavorable biomechanical environment, due to it being under tension, which can allow for progression of lumbosacral kyphosis (slip angle) and sagittal translation (slip). Open reduction of spondylolisthesis improves the biomechanical situation by allowing a trapezoidal interbody graft at L5-S1, but is associated with neurologic deficits in up to 30% of patients. The purpose of this study is to review results of treatment of high-grade isthmic spondylolisthesis at L5-S1 by decompression and trans-vertebral, trans-sacral strut grafting with fibular allografts. This particular technique achieves the biomechanical goal of a structural interbody construct without the necessity of anatomically reducing the translational slip. In this study, 25 patients with symptomatic high-grade isthmic spondylolisthesis at L5-S1 were treated by decompression and trans-vertebral, trans-sacral strut grafting with fibular allograft. The fibular strut grafts were placed through an anterior approach as part of an anterior/posterior procedure, or via a posterior approach as part of a posterior-only procedure. Translational reduction methods were not performed other than those achieved through patient positioning and intraoperative decompression.

METHODS: A consecutive series of 25 symptomatic patients with high-grade isthmic spondylolisthesis L5-S1 had an average age of 29.8 years. Six patients were 16 years or younger. Eight patients underwent a posterior-only approach with posterior transosseous fibular strut grafting across S1 into the L5 vertebral body combined with posterolateral arthrodesis L4-S1 using a pedicle screw-rod construct. Seventeen patients underwent a combined anterior/posterior approach with transosseous fibular allograft strut grafting L5-S1 and L4-L5 interbody arthrodesis using a femoral ring allograft supplemented with posterior pedicle screw-rod instrumentation L4-S1. No reduction attempts were performed, other than those occurring spontaneously by patient positioning and decompression. Patients were evaluated for clinical improvement as well as radiographically. Clinical outcomes were measured with the scoliosis research society (SRS) outcome instrument. Radiographs were followed for arthrodesis, translation, and slip angle. Mean follow-up was 39 months (range 30-71 months). All patients preoperatively had a grade III to V slip using the Meyerding classification (mean 3.7). The slip angle averaged 37 degrees.

RESULTS: The postoperative mean slip grade was 3.5 compared to 3.7 preoperatively (no significant difference). The mean slip angle improved to 27 degrees (8-40^{o}) postoperatively from 37 degrees (13-51^{o}) preoperatively ($p<0.05$).

All patients went on to a stable arthrodesis, with no progression in slip or slip angle. There were no permanent neurologic deficits among any of the subjects, and all patients demonstrated improvement in their preoperative gait disturbance. SRS functional outcome score showed 24/25 extremely satisfied or somewhat satisfied at latest follow-up.

CONCLUSION: Treatment by this method showed improvement in lumbosacral kyphosis while avoiding the neurologic injury risk associated with open slip-reduction maneuvers. Despite no reduction in translational deformity, this technique offers

excellent fusion results, good clinical outcomes, and prevents further sagittal translation and lumbosacral kyphosis progression.
Key words: spondylolisthesis, high-grade, L5-S1, lumbar fusion, fibular strut graft

Introduction

Spondylolysis, a lytic defect of the vertebral pars interarticularis, has long been recognized as a common cause of low back pain in childhood and adolescence. By adulthood, the prevalence of spondylolysis and isthmic spondylolisthesis (a resultant forward displacement - or translational slip - of one vertebral body on the caudal vertebra) is approximately 6%.[1] The etiology of the pars interarticularis defect is believed to be a stress fracture. Athletes that participate in sports that repeatedly stress a hyperextended spine, such as gymnasts, football linemen, wrestlers, divers, and weightlifters have a high incidence of spondylolysis.[2] These athletes biomechanically experience the greatest extension loading forces on the lumbar spine. A genetic predisposition with an increased familial incidence is apparent as well with a higher prevalence, up to 53%, in Eskimo populations.[3-5]

The risk of spondylolysis progressing to a high-grade spondylolisthesis (Meyerding grade III-V) is most common in the adolescent age range. Significant increase in slippage during adulthood is uncommon.[1] The most common vertebral segment affected is L5, comprising 80% of all cases, with the high-grade slip occurring at L5-S1. (Figure 1)

Indications for surgical intervention in patients with a high-grade spondylolisthesis include continued pain, progression of neurologic symptoms, or progression of the slip. Several techniques have been employed for surgical treatment including: posterior, posterolateral, anterior interbody (ALIF), and posterior interbody (PLIF) – all with or without instrumentation.[6] The indications, and role for reduction of the spondylolisthesis, are extremely controversial, due to there currently being no widely accepted guidelines that answer any of these questions.

The addition of an interbody fusion helps to increase fusion rates and minimize progression of slippage postoperatively.[7] Traditional ALIF and PLIF techniques are not possible in high grade slips when in situ fusion is performed, due to the significant translational and angular deformities. (Figure 2) The offset of the vertebral endplates on either side of the disc space does not allow a standard interbody graft, but interbody fusion using fibular struts placed across the L5-S1 disk space through the bodies of L5 and S1 has been described in high-grade isthmic spondylolisthesis.[7-12]

The arguments for reduction are to restore sagittal alignment, reduce lumbosacral kyphosis, translation, and restore normal lumbosacral biomechanics, limit extending fusion levels cranially, and improve the cosmetic deformity. Anatomic reduction of the high-grade slip, however, has never been demonstrated to result in improved functional outcomes. The main detraction of reduction of high grade slips is the significant associated complications-specifically L5 nerve root injuries. Neurologic deficits range from 25 to 30% after reduction of high grade slips.[13-17] Reduction complications also include increased rates of pseudarthrosis, progression of slip, and hardware failure when posterior instrumentation is used alone without addition of anterior interbody fusion.[18] The addition of fibular strut graft with posterior instrumentation has been shown to decrease these complications.

The factor most important in achieving a good clinical outcome in these patients is a solid fusion and the most reliable method of attaining a fusion is performing an interbody fusion with posterior instrumentation.[7] The purpose of this study is to describe the results with this technique of interbody fibular dowel fusion without forced reduction of the high-grade spondylolisthesis.

MATERIALS AND METHODS

Twenty-five consecutive patients with high-grade isthmic spondylolisthesis L5-S1, both pediatric and adult, were involved in the study. Operations were performed by the senior author between 1992 and 2002. All patients had a grade III to V slip using the Meyerding Classification. The average age at the time of surgery was 29.8 years. Six patients were less than or equal to 16 years old. A minimum of 2-years follow-up was achieved on all patients. None were lost. Follow up was on average 39 months (range 30-71). Radiographic evaluation at pre-op, post-op, and follow up, included anterior-posterior and lateral radiographs. Parameters measured included slip grade (mean 3.7 preoperatively) and slip angle (mean 37degrees preoperatively). Complete neurologic evaluation was performed with specific attention to the function of the L5 nerve root pre and post operatively.

None of the 25 patients had prior surgery. Procedures included posterior-only approach (8), and combined anterior-posterior (17).

Operative Techniques:

Posterior-only Approach:

Patients were placed in the prone position on a Jackson table after the induction of general anesthesia. Motor evoked EMG monitoring was performed both triggered and free-running with specific attention to the function of the L5 nerves. Standard posterior exposure was carried out from L4 to the sacrum. Decompression with Gill laminectomy was performed at L5 with complete release of both L5 nerve roots. Posterior pedicle screw instrumentation was placed from L4 to S1. Laminectomy of S1 was then performed for exposure of the S1-2 interspace, the S2 nerve root and the S2 pedicle. The dural sac is retracted toward the midline between the S1 nerve root and the S2 pedicle to reveal the entry site. (Figure 3) Under fluoroscopic control or image navigation, a guidewire is advanced from this entry point through S1 and across the lumbosacral disc space into the L5 vertebral body. A variable diameter ACL (anterior cruciate ligament) reamer is sequentially drilled over the guidewire to 1mm less than the diameter of the fibular allograft strut. The fibular allograft is measured, cut, and driven into position across the L5-S1 disc. This process is then repeated on the contralateral side of the dura for a second strut. (Figure 4)

Anterior-Posterior Approach:

A left-sided paramedian rectus-sparing mini-open retroperitoneal approach is performed exposing the L4-L5 disc which is completely removed. A guidewire is then drilled through the middle of the mid-aspect of the cephalad endplate of L5, across the L5 vertebral body and the L5-S1 disc space, docking into the S1 body at the hypoplastic S1-S2 disc level. (Figure 5) Reaming over the guide wire (Figure 6) is followed by placement of the transosseous fibular strut graft. (Figure 7) A trapezoidal femoral ring allograft is placed into the L4-L5 disc space covering the entry portal of the fibular strut graft in the L5 endplate. (Figure 8) The patient is then placed in the prone position for the Gill laminectomy and pedicle screw/rod stabilization L4-S1 as described above. The circumferential decompression and stabilization is performed under the same anesthesia on the same day. (Figure 9) No attempt was made at reduction, other than that accomplished with patient positioning.

RESULTS

Clinical evaluation of the 25 patients was done using the scoliosis research society (SRS) outcomes questionnaire. This score measured postoperative patient satisfaction and showed 24/25 were extremely or somewhat satisfied. The mean visual analog pain scale (VAS) score pre-operatively was 8.2 and improved to 3.4 post-operatively.

There were no permanent neurologic deficits. No neurologic deterioration occurred. Specific attention to the neurologic status of the L5 nerve root was assessed preoperatively and postoperatively. Extensor hallucis longus (EHL) muscle weakness was present in 4 out of 25 patients pre-operatively. This was decreased to 0/25 post-operatively. No patient had EHL weakness at their latest follow-up visit. There was one incident of transient postoperative radiculitis of the L5 nerve root, which resolved completely after one month.

According to the Meyerding Classification, the mean slip grade before surgery was 3.7. This was reduced to an average grade of 3.5 post-operatively (not significant). The slip angle, however, did demonstrate statistical improvement postoperatively. The mean slip angle improved to 27 degrees (8-40^{o}) postoperatively from 37 degrees (13-51^{o}) preoperatively ($p<0.05$).

The average intraoperative blood loss was 692 ml (range 500-1500). No differences between combined and posterior-only approaches were found. This statistic demonstrates the posterior approach with the neurologic decompression (Gill laminectomy) is the source of the intraoperative blood loss and the anterior fusion adds an insignificant amount.

Radiographic evaluation showed 100% fusion with no evidence of pseudarthrosis. There were no fractures of the interbody fibular strut grafts. There was no patient who had an increase in slip grade or an increase in slip angle.

One late hardware removal was performed secondary to prominence in a thin young woman. She developed a solid fusion as demonstrated by intraoperative exploration of the fusion mass. The patient developed no complications from this procedure and experienced relief of her symptoms postoperatively.

There were no cases of infection, dural tears, neurologic deficits, urinary incontinence, retrograde ejaculation, or fracture of the strut graft. There were no cases of neurologic decline, progression of the translational slip or slip angle progression, pseudarthrosis, or instrumentation failure associated with this treatment method. The SRS functional outcome questionnaire demonstrated 96% of the patients were satisfied with the outcome of their procedure. This was accomplished without forceful reduction maneuvers and no attempt to translate the L5 vertebrae.

DISCUSSION

The goals for surgical treatment of high-grade L5-S1 isthmic spondylolisthesis include neural decompression and achieving a solid fusion. There are no proven benefits for anatomic reduction of L5 on S1 although intuitively this seems favorable. What has been shown to highly correlate with a successful outcome is a solid fusion.[19] The advantage of reducing L5 on top of S1 is the ability to place a trapezoidal bone graft into the L5-S1 interbody space and therefore increase the fusion potential. The problem with anatomic reduction is the high rate of neurologic decline, specifically L5 nerve root dysfunction. The incidence of permanent neurologic changes has been as high as 20-25%.. Also, anatomic reduction increases the operative time and concomitant blood loss. A human cadaver study showed a 4% strain of the [13,15]L5 nerve with the first 50% reduction of L5 on S1. The strain increases to 10% with the second half of reduction. Conduction loss of the L5 nerve occurs with only 6% strain and permanent damage happens at 12% strain.[20] Anatomic reduction, however, is not required for a circumferential construct. Rather than a trapezoidal graft, a dowel strut graft is driven across the lumbosacral disc in an unreduced position. This strategy allows for anterior and posterior stability without requiring an anatomic reduction to position a traditional trapezoidal interbody graft. In the current study, in which no attempt at reduction was made, no permanent neurologic deficits occurred, no pseudarthrosis were seen, and the patients were satisfied with their result. Peek published in 1989 a series of unreduced high-grades spondylolisthesis patients who did not have any cosmetic dissatisfaction after surgery.[19] The important factor for a good result was a solid fusion. Grzegorzewski has shown progression of the spondylolisthesis after fusion attempt if instrumentation is not utilized.[21] Molinari demonstrated the importance of a circumferential construct with instrumentation to yield the highest chance of fusion success.[6] The present study establishes that a circumferential fusion with instrumentation can be performed without anatomic reduction of the high-grade slip with excellent outcomes and a high fusion rate using fibular strut grafts. The fibular struts can be placed from an anterior or a posterior approach with similar good outcomes. The advantage of the anterior approach is that a solid femoral ring allograft can be positioned in the L4-5 disc space after the strut graft has been driven through the superior endplate of L5 and across the lumbosacral junction. The disadvantage is the potential for retrograde ejaculation in a young male.[22]

The decision to attempt an anatomic reduction in high-grade spondylolisthesis is controversial. The SRS morbidity and mortality committee in 2003 evaluated the incidence and complication rates of spondylolisthesis reduction in degenerative and isthmic slips from 1996 to 2002. Over six thousand degenerative and 3,619 isthmic spondylolisthesis cases were evaluated. While reduction of both types increased over time, the incidence of neurologic deficits remained the same in the degenerative group, but the neurologic injuries increased from 1.3% to 3.1% in the isthmic group. The conclusion of the committee is that the reduction of isthmic slips resulted in a significant increase in neurologic deficits.[23]

This study also utilized only fibular allografts as struts. It is important to note that all patients had radiographic evidence of fusion and no cases of pseudarthrosis were identified. Burns in 1933 is believed to be the first to use a dowel shaped graft. Jenkins and Speed also described similar techniques in the 1930's. Bradford and Gotfried performed salvage procedures for failed fusion using either a bicortical iliac crest graft or fibula autograft. The authors preferred the fibula because of its increased stability and fixation.[17] Hanson et al recommended the use of fibula allograft after their study found no difference in rates of remodeling when compared to autograft.[7] They reported high fusion rates so long as the strut graft was protected with posterior segmental spinal instrumentation, as was the case in this study.

CONCLUSION

Complete reduction of high-grade slips is not supported in the literature. Partial reduction, specifically of the slip angle, is achieved with minimal complications. Circumferential fusion with fibular allograft strut grafts result in a high fusion rate with low complications and good functional outcome.

Figures

Figure 1: Lateral radiograph of a high-grade isthmic spondylolisthesis. There is 100% anterior displacement of the L5 vertebral body on the sacrum; therefore, this is a Meyerding Grade IV slip.

Figure 2: Sagittal MRI of high-grade isthmic spondylolisthesis L5-S1 demonstrating the very abnormal L5-S1 disc unsuitable for standard trapezoidal interbody grafts.

Figure 3: Intraoperative photograph with the white arrow marking the entry point for the fibular strut graft. The S1 nerve root is defined as well as the S2 nerve root. The surgical probe is pulling the S2 nerve root and the dural sac medially to expose the entrance. The S1 pedicle screw and posterior instrumentation is also seen.

Figure 4 (A, B, and C): Postoperative sagittal CT reconstruction (4A) with fibular strut grafts across the high-grade spondylolisthesis L5-S1. Coronal CT reconstruction (4B) showing the 2 fibular strut grafts across the L5-S1 disc space. Anteroposterior radiograph (4C) with the pedicle screw/rod construct L4-S1 and the 2 fibular strut grafts (arrows).

Figure 5: Intraoperative fluoroscopic image of guidewire driven across the high-grade spondylolisthesis from the L4-5 disc space and docking into the S1 body.

Figure 6: Intraoperative photograph of reaming across the high-grade slipped lumbosacral disc from an anterior approach.

Figure 7: Intraoperative photograph of the fibular strut graft just before driving it across the high-grade spondylolisthesis.

Figure 8: Intraoperative lateral radiograph of fibular strut graft (white arrows) across the L5-S1 disc and femoral ring allograft (black arrow) in the L4-L5 disc space.

Figure 9 (A and B): Final circumferential construct: Anteroposterior radiograph (9A) and lateral radiograph (9B).

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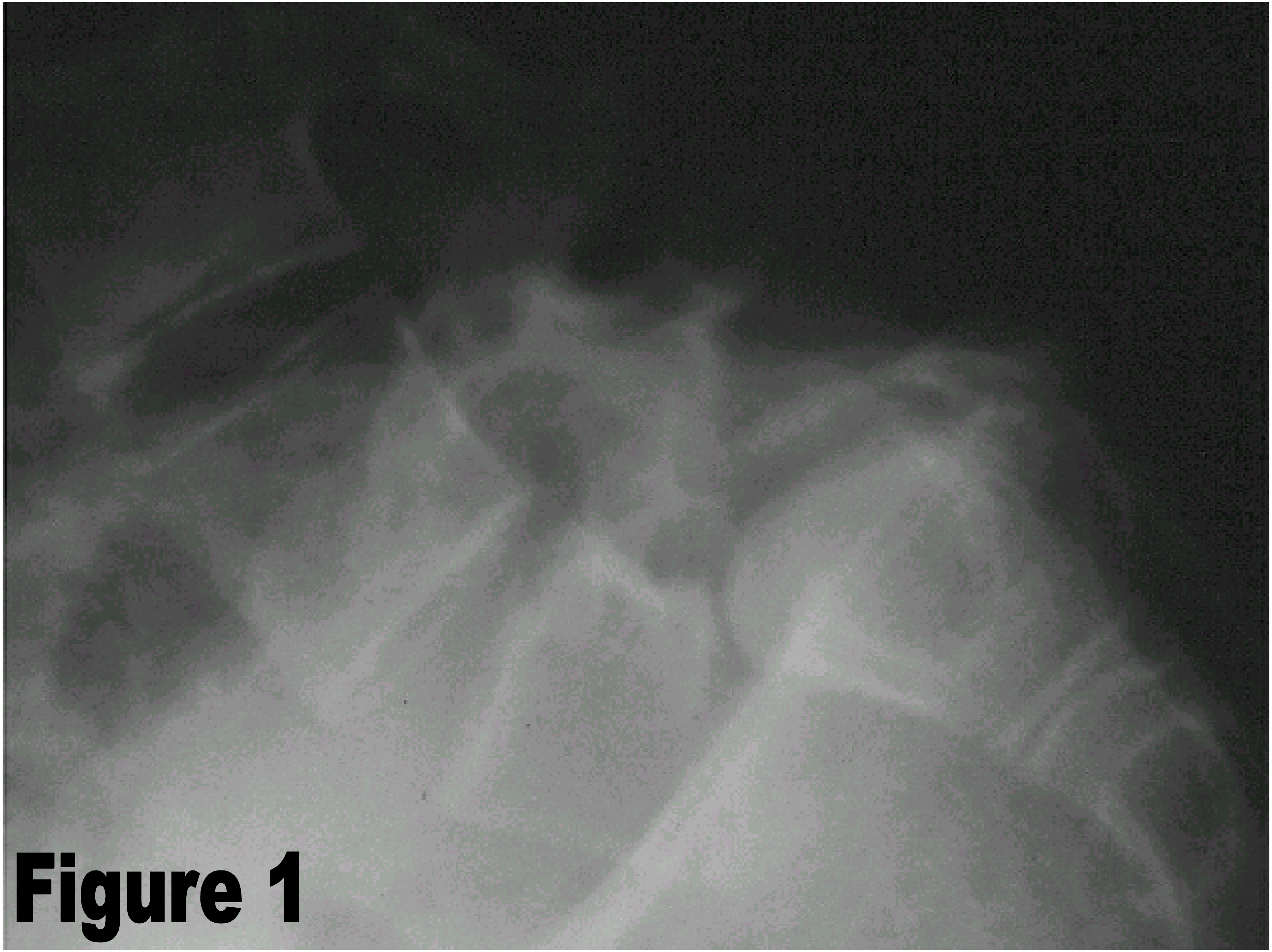

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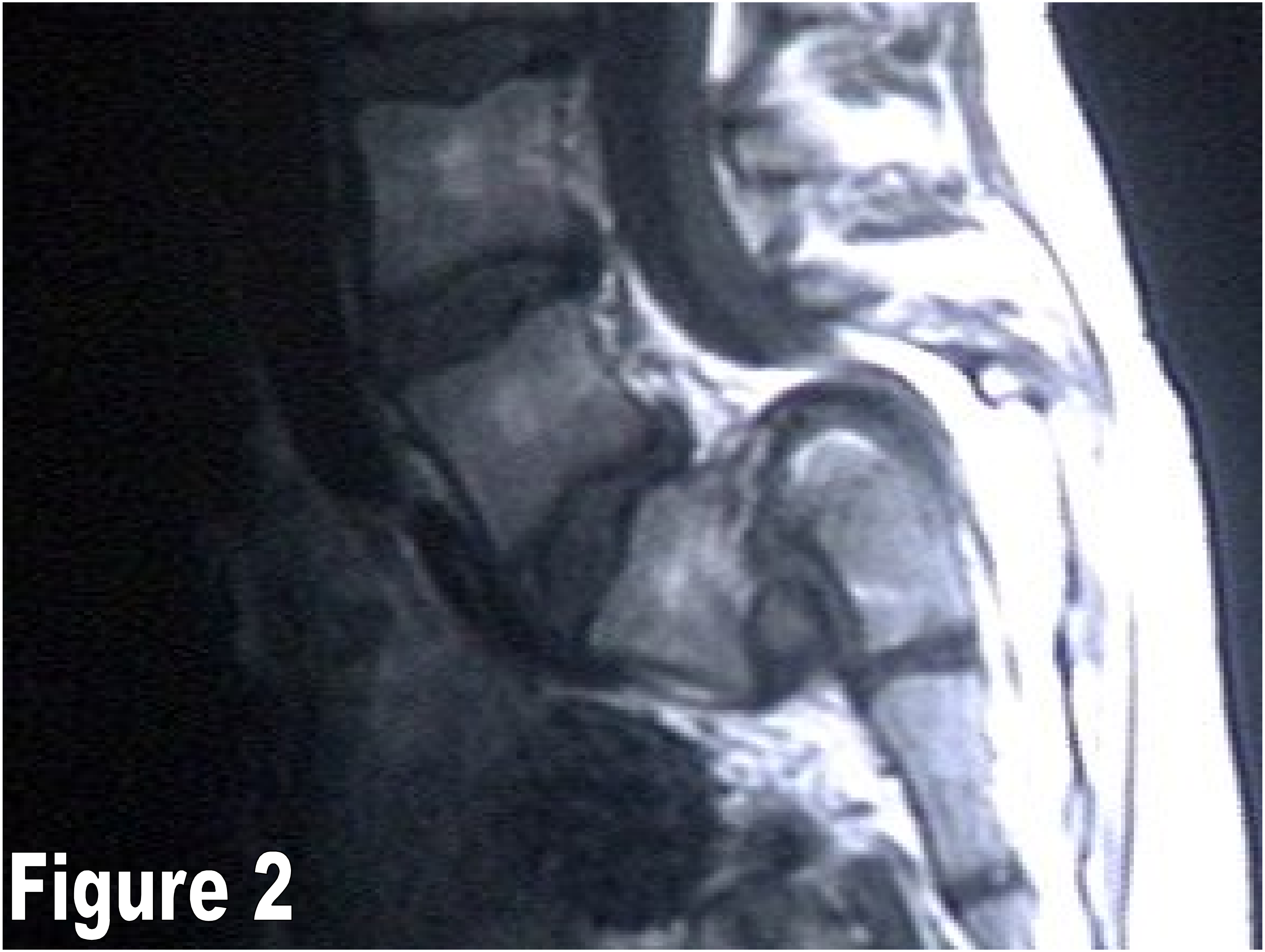

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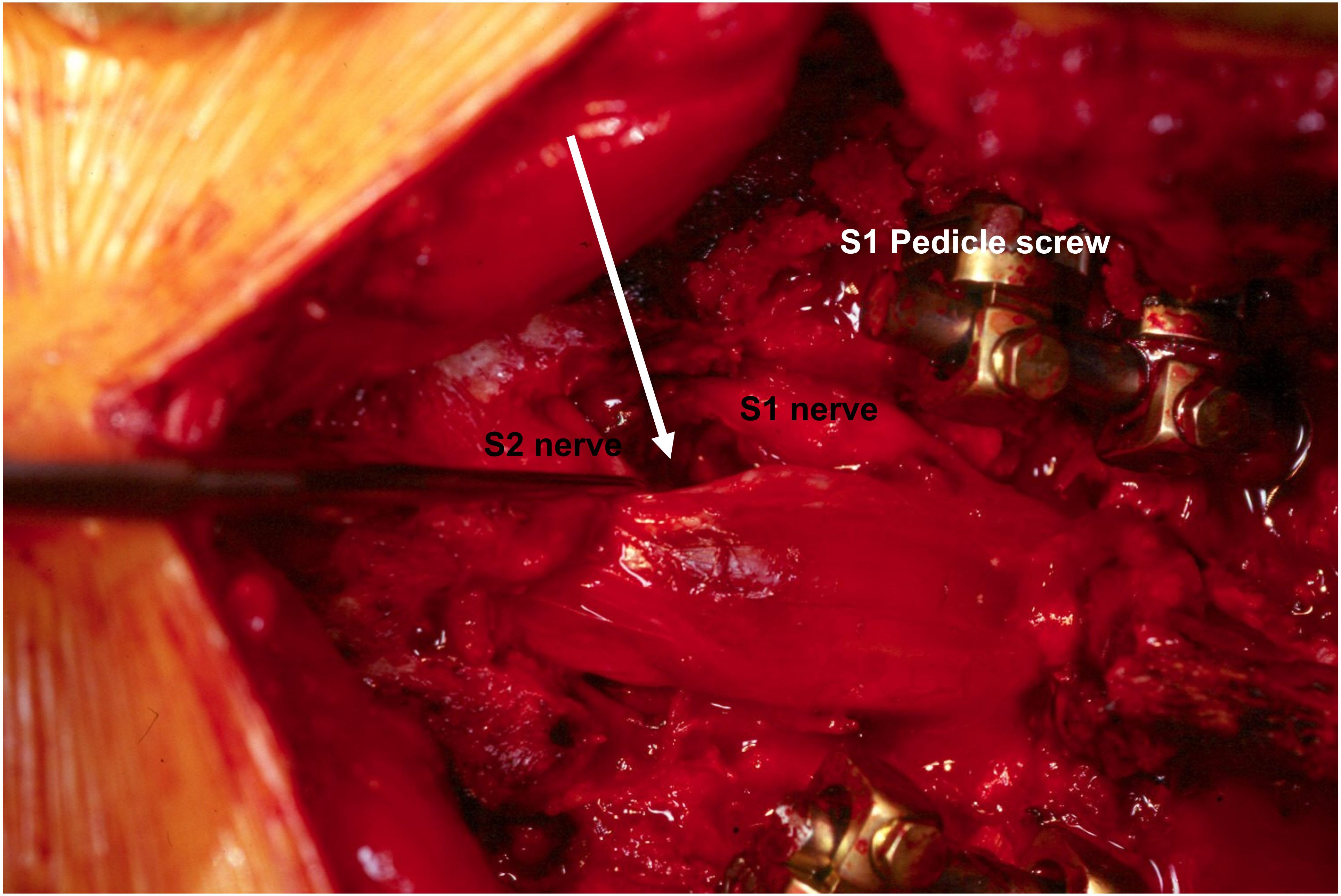

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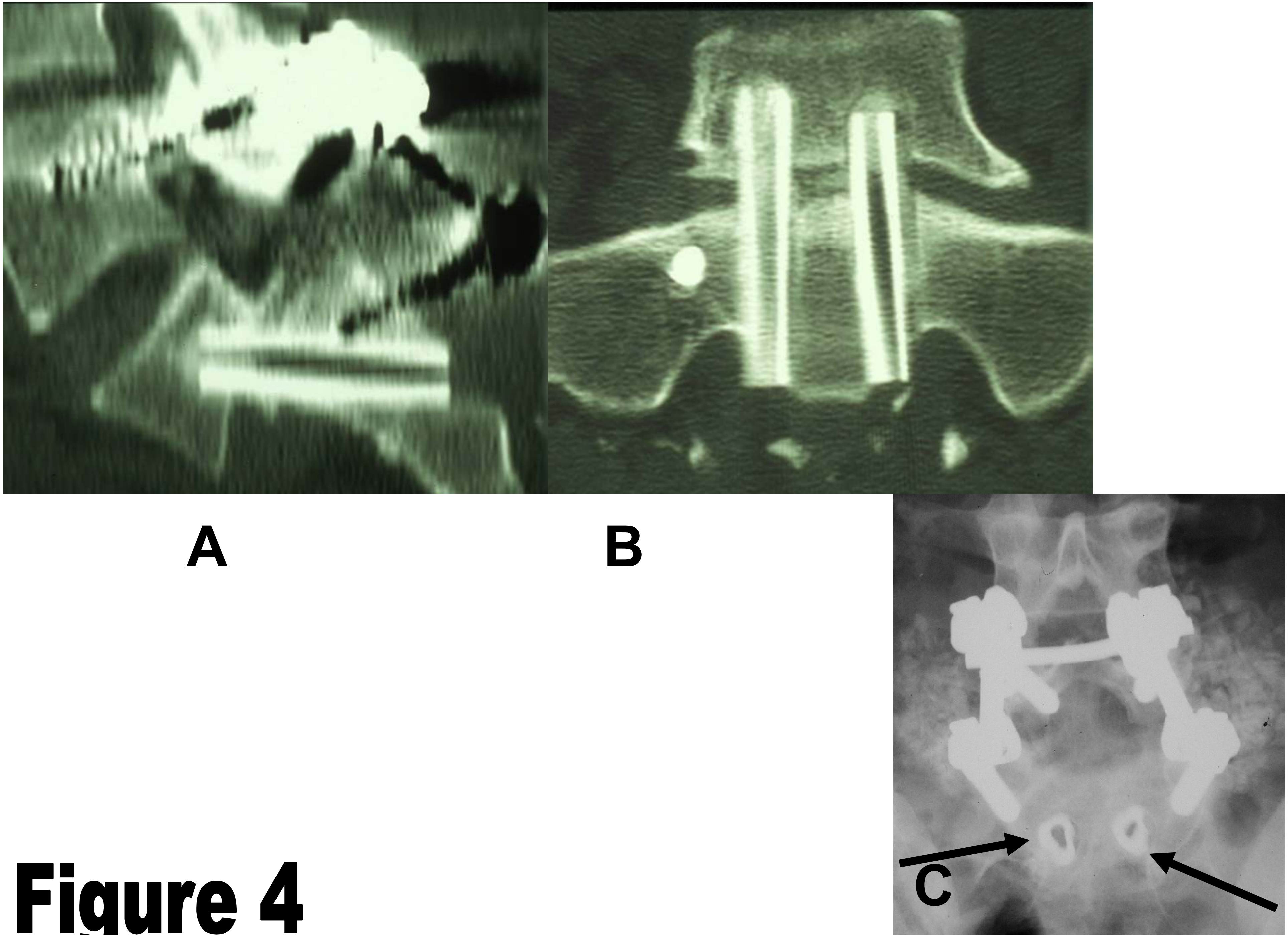

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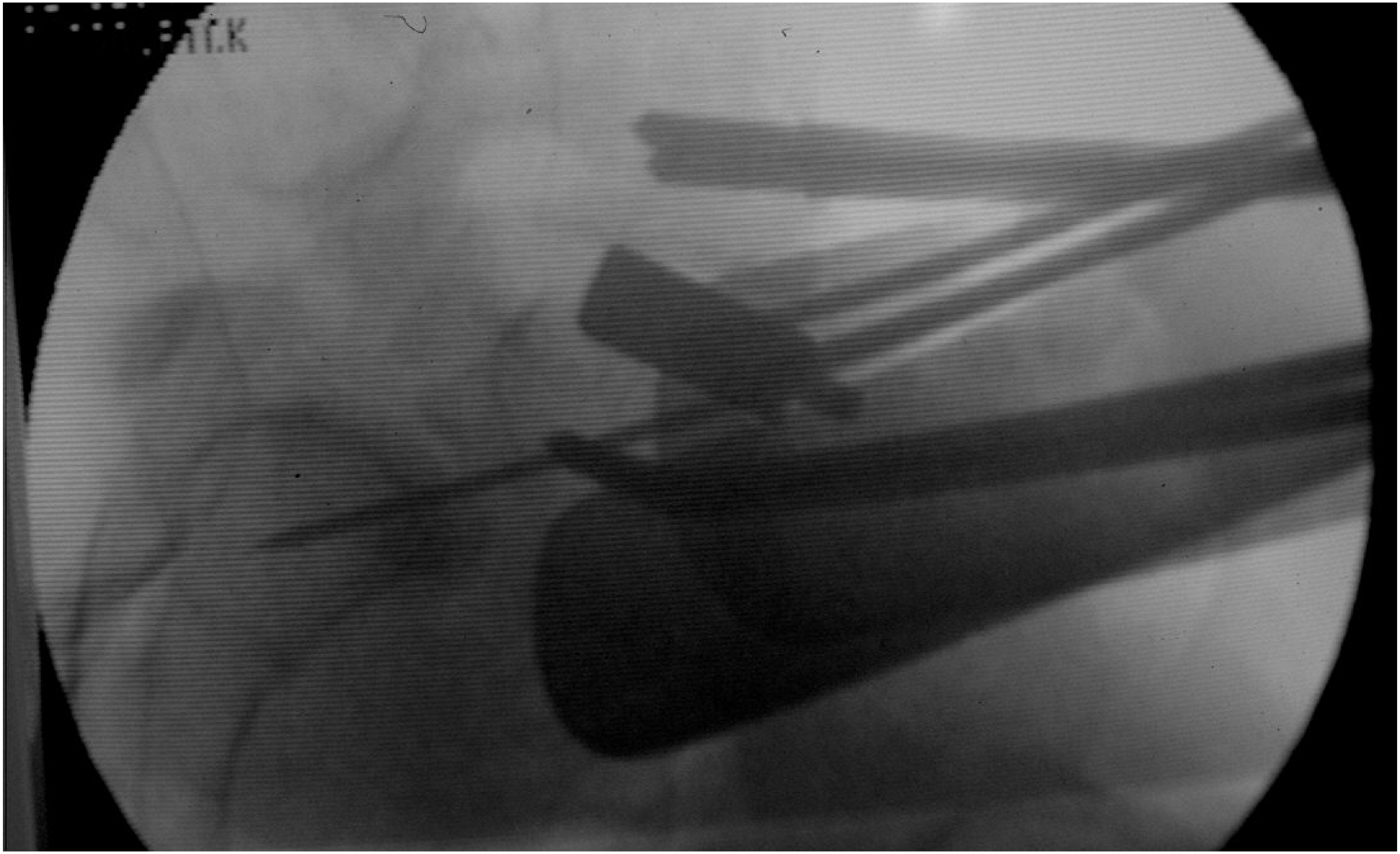

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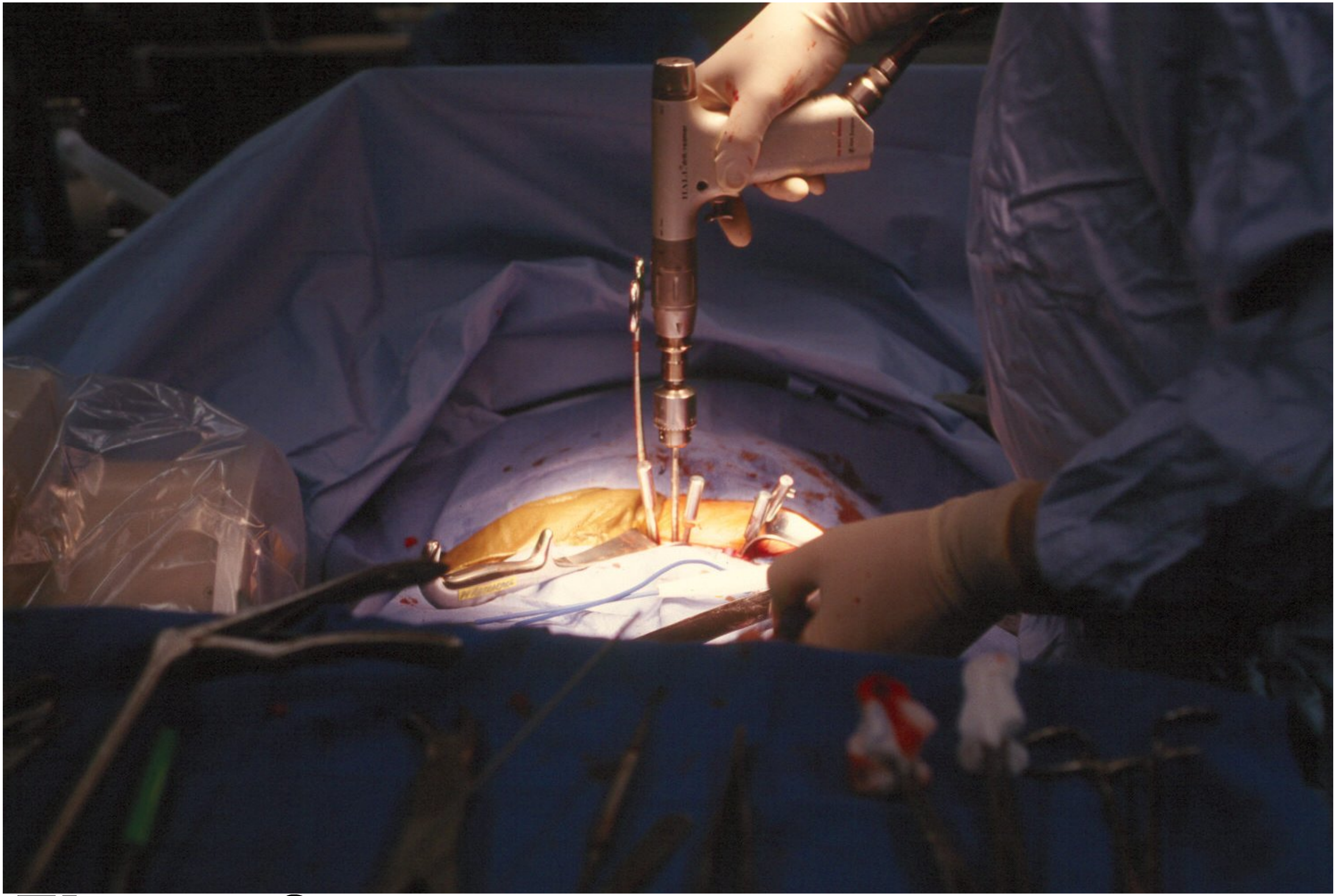

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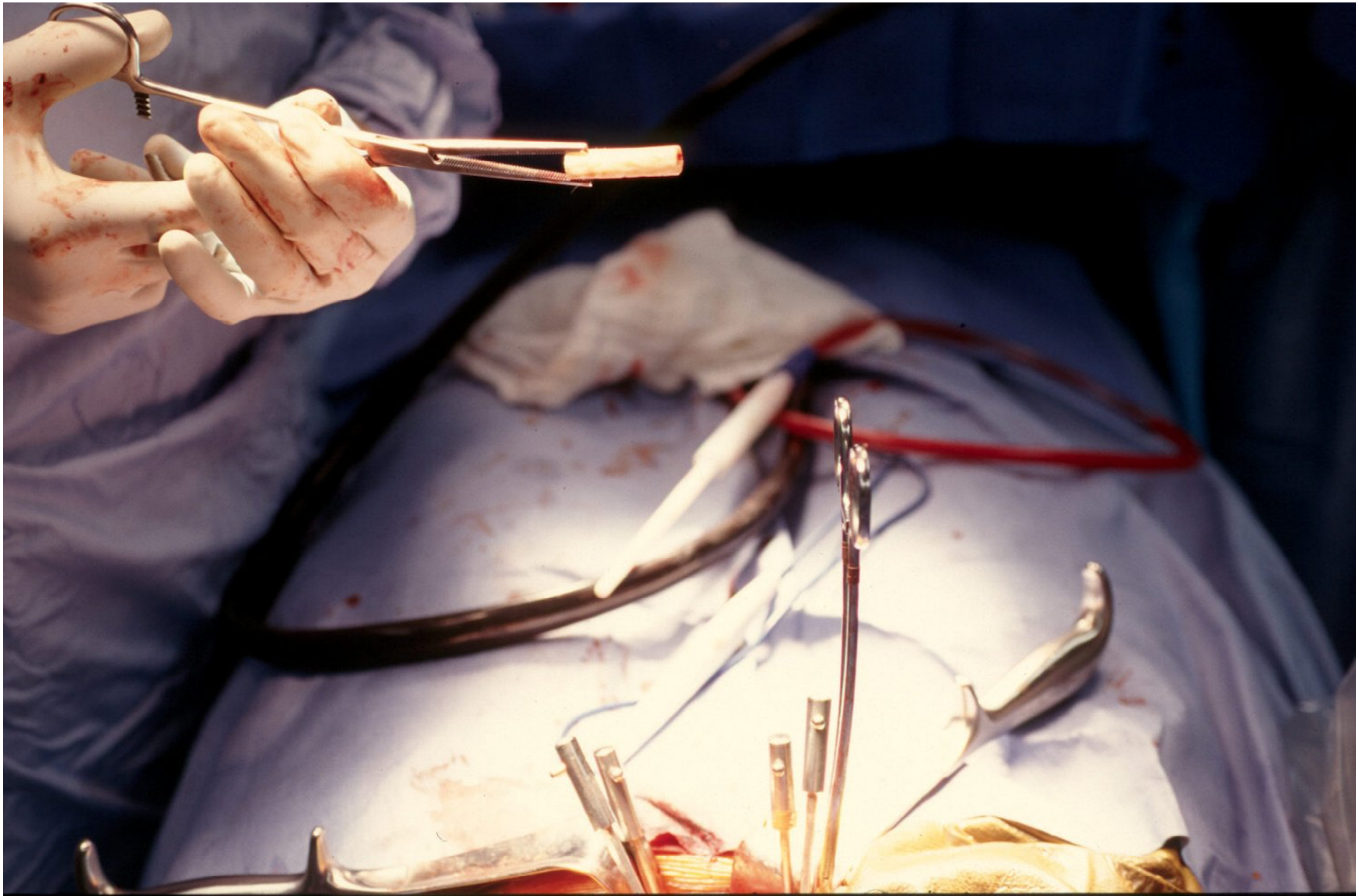

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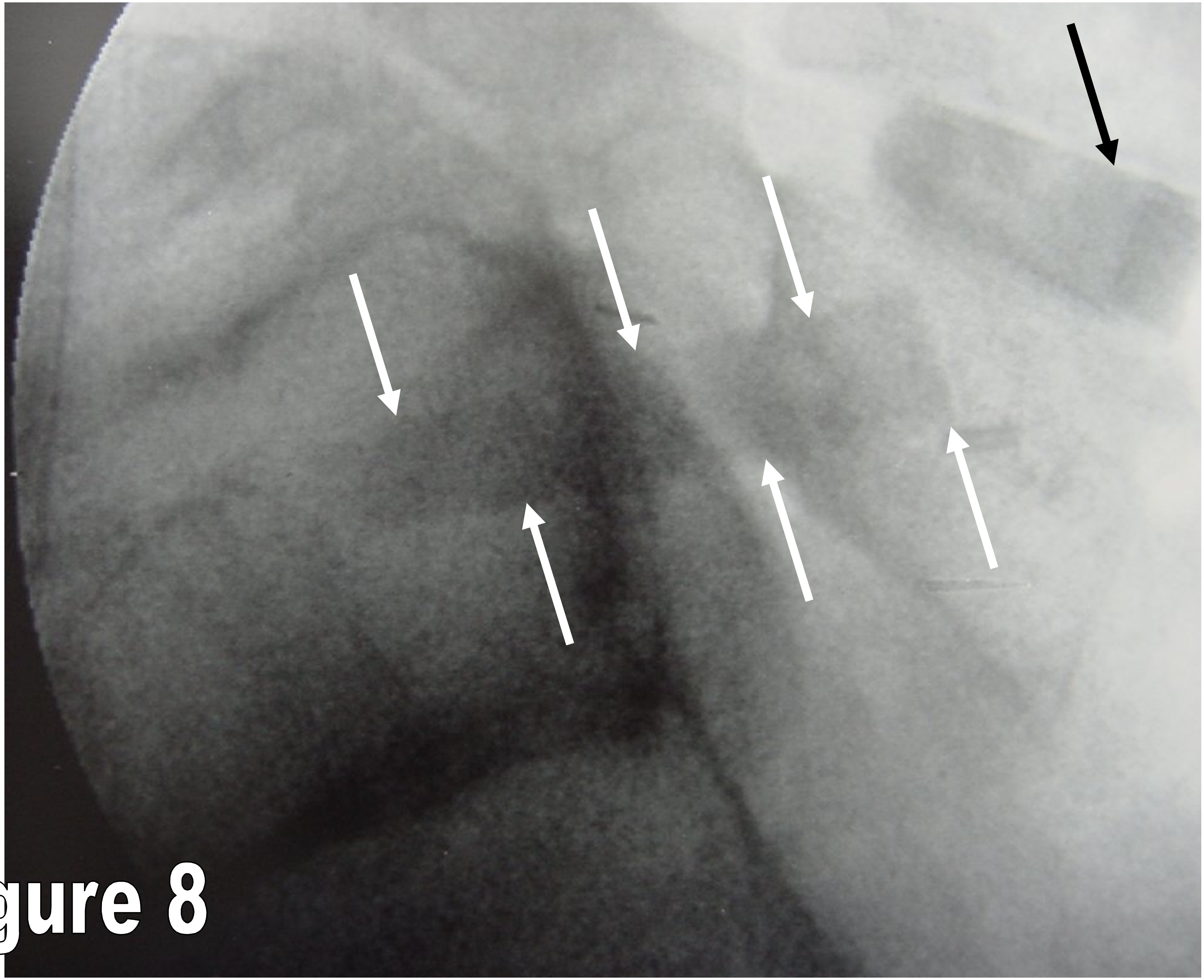

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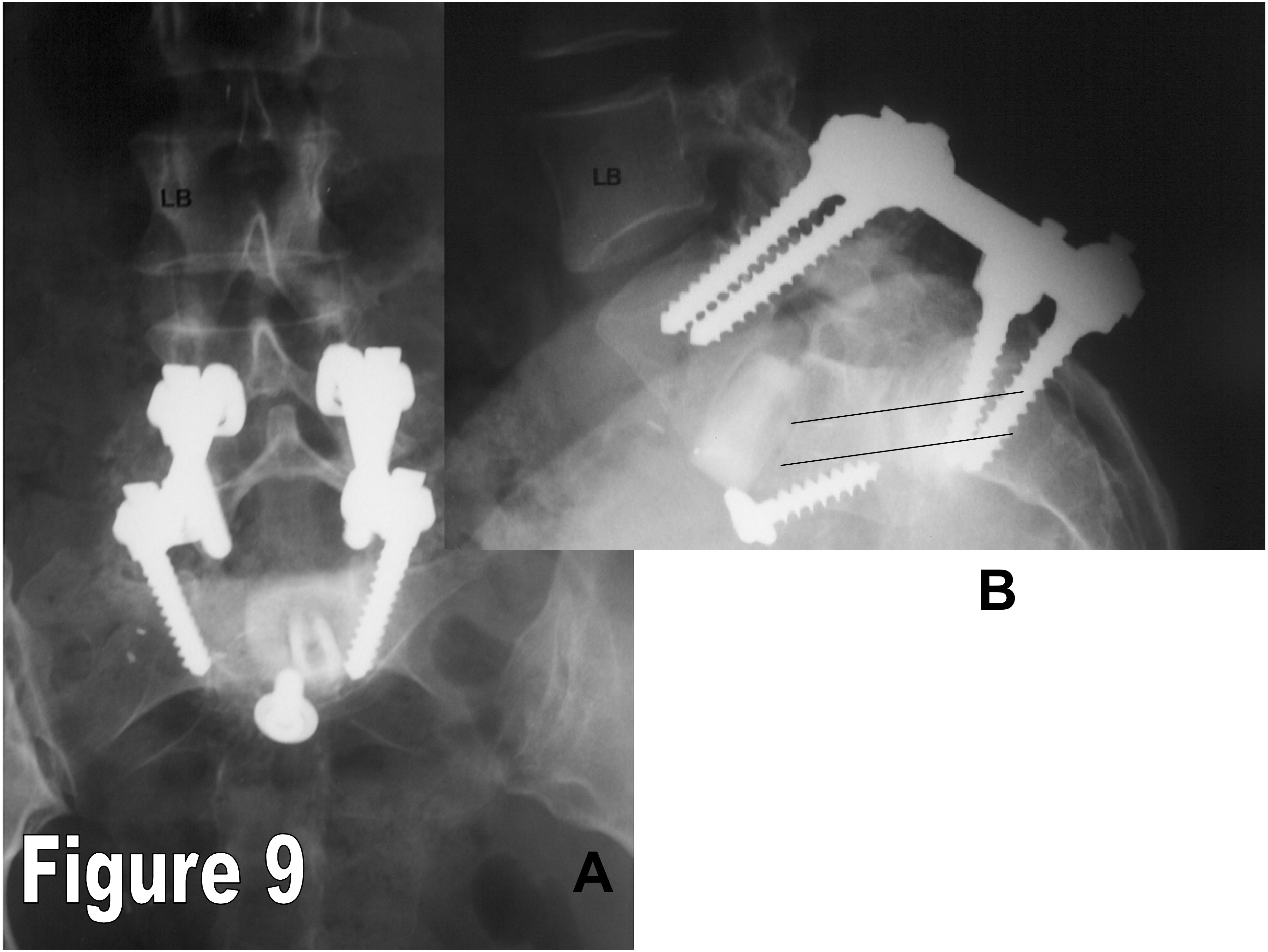

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Figure 9