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THERAPEUTICAL NOTE

Maximal access surgery for posterior lumbar interbody fusion with divergent, cortical bone trajectory pedicle screws: a good option to minimize spine access and maximize the field for nerve decompression

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ABSTRACT

BACKGROUND: First advocated by Santoni *et al.* in 2009, the cortical bone trajectory pedicle screw technique is an alternative to the traditional, convergent technique that shows comparable biomechanical features and potentially requires less aggressive tissue retraction. Aim of this therapy note is to describe this new technique focusing on main advantages and limitations.
METHODS: The authors provide a detailed description of the surgically relevant anatomy focusing on the positioning of the cortical trajectory screws. The surgical technique is then described in a precise step-by-step manner, stressing complication avoidance.
RESULTS: The maximal access surgery posterior lumbar interbody fusion approach is a safe, reproducible procedure allowing for a traditional lumbar spine approach with the benefits of minimal facet joint manipulation and potentially preserving part of their neural innervation and a large part of the paraspinous musculature.
CONCLUSIONS: A dedicated self-retaining retractor and directional neuromonitoring may guide surgeons during the procedure. Nevertheless, the surgeon's knowledge of anatomical landmarks, response to visual and tactile cues and intraoperative decision-making skills remain of paramount importance.

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Key words: Minimally invasive surgical procedures - Spinal fusion - Pedicle screws.

Many different surgical techniques have been described in attempt to eliminate pain and instability in degenerative spine pathology. The main target of these different approaches is to guarantee neural element decompression and secure fixation, stabilization, bony fusion and balance;[1] these surgical goals can be achieved with pedicle screw fixation combined with interbody fusion techniques, such as transforaminal lumbar interbody fusion (TLIF), posterior lumbar interbody fusion (PLIF) and extreme-lateral interbody fusion (XLIF).[2-7]

The most described and performed "open" technique for stabilization of lumbar spine is classic pedicle screw fixation. This technique requires a lateral to medial approach with aggressive muscular detachment extending to the transverse processes. The entry point is located at the junction of transverse process and lateral wall of the facet. For this reason, a major disadvantage of traditional pedicle screw fixation is the aggressive muscle dissection needed to expose bony landmarks to facilitate a correct trajectory for screw placement.[8] An alternative to the open setting is the placement of percutaneous screws.[9] This method of fixing the lumbar spine makes more artful the decompression of the spinal canal and imposes an important and constant use of fluoroscopy. Moreover placing percutaneous screws and then performing a decompression likely requires more time and needs more incisions.

First described by Santoni *et al*. in 2009 [10] the cortical trajectory is a modality of pedicle screw insertion where implant to bone contact occurs to a larger extent in cortical bone. This characteristic likely denotes a higher pullout resistance and superior toggle behavior with smaller diameter and shorter shanks (*i.e.* 5×35 mm) when compared to standard pedicle-screws (typically 6.5×45 mm or longer). While standard pedicle screws require a convergent trajectory, requiring muscle dissection lateral to the facet joints and retraction to permit passage of the screw-screwdriver complex in the desired direction, the divergent cortical bone trajectory technique uses a medial to lateral direction that significantly reduces the need of tissue dissection and retraction.[11] For this reason, the CBT technique is an attractive alternative for procedures requiring posterior decompression and stabilization. Though this technique can be combined with anterior and extreme lateral interbody fusion (to provide a posterior tension band) and postero-lateral fusion one of its most interesting applications is in combination with posterior lumbar interbody fusion (PLIF). This combination permits reduced tissue damage, interbody fusion, neural decompression and posterior fixation, meeting the biological and biomechanical standards of traditional techniques.

Materials and methods

Surgical anatomy

The anatomical relationship of the lamina, pars interarticularis, articular processes of the adjacent vertebral bodies should be familiar (Figure 1), as a too lateral en-

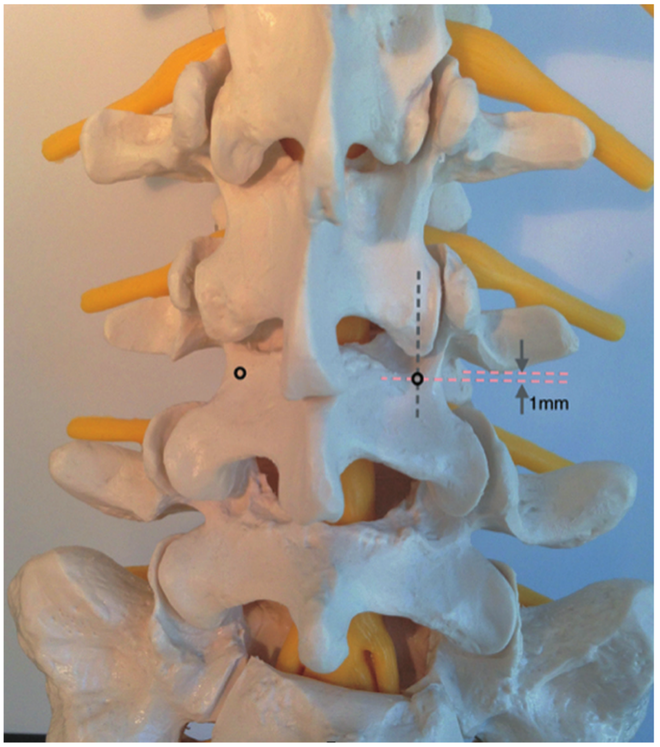

Figure 1.—The starting point is the junction of the center of the inferior articular process (that belongs to the vertebra above the instrumented pedicle) and 1 mm inferior to the inferior border of the ipsilateral transverse process (of the instrumented vertebra).

try point or a too large CBT screw may decrease bony screw purchase.[10] Moreover, the relationship of exiting nerve root to the pedicle is considered, as potential injury can occur if the CBT screw diameter is too large or too long, and the lower nerve root may be at risk if the screw has an insufficient caudo-cranial trajectory.[12] The CBT screws use a starting point in the thick cortical bone of the pars interarticularis and a final anchor on the lateral ring apophysis of the upper endplate, resulting in a large proportion of screw coverage by cortical bone with optimal mechanical resistance to pull-out.[10]

Description of the surgical technique

After standard antibiotic prophylaxis, the patient is placed in a prone position on appropriate padded support to avoid increased intra-abdominal pressure. Skin preparation and sterile drapping are performed. A 4- to 6-cm skin incision is used for a single-level procedure (Figure 2A). Spinous processes and bilateral laminae are exposed

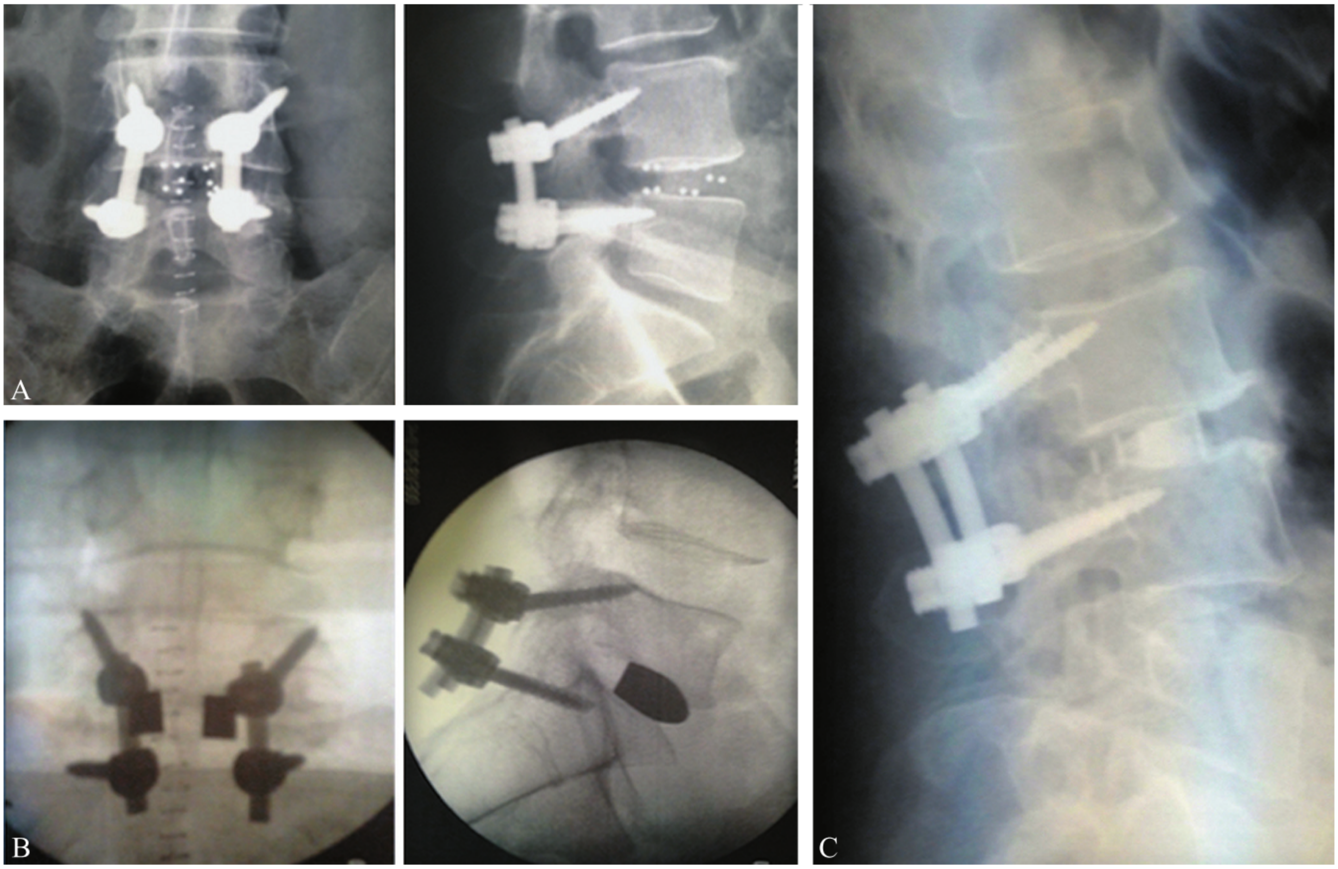

Figure 2.—A) Final fluoroscopic control (AP and lateral) with the superior cortical bone trajectory (CBT) screws in a medio-latero-superior trajectory (and the alternative technique for the inferior screws). B) Final fluoroscopic control (AP and lateral) showing the same screw placement technique with standard tantalium cages positioning. C) CBT screws fixation associated with XLIF procedure.

with preservation of the cranial facet joint. After hemostasis, a size and length-adapted self-retaining retractor with an integrated light source is positioned (Figure 2B).

The CBT entry point is identified at the junction of the center of the inferior articular process of the vertebra above and 1 mm inferior to the inferior border of the transverse process (Figures 1, 2B). After opening the cortical bone layer with a 3-mm burr, the screw trajectory is drilled and tapped in an 8-10° divergent (medio-lateral) and 25° caudo-cranial direction, and the screw is then inserted [12] (Figure 3). The cortical trajectory screws have a tri-zone thread (cortical-spongious-cortical). Screws are usually 4.5 or 5 mm in diameter and 30 to 35 mm long. Each step can be controlled with lateral fluoroscopic guidance. An alternative technique for the inferior screws of the construct is to insert cortical screws after having performed inferior facetectomy. In that case, the entry point will be in the concavity of the remnant superior facet and the trajectory about 15° caudo-cranial. The integrity of the pedicle cortical bone walls can be checked with the intraoperative use of triggered electromyography with stimulation with integrated instruments (drill, ball-tip probe, tap and screws).

A partial laminectomy and medial atherectomy is performed under direct visual control. The surgical microscope can be used depending on the surgeon's preference. Slight medial retraction of the passing root and sac and protection of the laterally exiting root under the pedicle allows for disc exposure, discectomy and end-plate preparation. Complete end-plate preparation in the medial and lateral direction is of paramount importance in order maximize fusion area and enable far lateral positioning of interbody cages enabling to be in contact to the areas of maximum bone resistance. An appropriate

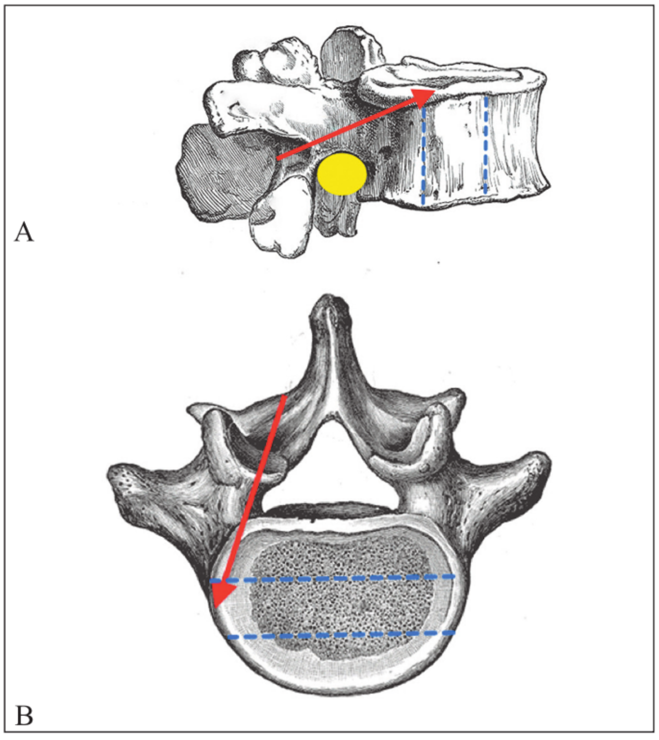

Figure 3.—The screw trajectory in both axial and sagittal view is shown (arrows): the tip of the screw has to be placed ideally just over the posterior third of the vertebral body (dotted line). The yellow spot indicates the exiting nerve root.

size and height of the cage is selected. Thereafter, the definitive cages are filled with autologous morselized bone graft. After positioning is confirmed, the cage is rotated 90° (increasing height and lordosis) (Figure 4A). After implantation of both cages, the remaining disc space is filled out with autologous bone graft. Depends on surgeon's preferences other kind of cages can be used to guarantee fusion and correct lordosis such as standard tantalium cages (Figure 4B). If indications require the use of a lateral approach, the surgeon with first perform the lateral interbody fusion [6] and then will proceed with posterior screws insertion and decompression as described above (Figure 4C). The screw heads are assembled on the screw shanks (Figure 2C). Thereafter, compression can be applied in order to load the cages and to increase lumbar lordosis. Proper positioning of the implants and alignment is finally verified on biplanar fluoroscopy (Figure 4A-C). After thorough irrigation and hemostasis, the surgical site is closed in the usual manner.

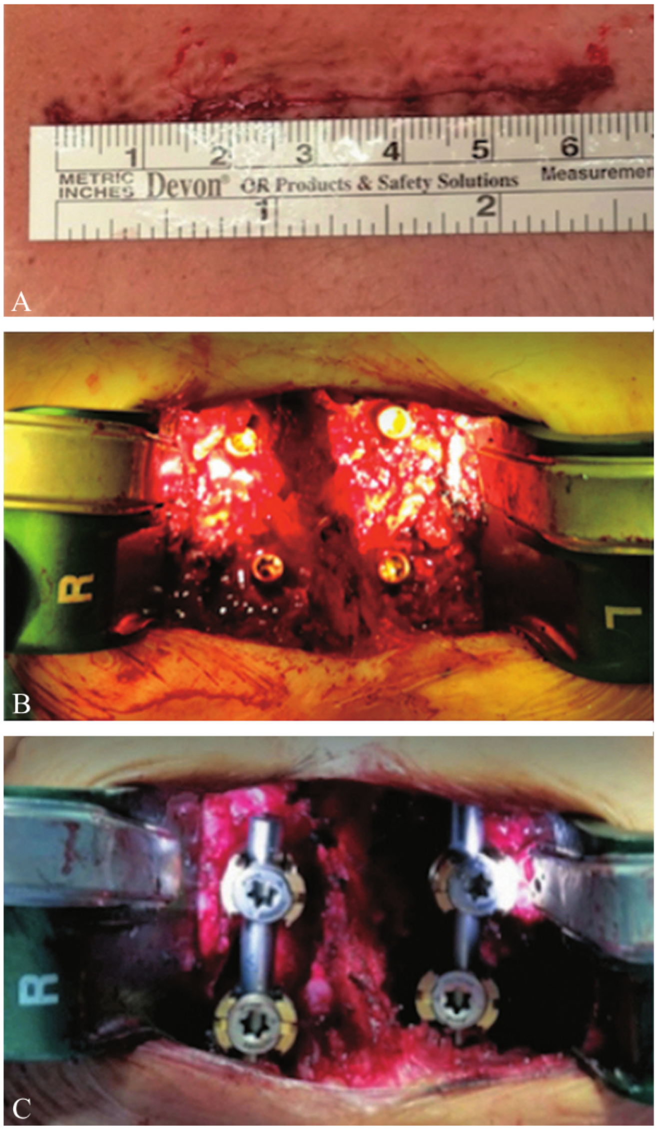

Figure 4.—A) Skin incision dimension for a one level procedure. B) Size- and length-adapted self-retaining retractor with an integrated light source is positioned. Screws are already positioned showing the correct entry point. C) Procedure completed with screws head and rods positioning.

Discussion

Indications

Surgical indications for CBT plus PLIF procedures are not specific and can include most indications for fusion in the lumbosacral spine. Examples are degenerative disc disease, degenerative spondylolisthesis,

TABLE I.—*Indications.*

Indications	MAS
Intraforaminal herniation	++
Mono/bi-segmental discopathy	+++
Mono/bi-segmental stenosis	++
Junctional segment	+

MAS: maximal access surgery.

lumbar degenerative spinal stenosis requiring fusion, post-discectomy instability and adjacent segment disease with extension of the posterior fusion (Table I). Additionally, the CBT+PLIF or XLIF technique can be used to minimize the morbidity and mortality associated with a classical open posterior approach in elderly patients.

Approach advantages

The CBT technique is safe, reproducible and an attractive alternative to the traditional open techniques of posterior fixation. This medialized approach also resulted a familiar technique for spine surgeons with the possibility to easily dominate the dural sac, reducing the risk of neuro-vascular injuries. Although its minimally invasive characteristic, the technique also allows to obtain a wide lateral decompression involving articular process with the possibility to complete the stabilization with different kind of interbody fusion graft like TLIF (transforaminal lumbar interbody fusion) and PLIF. It can also be used as a complement during antero-lateral approaches to the disc space (ALIF or XLIF).

Strengths

The medial entry point and vertical trajectory directed anterior through the pedicle and into the vertebral body will penetrate the denser regions of the trabecular bone and into the cortical wall of pedicle and VB itself.[13] This anatomical consideration is an important difference when compared to traditional pedicle screw insertion, in which the screw only engages the trabecular core of bone along the axis of the pedicle. Multiple studies, in fact, demonstrated that this CBT technique, with its cortical trajectory, would provide an equivalent pull-out strength if compared to traditional trajectory.[10, 14, 15]

Invasiveness in percutaneous screwing technique vs. CBT technique

Surgical goals can be obtained with a smaller skin incision (≤6 cm) when compared to the traditional “open” technique or to percutaneous screw fixation, where the total length of the incisions, obtained by adding all the cuts required for each screw, is even higher.

Other advantages include a surgical time equal to traditional pedicle screw technique, estimated at 90 minutes for a bi-segmental stabilization with low blood loss (<100 cc).

Like the traditional lateral to medial trajectory, fluoroscopy guidance is needed during surgery. As reported by Rampersaud *et al.*[16] fluoroscopy-assisted pedicle screw implantation is associated with a 10 to 12 times greater radiation exposure to the spinal surgeon than in non-spinal orthopedic procedures.[17] Although the use of fluoroscopy during the medio-lateral approach for pedicle screw placement is equivalent to the traditional technique, the dose of radiation to the surgeon is very low when compared to the percutaneous approach, in which a constant use of image guidance is required during surgery.

Patient’s outcome

The last advantage of the medio-lateral trajectory technique is represented by the differences in the acute hospitalization charges when compared to traditional pedicle screw fixation. In our experience, length of stay (LOS) averaged 4 days. This data is comparable to LOS after minimally invasive surgery for spinal decompression alone and lower than traditional open approach (6 days), as demonstrated in previous studies.[18] The reduced tissue dissection and less blood loss, in fact, bring to a superior clinical result resulting in reduced post-operative pain,[11] reduced narcotic use and faster recovery with a possible cost reduction during hospitalization (Table II).

Limitations

The CBT+PLIF/XLIF technique is limited to levels from L1 or L2 (depending on the position of the conus medularis) down to S1. Previous surgery including extensive laminectomy and/or facetectomy may increase the difficulty or even preclude this technique. Severe osteoporosis is a relative contraindication for any interbody fusion technique because of an increased risk of cage subsidence.

TABLE II.—*Comparison among different techniques.*

	MAS	Open	Percutaneous
Length of skin incision	+	+++	++
Blood loss	+	+++	+
Hospitalization	+	+++	+
Intraoperative radiations	+	++	+++
Duration of surgery	++	++	++

MAS: maximal access surgery.

There is no evidence in the literature on the efficacy of CBT screws in the treatment of patients needing correction of deformity and in more than 2-level pathology.

Complication avoidance

A thorough radiologic al preoperative assessment of the lumbar spine with a meticulous planning of entry points for the CBT screws is essential. Guidance systems such as intraoperative fluoroscopy, navigation or neuromonitoring can be considered by the surgeon depending on the level of expertise and preference. In case of previously instrumented pedicles, intraoperative CT navigation may further increase the safety and accuracy of CBT pedicle screw fixation.[19] Although the former options may increase the safety of the surgical procedure, the surgeon's knowledge of anatomical landmarks, response to visual and tactile cues, and intraoperative decision-making remain of paramount importance and with a short learning curve allow the surgeon to use really few fluoroscopy for this technique.

Specific perioperative considerations

After the procedure, the authors' preference is allowing for bed rest for the day of surgery. Low molecular weight heparin is administered according to the center's protocol that dictates the duration of the prophylaxis. A standing biplanar full spine X-ray or EOS image is obtained before the discharge and at 6 weeks after surgery. A follow-up CT scan is suggested at 6 months to assess fusion, but this can be changed depending on the local protocol.

Specific information to give the patient about surgery and potential risks

Patients sign an informed consent where the type and site of surgery, the most common side effects, complications and surgical expectations are detailed. Specific complications include surgical site deep or superficial infections, hematoma and wound dehiscence, damage to the dura with cerebrospinal fluid leak, nerve root irritation, permanent root damage, pseudo-arthrosis, endplate subsidence, and implant failure. Additionally, possible long-term consequences of fusion procedures, as adjacent segment failure, should be mentioned.

Conclusions

The medio-lateral trajectory technique for screw placement has proven to be an useful alternative to traditional "open" or percutaneous fixation techniques. This medialized approach is safe, reproducible, and familiar for surgeons with experience in minimally invasive surgery. For its versatility, it is possible to complete the fixation with most interbody grafts such as PLIF, XLIF or even TLIF.

Compared to the traditional pedicle screw placement technique, there is no great difference in pull out strength or length of the operation. The main advantage is represented by the possibility of a very small skin incision, a minimal muscle dissection and a poor blood loss with an important reduction of post-operative pain and a faster recovery after surgery. The CBT technique can be considered equivalent to other minimally invasive approaches like percutaneous screw placement, with the advantage of a lower dose of radiation to the surgeon and patient during the procedure.

In conclusion CBT technique is an additional option for spine surgeons to treat mono or bi-segmental degenerative pathologies of lumbar spine with a lower risk of neurovascular injuries during surgery, while it is still not suitable for longer stabilization, high grade spondylolisthesis reduction or deformities such as scoliosis or kyphosis due to the higher correction needed. Further studies will be needed to determine other applications of the technique described and its future potential.

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