Acta Neurochirurgica (2019) 161:2423–2428
https://doi.org/10.1007/s00701-019-04067-0

HOW I DO IT - SPINE DEGENERATIVE

How I do it? Lumbar cortical bone trajectory fixation with image-guided neuronavigation

Juan Delgado-Fernández[1] · Paloma Pulido Rivas[2] · Ricardo Gil-Simoes[2] · Rafael García de Sola[3]

Received: 13 June 2019 / Accepted: 9 September 2019 / Published online: 15 October 2019
© Springer-Verlag GmbH Austria, part of Springer Nature 2019

Abstract

Background Cortical bone trajectory was described in 2009 to reduce screw loosening in osteoporotic patients. Since then, it has demonstrated improvements in biomechanical and perioperative results compared to pedicle screws, and it have been described as a minimally invasive technique.

Method We describe our experience with the technique assisted by 3D neuronavigation and review some of the complications and tools to avoid them together with limitations and pitfalls.

Conclusion Cortical bone trajectory guided by 3D neuronavigation helps to reduce the need for radiation and incidence of complications.

Keywords Cortical bone trajectory · Neuronavigation · Pars articularis · Minimal invasive · Lumbar spine

Relevant surgical anatomy

In 2009, Santoni et al. [7] described a new trajectory for the insertion of spinal screws aiming to reduce the incidence of screw loosening in osteoporotic patients. This technique increased thread contact with cortical bone compared with cancellous bone, which is more affected in this condition (Fig. 1). Many biomechanical studies have shown better outcomes in pull-out strength, greater stiffness in cephalocaudal and mediolateral loading, superior resistance to flexion/extension, and better immediate implant stability [1]. Also, better perioperative results and less muscle dissection have been described in this technique [2, 6]. Cortical bone trajectory (CBT) has a superior caudo-cephalad direction in the sagittal plane and mediolateral path in the axial one. Main anatomical landmarks have been previously described [7, 9], locating the entry point 1 mm inferior to the inferior border of the transverse process and 3 mm medial to the lateral margin of the isthmus, and projecting to the 5 o'clock location in the left pedicle and to the 7 o'clock in the right pedicle. A caudo-cranial angulation of 25–30° direction to the superior endplate should be performed (Fig. 2). This trajectory achieves the fixation at the dorsal, posteromedial, and anterolateral sides of the pedicle and the marginal region of the vertebral body, where cortical bone is thicker.

Key points • Preoperative CT scan to measure pedicle diameter and grade of osteoporosis.
• Neuronavigation array is fixed with iliac crest pins.
• 3D fluoroscopy is obtained before opening, reducing the need for localization with radioscopy.
• Wound incision could be limited to 5–7 cm.
• Muscle dissection is limited to the lateral part of the pars without the need of transverse process exposure.
• Insertion point and path is described with the drill and neuronavigation probe with a medial to lateral and caudo-cephalad disposition.
• Use the tap to avoid widening of the path and avoid pedicle fracture.
• Guided-screws of at least 5.5mm diameter should be inserted to avoid breakage.
• Check correct positioning of screws with 3D fluoroscopy.
• Decompression of intervertebral space with laminectomy or hemilaminectomy before attachment of the screw head to the body.

This article is part of the Topical Collection on *Spine degenerative*

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00701-019-04067-0) contains supplementary material, which is available to authorized users.

✉ Juan Delgado-Fernández
juan.delgado.fdez@gmail.com

Extended author information available on the last page of the article

Description of the technique

Positioning and neuronavigation setup

The patient is placed in the prone position on a Jackson radiolucent spinal surgical table and reference array is then placed

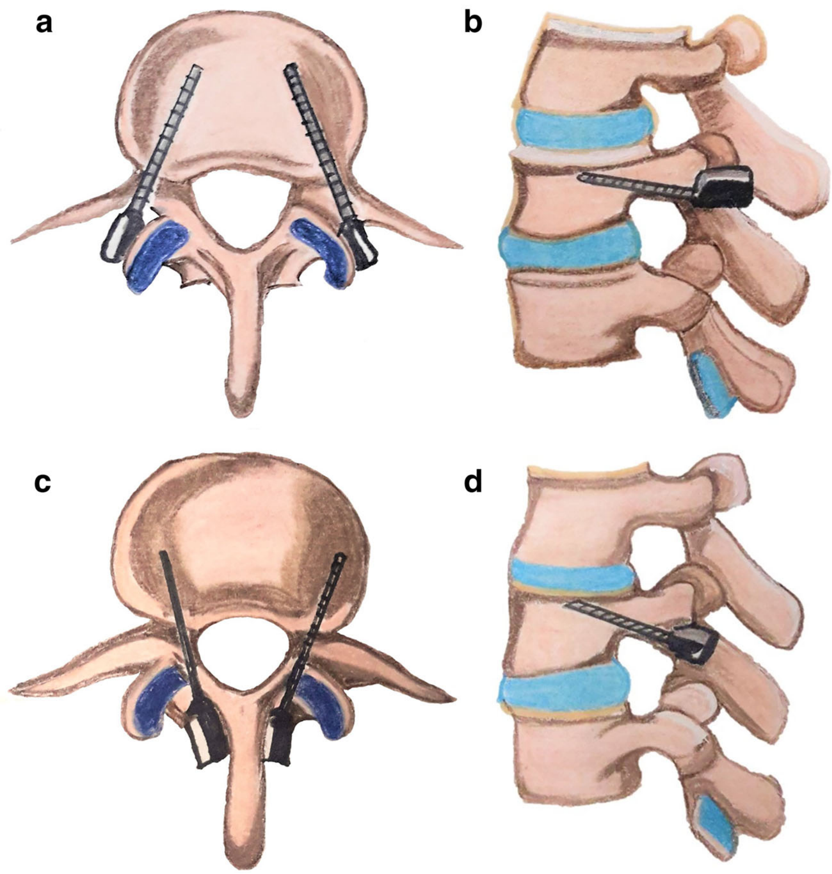

Fig. 1 Diagram of pedicle and cortical screws. **a**, **b** Axial and sagittal plane views of pedicle screw trajectories. **c**, **d** Axial and sagittal plane views of cortical bone trajectories

as a minimally invasive procedure, attached to a 2-pin fixator that is fixed to the patient's iliac crest (BrainLab®). Afterwards, images are obtained with intraoperative 3D fluoroscopy (Arcadis Orbit 3D, Siemens Medical Solutions) and 3D reconstruction is performed with the Brainlab software for spine navigation.

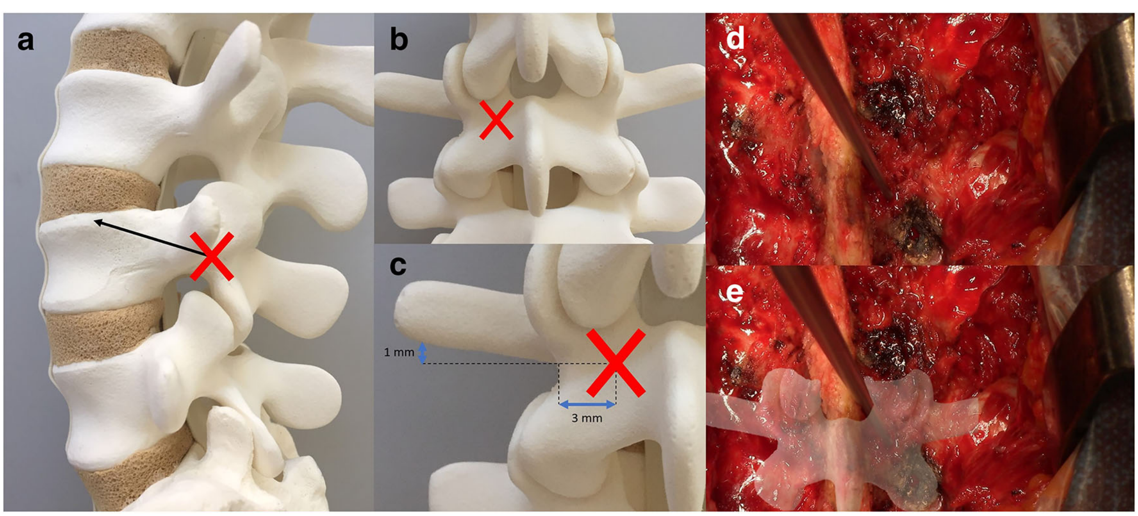

Fig. 2 Insertion point of the cortical bone screws in a sawbone and in an intraoperative reconstruction. **a** Sagittal view of a sawbone showing insertion point and caudo-cranial angulation of 25–30° to the superior endplate. **b** Coronal view of a sawbone showing insertion in the medial border of the pars articularis. **c** Detail of the coronal view of a sawbone locating entry point, as previously described, 1 mm inferior to the inferior border of the transverse process and 3 mm medial to the lateral margin of the isthmus. **d** Intraoperative image with neuronavigation probe showing entry point as previously described. **e** Scheme of the intraoperative view and a coronal view of a vertebral model correlating intraoperative and sawbone entry point

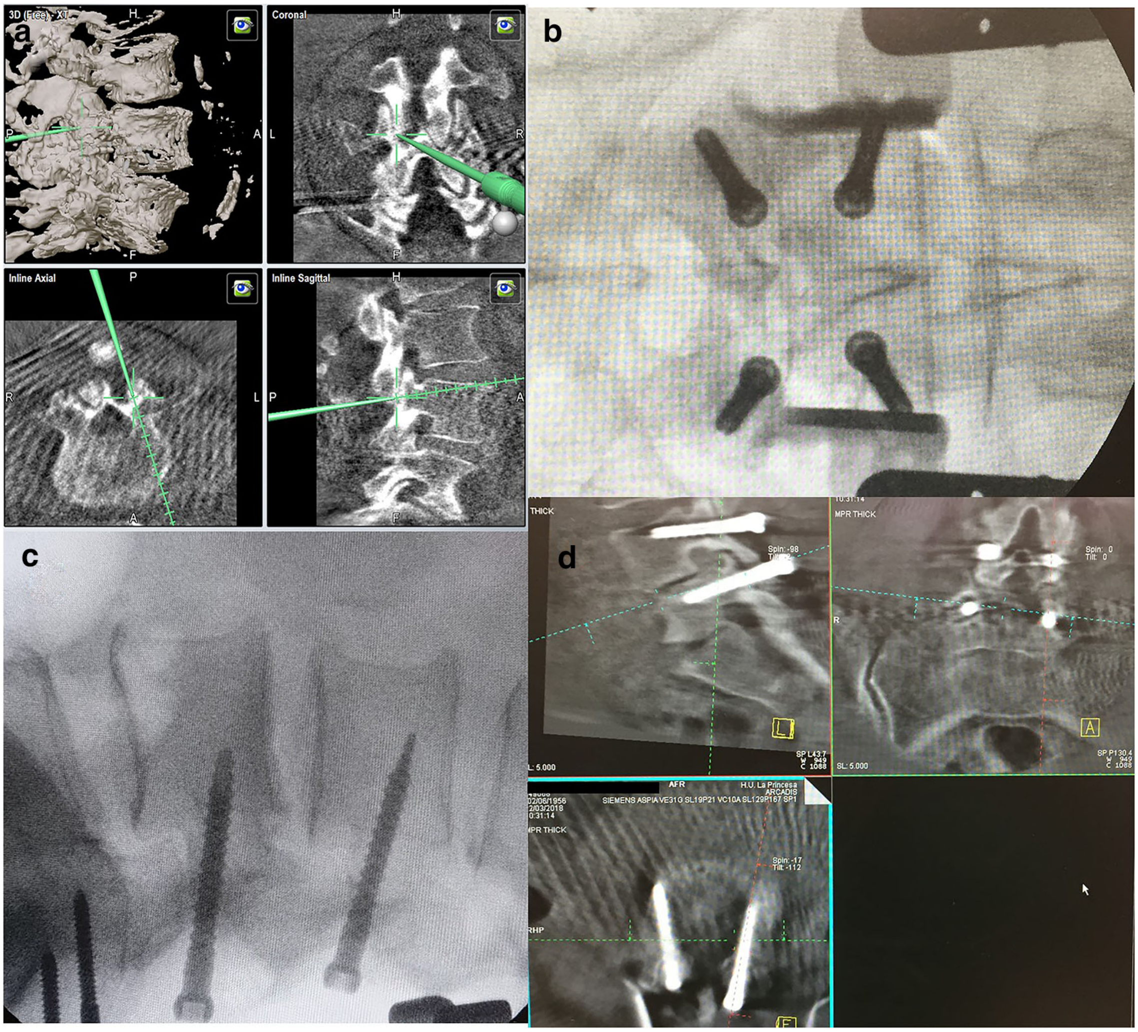

Fig. 3 Intraoperative images of CBT surgery. **a** Skin incision and neuronavigation array fixed at the iliac crest. **b** Intraoperative spine navigation screen showing the correct positioning of the screw. **c** Screw fixation before starting decompression. Although medial to lateral trajectory could be difficult because of the spinous process, the absence of the body base of the screw facilitates screw insertion and allows decompression before it is done. **d, e** Decompression after fixation is completed, with body base screw and rods. **d** Hemilaminectomy with bilateral decompression and (**e**) laminectomy. **f** Wound closure demonstrating length of skin incision

Skin incision and spine exposure

Surgery starts with a midline incision tailored to 5–7 cm over the pathological level using image guidance without radiological localization (Fig. 3a). Subperiosteal dissection is performed until pars articularis is exposed in both superior and inferior vertebrae. Only the medial part of the transverse process is exposed. Once pars articularis is exposed, the insertion point is defined as previously described with the help of a neuronavigation probe (Fig. 2c). Occasionally, supraspinous ligament could be removed with a rongeur to obtain a better mediolateral trajectory.

Screws insertion

A drill is used to perforate cortical bone at the entry point. In this case, it should be remarked that the strength of cortical bone is higher and sometimes drilling could be harder than when we perform pedicle screws. Afterwards, an image-guided tap is used to enlarge the medial to lateral trajectory performed, reducing the incidence of pedicle fracture (Fig. 3b). Once we have checked that our path is correct with the neuronavigation probe and ball tap, we measure the screws. We use cortical screws that have a denser thread (Janus, Orthofix), with 5.5 mm diameter and 40–45 mm length. Finally, screws are inserted and intraoperative 3D fluoroscopy scan is performed again to ensure adequate positioning and check that there are no complications related to screw insertion (Fig. 4).

Decompression and rod insertion

Bilateral laminectomy or hemilaminectomy with bilateral decompression is performed (Fig. 3c, d) under microscopic

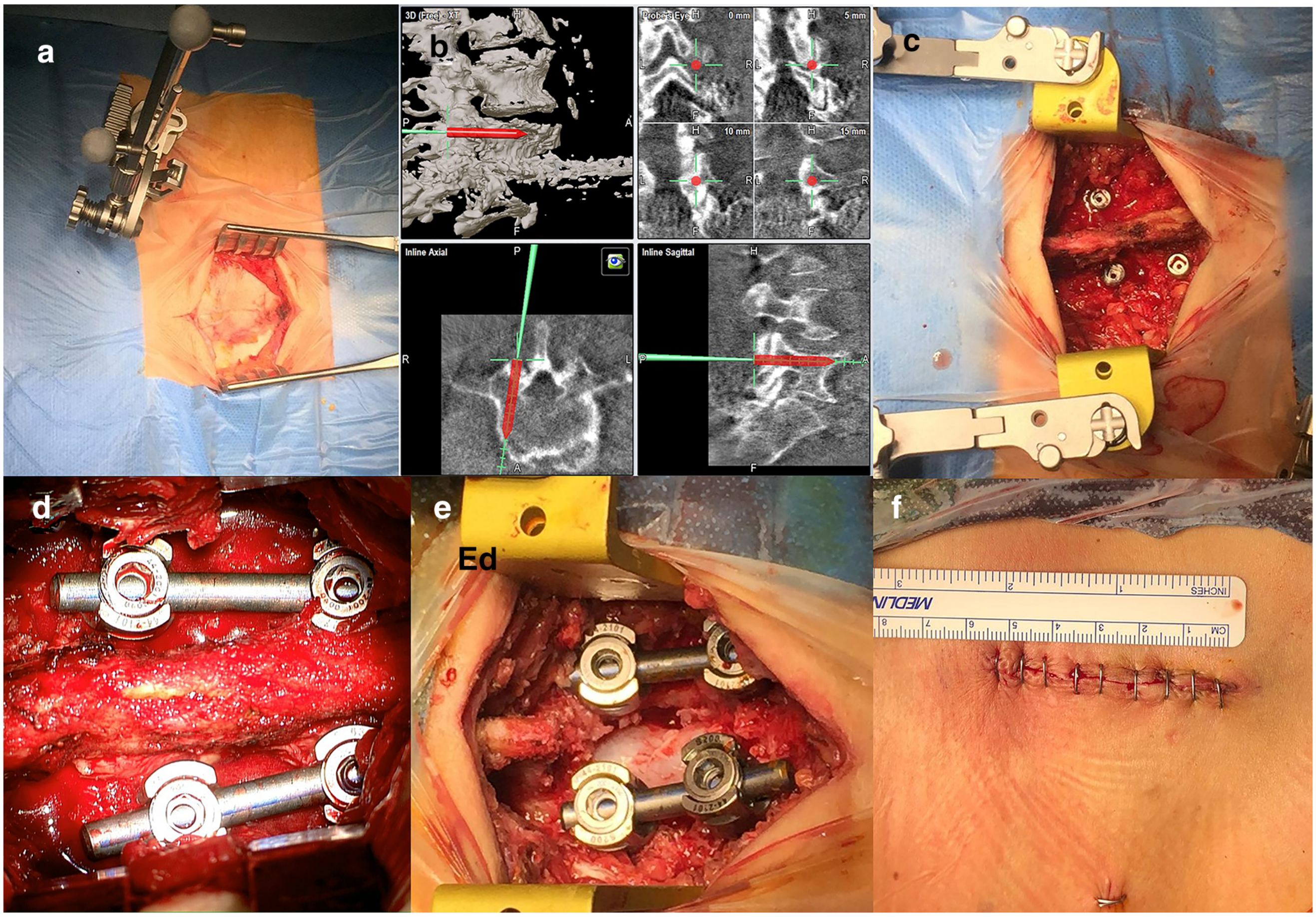

Fig. 4 Radiological intraoperative imaging. **a** Image of the neuronavigation screen showing cortical bone trajectory. **b** AP and **c** lateral radiograph demonstrating positioning of L4–L5 CBT fixation. **d** Intraoperative axial, coronal, and sagittal CT image showing correctly positioned CBT screws

assistance until the spinal canal and nerve roots of the pathological level are fully freed. After decompression, the body base of the screw is applied into the spherical head of the screw. In some cases, a previous decortication is needed to allow attachment of the body to the head of the screw. Body attachment is needed after decompression to obtain a better visualization of the space, which otherwise could be limited afterwards. Once all the bodies are applied, a rod is prepared and fixed with nuts (Fig. 5).

Indication

The main indication for CBT technique is degenerative lumbar spine, but indications are increasing every day. However, as previously mentioned, CBT would be more suitable for osteoporotic and elderly patients with bad bone quality and also for patients that could have complications related to wound healing, as it will be shorter, such as patients with a bad nutrition profile or obese patients. Likewise, CBT has been recommended for adjacent level syndrome or as a rescue technique after pedicle screw failure [1]. Moreover, new indications have been described recently in thoracic spine, fractures, and pediatric patients [8, 10].

Limitations

Some limitations of this technique have been described, mainly in relation to biomechanical properties and anatomical concerns. Firstly, Matsukawa et al. [4] described that CBT screws have lower stabilizing properties in spondylolytic vertebra due to a lower fixation strength compared with pedicle screws. Secondly, these authors have also described that CBT should have a different entry point and penetrate S1 endplate when it is performed in a L5–S1 fixation, as CBT have been considered inadequate for this level [5]. However, in different clinical series already published, both spondylolytic patients and L5–S1 levels have been fixed with the CBT technique without higher complication rates [3, 9]. Anatomical concerns also include a big spinous process that could hinder screw positioning, even without the screw head, and it should be resected totally or in some part of it.

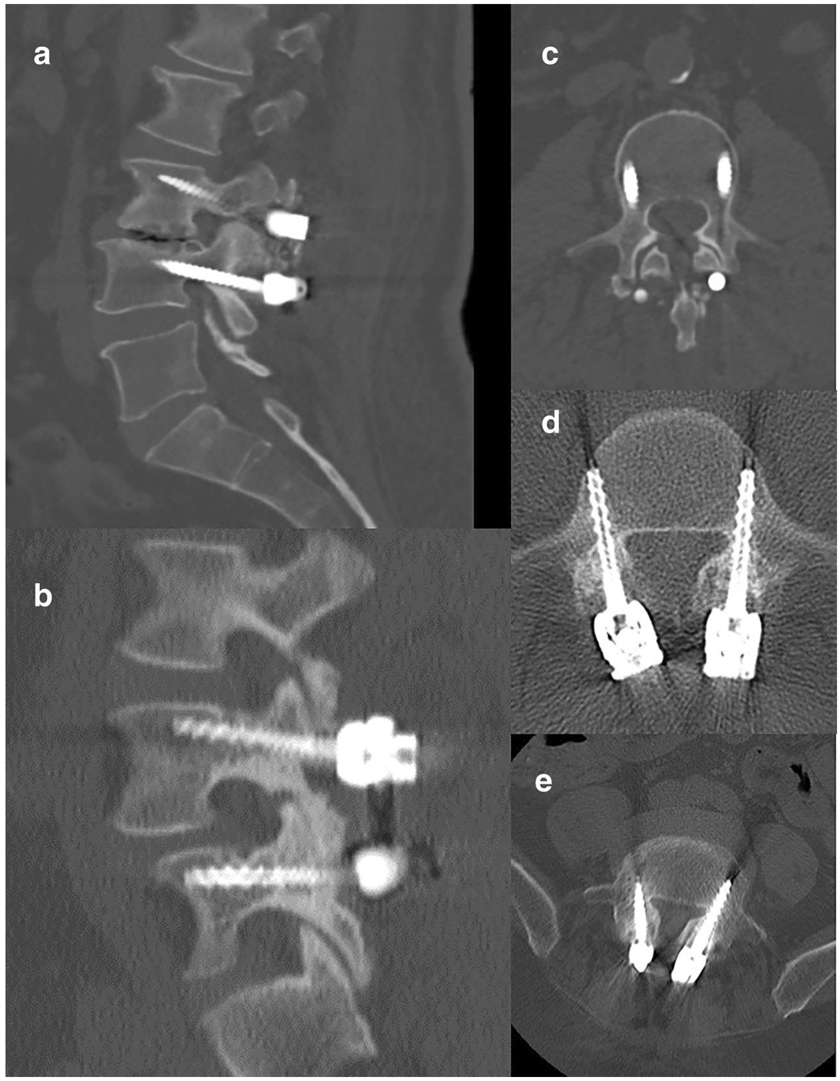

Fig. 5 Postoperative CT scan. **a** and **b** sagittal and **c**, **d**, and **e** axial views demonstrating correct positioning of CBT fixation technique

How to avoid complications

One of the main complications in relation to CBT is the high incidence of pedicle fracture, due to pedicle diameter which is described in 4% of patients, and could be as high as 8.3% [1]. To avoid this complication, after drilling, we recommend to use a tap with a diameter slightly smaller than the definitive screw reaching the full length of it. Also, screw breakage has been reported with screws' diameters smaller than 4.75 mm; therefore, we always use a diameter of 5.5 mm or bigger [1]. In this case, it would be also advisable to measure pedicle diameter in the preoperative CT scan before surgery to confirm that these screws could be inserted.

Specific perioperative considerations

In some cases, one of the complaints of patients is related to pain in the iliac crest in relation to fixation of the neuronavigation array system. Surgeons must be aware of this situation to avoid confusing it with a clinical worsening of the patient. This condition should be limited and improved with standard analgesia. As previously said, preoperatively, a CT scan is recommended to measure pedicle diameter and grade of osteoporosis.

Specific information to give to the patient about surgery and potential risks

Main considerations of this procedure are similar to pedicle screws. Some authors have described CBT as a minimally invasive technique [1, 2, 6], as smaller dissection and less muscle retraction are needed. Therefore, advantages in relation to less wound incision and shorter hospital length stay should be discussed. However, the patient should be informed that a higher risk of pedicle screw and a risk of iliac crest pain are a disadvantage related to this procedure.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Delgado-Fernandez J, García-Pallero MÁ, Blasco G, Pulido-Rivas P, Sola RG (2017) Review of cortical bone trajectory: evidence of a new technique. Asian Spine J. https://doi.org/10.4184/asj.2017.11.5.817
2. Hung C, Wu M, Hong R, Weng M, Yu G (2016) Comparison of multifidus muscle atrophy after posterior lumbar interbody fusion with conventional and cortical bone trajectory. Clin Neurol Neurosurg 145:41–45
3. Khanna N, Deol G, Poulter G, Ahuja A (2016) Medialized, muscle-splitting approach for posterior lumbar interbody fusion. Spine (Phila Pa 1976) 41(8):90–96
4. Matsukawa K, Yato Y, Imabayashi H, Hosogane N, Asazuma T, Chiba K (2016) Biomechanical evaluation of lumbar pedicle screws in spondylolytic vertebrae: comparison of fixation strength between the traditional trajectory and a cortical bone trajectory. J Neurosurg Spine 24(6):910–915
5. Matsukawa K, Yato Y, Kato T, Imabayashi H, Asazuma T, Nemoto K (2014) Cortical bone trajectory for lumbosacral fixation: penetrating S-1 endplate screw technique. J Neurosurg Pediatr 21(August):203–209
6. Ohkawa T, Iwatsuki K, Ohnishi Y, Ninomiya K (2015) Isthmus-guided cortical bone trajectory reduces postoperative increases in serum creatinine phosphokinase concentrations. Orthop Surg 7(3):232–238
7. Santoni BG, Hynes RA, McGilvray KC, Rodriguez-Canessa G, Lyons AS, Henson MAW, Womack WJ, Puttlitz CM (2009) Cortical bone trajectory for lumbar pedicle screws. Spine J 9(5):366–373
8. Sellin J, Raskin J, Staggers K, Brayton A, Briceño V, Moreno A, Jea A (2018) Feasibility and safety of using thoracic and lumbar cortical bone trajectory pedicle screws in spinal constructs in children: technical note. J Neurosurg Pediatr 21(2):190–196
9. Snyder LA, Martinez-Del-Campo E, Neal MT, Zaidi HA, Awad AW, Bina R, Ponce FA, Kaibara T, Chang SW (2016) Lumbar spinal fixation with cortical bone trajectory pedicle screws in 79 patients with degenerative disease: perioperative outcomes and complications. World Neurosurg 88:205–213
10. Wochna JC, Marciano R, Catanescu I, Katz J, Spalding MC (2018) Cortical trajectory pedicle screws for the fixation of traumatic thoracolumbar fractures. Cureus 10(6):e2891

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Affiliations

Juan Delgado-Fernández[1] • **Paloma Pulido Rivas**[2] • **Ricardo Gil-Simoes**[2] • **Rafael García de Sola**[3]

1 Division of Neurosurgery, Department of Surgery, University Hospital 12 de Octubre, Avda de Córdoba S/N, 28041 Madrid, Spain

2 Division of Neurosurgery, Department of Surgery, University Hospital La Princesa, Madrid, Spain

3 Director of UAM Chair "Innovation in Neurosurgery" Department of Neurosurgery, Hospital del Rosario, Universidad Autónoma de Madrid, Madrid, Spain