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Navigated Robotic Guidance for Minimally Invasive Bertolotti Resection: Technical Feasibility and Workflow Evaluation

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Research Article

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Navigated Robotic Guidance for Minimally Invasive Bertolotti Resection: Technical Feasibility and Workflow Evaluation

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Abstract

Bertolotti syndrome is characterized by symptomatic lumbosacral transitional vertebral anatomy in which an enlarged transverse process articulates or fuses with the sacrum or ilium. Diagnosis can be difficult because transitional anatomy is common, symptoms may overlap with other spinal disorders, and the pain generator may arise from the pseudoarticulation, adjacent disc or facet, instability, or nerve compression. When targeted nonoperative treatment fails, surgical options include resection, nerve decompression, or fusion depending on anatomy and the dominant pain mechanism. Published evidence supports image guidance for localization and confirmation of resection and describes early robotic assistance for trajectory and incision planning; however, evidence specific to robotic Bertolotti resection remains limited. This article evaluates the feasibility of a preoperatively planned, navigated robotic workflow for minimally invasive Bertolotti resection. A framework is presented for preoperative computed-tomography planning, convergent access through a minimally invasive incision, trajectory-controlled drilling of bone-cut trajectories across the transverse processes and pseudoarticulations, navigated osteotomy, fragment removal and verification of complete decompression or resection.

Feasibility was assessed by completion of planned robotic and navigated steps, intraoperative confirmation of registration and resection, and review of technical, perioperative, and imaging outcomes. These concepts may improve reproducibility and reduce challenges related to limited visualization and complex three-dimensional anatomy, but do not prove superior outcomes. This paper outlines a novel technique; however, further comparative studies using standardized measures of pain, disability, operative time, blood loss, radiation exposure, navigation accuracy, resection quality, and reoperation rate are needed before the clinical value of robotic guidance is established.

Key Words: Bertolotti Syndrome, Minimally Invasive Surgery (MIS), Robotic Guidance, Surgical Navigation, Castellvi Classification

Introduction

Bertolotti Syndrome (BS) is low back pain and/or nerve pain that is caused by a lumbosacral transitional vertebrae (LSTV) [1]. Transitional lumbosacral anatomy is very common and often asymptomatic. When symptoms related to LSTV are present, the most common type is pain around the sacroiliac joint, groin, and hip area [2]. Diagnosis can be difficult because transitional anatomy is common, symptoms may overlap with other spinal disorders, and the pain generator may arise from the pseudoarticulation, adjacent disc or facet degeneration, instability, or nerve compression. Bertolotti Syndrome is commonly overlooked when evaluating a patient's pain because back pain is widely prevalent and has many causes [3,4]. The reported prevalence of BS is 5 to 30% and the reported incidence is between 4 and 36% [2,5]. Previously, the Castellvi classification system, established in 1984, was used for LSTV identification and BS diagnosis. It assumed that pain was caused by disc degeneration at the transitional level rather than contact between transitional anatomy and sacral ala or the Ilium [6]. This system identified LSTVs by height measurement of the transverse process in the sagittal orientation for patients without a complete pseudoarticulation or presumed lateral intertransverse fusion and divides into seven categories. This system has become outdated as there are many patients with clear anomalies who do not fit into one of seven categories. The Jenkins classification subsequently improved on the prior Castellvi classification and better predicts optimal surgical procedures to treat Bertolotti syndrome [7]. This new system is based on the idea of a reduced space between the transverse process and sacral ala being the cause for BS pain, rather than disc degeneration alone. [6]

Symptomatic patients should be offered non-operative treatment and other less invasive treatments before they consider surgery. Conservative management for Bertolotti Syndrome includes pharmacologic therapy, activity and lifestyle modification, physical therapy, and

injections. Traditional injections with local anesthetics and steroids can be effective in relieving pain and confirming the diagnosis. More recently, radiofrequency ablation and regenerative medicine techniques have gained popularity as treatment options [2].

When targeted nonoperative treatment fails, surgical options include resection, nerve decompression, or fusion depending on anatomy and the dominant pain mechanism. The goal of resection surgery is to alleviate pain generated by mechanical stress at the articulation site between the spine and pelvis and may increase mobility. Bertolotti resection surgery outcomes are best in patients whose pain arises completely from LSTV articulation and should be recommended with caution in patients with co-existent pain from adjacent segment degeneration or other pathologies [2]. Fusion is the preferred alternative in the case of hypermobility and adjacent segment degeneration [8]. Open, tubular minimally invasive, endoscopic, and navigation-assisted resections have been described. Limited visualization in minimally invasive surgery makes incision placement, trajectory selection, registration accuracy, and confirmation of complete resection particularly important. Published evidence supports image guidance for localization and confirmation of resection and describes early robotic assistance for trajectory and incision planning; however, evidence specific to robotic Bertolotti resection remains limited.

An expanding body of literature suggests that robotic-guided spine surgery is associated with reduced implant-related complications, revision procedures, and intraoperative radiation exposure while maintaining a high degree of implant placement accuracy [9-12]. Given the potential advantages of combining robotic guidance and navigation with minimally invasive spine surgery, along with continued advancements in robotic software and instrumentation, the utilization of these technologies is likely to increase. The authors anticipate that future applications will continue to expand well beyond implant placement to more advanced bony procedures, including facet decortication, osteotomies, and robot-assisted spinal decompression.

Modern navigated-robotic guidance integrates three-dimensional (3D) preoperative planning software with intraoperative robotic guidance and navigation and has been shown to provide accuracy and efficacy for minimally invasive pedicle and cortical screw placement across multiple studies. Recent software evolution has expanded surgical planning capabilities beyond

implant placement and permits the use of multiple diameter (3mm and 7.5mm) high-speed burrs for bone cannulation and trajectory preparation, as well bone cutting and decortication. In addition to trajectory planning, the software facilitates optimization of skin incision and trajectory alignment as well as implant size and location alignment

This original article evaluates the technical feasibility and workflow of a preoperatively planned, navigated robotic workflow to perform minimally invasive Bertolotti resection. A technical framework is presented for preoperative computerized computed-tomography planning, convergent access through a minimally invasive incision, trajectory-controlled drilling of bone-cut trajectories across the transverse processes and pseudoarticulations, navigated osteotomy, fragment removal and verification of complete decompression or resection. Feasibility was assessed by completion of the planned robotic and navigated steps, intraoperative confirmation of registration and resection, and review of technical, perioperative, and imaging outcomes. These concepts may improve reproducibility and reduce the challenges related to limited visualization and complex three-dimensional anatomy, but they should not be interpreted as proof of superior outcomes. This initial paper outlines a novel technique, however; further comparative studies using standardized measures of pain, disability, operative time, blood loss, radiation exposure, navigation accuracy, resection quality, and reoperation are needed before the clinical value of robotic guidance can be established.

Materials and Methods

Study Design and Ethics

This was a technical-feasibility evaluation of a surgeon-developed navigated robotic workflow used during a bilateral minimally invasive Bertolotti resection. The primary aim was to describe how the planned workflow could be executed through the minimally invasive corridors while maintaining registration and confirming completion of the targeted bone removal. The clinical application was not designed or powered to compare outcomes with another technique.

Institutional Review Board (IRB) approval was not required for this manuscript because it describes a surgical technique and does not constitute human subject research or include patient specific or identifiable data

Clinical Selection and Technical Measures

The workflow was applied after diagnostic evaluation localized symptoms to bilateral lumbosacral pseudoarticulations and targeted injection produced substantial temporary relief. Preoperative radiographs, computed tomography (CT), and magnetic resonance imaging were reviewed to define osseous anatomy and competing pain generators. The operative record, planning images, intraoperative imaging, postoperative imaging, and follow-up documentation were reviewed.

Preoperative Surgical Planning

Precise surgical planning for minimally invasive spine surgery can be made using segmental planning software prior to surgery using high resolution 3D computed tomography (CT scan) images or during surgery using a three-dimensional scan. The authors' preferred workflow is to use preoperative CT images to plan most spine surgeries, which allows more time for thought and strategic planning before the start of the surgery or anesthesia. The authors strongly advocate for preoperative CT-based planning in lumbopelvic procedures such as Bertolotti

resection, sacroiliac joint fusion, and pelvic osteotomy as these procedures may require more complex and time-intensive surgical planning and the higher-resolution images provided by preoperative CT may offer greater detail for trajectory and resection planning than intraoperative three-dimensional imaging (Figure 1).

The first step in planning a robotically guided minimally invasive Bertolotti resection is to define the bone cuts required to release the transverse process. Each cut can be planned at the segmental level, with each trajectory carefully adjusted to minimize the required skin incision. The goal is to complete all cuts necessary to release the Bertolotti articulation through the smallest practical exposure, ideally using a 3–4 cm muscle-splitting incision, depending on the angles required to achieve the desired osseous trajectories. In this case, bilateral resections were planned (Figure 2).

In addition to planning bone-cutting trajectories across the transverse process with the robotic burr, trajectories are also planned across the pseudoarticulation where the transverse process joins the sacrum and/or pelvis. The software allows for the use of different burr sizes and cutting trajectories. Available options include a 3-mm high-speed end-cutting burr, traditionally used for pedicle screw preparation, and a 7.5-mm burr, traditionally used for facet decortication. In this case, the authors selected the larger-diameter burr for all planned cuts; however, multiple smaller trajectories may also be used when greater precision or more angular resection is required. Trajectories can be planned in multiple orientations according to the patient's specific anatomy and the surgeon's preference. It is the authors recommendation to plan all bone cutting trajectories to stop 2 mm before the deep cortical margin and to then use robotic-guided / navigated osteotome to release the ventral cortical bone edge to minimize risk of soft tissue damage or entanglement at the deep edge of the burr cut. The depth of the bone cuts can vary depending on patient anatomy, but the cut is always stopped at least 2 mm away from the deep cortical margin and soft tissues beyond.

It is the authors' preferred technique to initially plan multiple trajectories across both the transverse process and the pseudoarticulation with the sacrum and/or pelvis, then closely evaluate each trajectory at the skin level. The trajectories can subsequently be refined to optimize both the location of the planned bone cuts and the corresponding skin incision. These same planned trajectories may also be used intraoperatively to guide the robotic/navigation probe, osteotome, curette, and other surgical instruments.

Intraoperative Technique

Overview

Robotic operating room setup, robotic system bed mounting, robotic arm positioning, and CT-to-fluoroscopy registration have all been described in detail in the literature. It is the authors' strong opinion that best practice in any robotic guided minimally invasive procedures is to address the most mobile and distal segment from the bone or navigation mount first and work from the most mobile segment of the spine toward the least mobile segment of the spine in order to decrease chances for bone shift, skive, and potential inaccuracy.

Skin Incision

The robotic arm is sent to a central trajectory on each side, and the skin is marked to determine the location of the skin incision. If necessary, the robotic arm can be sent to each of the different trajectories to align the trajectories to make sure one incision will work for all the necessary trajectories. A traditional skin incision is made, and then the robotic-guided scalpel is used to perform the muscle splitting dissection down to the level of the bone. The robotic-guided \ navigated dilator is then advanced close to, but without contacting, the bony anatomy. Care is taken to avoid applying excessive pressure against the bone, which could cause spinal movement or instrument skiving.

Bone Cutting

To accomplish the bone cuts, the robotic guided scalpel is placed down to bone along each of the preplanned bone cutting trajectories. It is the authors' preference to perform bone cuts along the pseudoarticulation with the sacral ala and/or the ileum first and then to perform the bone cuts along the transverse process to keep the resection fragment stable as long as possible. It is the author’s experience that there is a clear tactile sensation of cutting across the pseudo capsule and cartilaginous surface of the articulation. For each trajectory, there is a palpable feeling as the dilator or drill touches the bone and this sensation should correlate perfectly with the navigation screen, which verifies visually that the tool is touching the bone at the same instant. The surgeon independently verifies the tool, touching the bone vision, tactically, and visually on the screen. If

at any point, the visual does not line up with the tactile feedback, abort the bone cutting, and consider re-registration.

The navigated drill is activated 1–2 mm above the bone and then advanced with light pressure to the planned depth, as visualized on the navigation screen. The authors strongly recommend stopping all bone cuts at least 2 mm short of the deep cortical margin to minimize the risk of the high-speed burr contacting the soft tissues within the pelvis. This illustrates one of the many benefits of the navigation software, which enables precise preoperative planning of the intended cuts. Drill position and depth should always be confirmed using navigation; intraoperative fluoroscopy may also be used for additional confirmation if desired.

Bone cuts across the pseudoarticulation are performed first, followed by cuts through the transverse process (Figure 3). A robotic-guided / navigated osteotome is then advanced along the same trajectory as each transverse process cut. Gentle taps with a mallet are used to safely complete the osteotomy along each planned trajectory. Once the final bone cut is completed, the transverse process and Bertolotti fragment should be mobile, with only the ventral soft-tissue attachments remaining. A navigated probe (“chicken foot”) can be used to confirm the location of all bone cuts and verify, both visually and tactilely, that the ventral bony cortex has been sufficiently released. This allows the surgeon to outline the entire bone cut and visualize, from the navigation perspective, that the entire fragment of bone that has been released. Finally, a navigated angled curette can be inserted using robotic guidance or freehand to dissect around the ventral edge of the bony articulation, “hook” the fragment, and remove it either in one piece or in a morselized fashion (Figure 4). In the authors' experience, releasing the pseudoarticulation with a robotic-guided drill increases the likelihood of achieving a clear resection margin. Alternatively, the robotic drill may be used to cut across the transverse process, followed by curettes and other instruments to remove articulation. However, because the articulation is firmly fixed against the sacral ala, this approach often results in multiple fragments. Morcellation may increase the risk of retaining a bone fragment, which could contribute to residual symptoms.

Once the Bertolotti fragment has been removed in its entirety, a navigated probe is used to examine the entire area of the resection, verifying all bone removal and a clean margin on the edge of the sacral ala and ilium without a residual pseudoarticulation.

Once complete bone resection has been achieved, final fluoroscopic images are obtained to confirm the surgical resection margins. The authors also strongly prefer to obtain three-dimensional imaging at this stage for additional confirmation of complete resection and no residual articulation.

The authors recommend leaving the robotic system attached and registered during three-dimensional imaging. If any residual fragments are identified or additional surgical objectives remain, the robotic navigation system can then be used to further refine the resection as needed. Figure 5 shows intra-operative imaging confirming the resection margins and post-operative x-rays confirmed alignment and improved range of motion of the arthroplasty at that level.

Use of Artificial Intelligence Tools

A large language model (OpenAI ChatGPT) was used to assist with manuscript editing and review of journal formatting requirements. It was not used for manuscript writing or to create or alter patient data, images, operative measurements, or study results. The authors are responsible for verifying every reference, all scientific and clinical statements, the accuracy of the reported data, and the final manuscript.

Discussion

Bertolotti syndrome is a lumbosacral disorder characterized by abnormal morphology or enlargement of the most caudal lumbar transverse process, resulting in articulation or fusion with the sacrum and/or ilium and associated pain. General anomalies in this region are quite common and are frequently asymptomatic. Bertolotti syndrome refers to the presence of this anomaly in a patient with associated symptoms, including back, buttock, and/or leg pain. Confirming that the pseudoarticulation is the source of the patient's symptoms is critical, as other regional conditions-including disc degeneration, adjacent-segment degeneration, instability, facet pathology, and stenosis- may produce overlapping symptoms. In addition to a thorough history and physical examination, advanced imaging- including X-ray, CT, and MRI- are obtained in most cases. In the authors' opinion, confirming symptom relief following a diagnostic local

anesthetic injection into the Bertolotti articulation is highly beneficial. Additionally, consideration should be made for lumbar discography, diagnostic sacroiliac arthrogram, or diagnostic facet block if pathology in those areas is identified or suspected. If concomitant symptomatic disc degeneration, adjacent-segment degeneration, or facet pathology is confirmed, surgical fusion should be considered instead of resection of the Bertolotti articulation. Additionally, in patients with confirmed discogenic pain at the level of the Bertolotti joint, resection should be approached with caution, as restoring motion to the affected segment could worsen symptoms and necessitate additional surgery.

For patients with confirmed symptomatic Bertolotti syndrome in the absence of pain attributable to instability, discogenic pathology, adjacent-segment disease, or facet pathology, L5 transverse processectomy, or "Bertolotti resection," may be an effective surgical treatment. The procedure can be performed through a traditional open approach, a navigated mini-open approach, or a minimally invasive tubular approach. In the tubular technique, sequential dilators are advanced through a small incision to progressively establish a working corridor while minimizing disruption of the surrounding soft tissues. Minimally invasive approaches for spinal surgery have the potential to decrease short and long-term complications compared to traditional open techniques and may also minimize blood loss, anesthesia time, postoperative pain level, narcotic use, length of hospitalization and recovery time. O'Toole et al. found that minimally invasive spine surgery may reduce wound infection rates as much as 10-fold when compared with open spine surgery and McAfee et al. also compared MIS versus open spine surgery and found lower rates of infection with MIS [13,14]. In a further comparison, Banczerowski et al. described lower rates of complications and improved cosmetic outcome with MIS [15,16]. The addition of navigation guidance to MIS Bertolotti resection has also become increasingly common and may offer several potential advantages, including smaller incisions, improved surgical accuracy and safety, and potentially more complete resection of the Bertolotti fragment. While MIS has many potential benefits, it is critical not to jeopardize thorough resection of the abnormal bone articulation given the decrease in direct surgical visualization.

When minimally invasive techniques are utilized, optimization of surgical trajectories, skin incision, and retractor replacement are of paramount importance. With standard navigation, one

common workflow is to use fluoroscopy to localize the affected area and guide incision placement and surgical exposure. Once exposure is completed, a navigation reference frame is attached, and an intraoperative three-dimensional scan is obtained to enable image-guided navigation. This workflow reduces the risk of spinal shift compromising navigation accuracy during exposure; however, it requires the initial incision and surgical exposure to be performed without the benefit of three-dimensional navigational guidance or precise trajectories needed for the purpose of resection. An alternative workflow involves placement of the three-dimensional navigation reference frame and acquisition of a three-dimensional scan before the incision is made. This approach allows the navigation data to be used for skin-incision planning and trajectory selection; however, subsequent surgical exposure and muscular retraction may introduce spinal movement that could compromise navigation accuracy. Prior to the use of a combined robotic-navigation system, the authors preferred to place the navigation reference frame and obtain three-dimensional imaging before surgical exposure. This approach allowed optimization of skin-incision placement and planning of the ideal surgical trajectories before exposure, thereby reducing the risk of creating an incision that could limit access or make the necessary trajectories difficult to achieve.

The addition of robotic guidance to surgical procedures has a number of potential benefits. In the multicenter prospective comparative MIS refresh study, Good et al. showed that minimally invasive robotic guided surgery had 5.8 times fewer surgical complications and 11 times fewer revision surgeries compared to traditional MIS fluoroscopic-guided techniques [9]. The study also showed a reduction of intraoperative exposure by 80% with robotic guidance compared to fluoroscopy.

While potential disadvantages of advanced surgical technologies like navigation and robotic guidance include increased cost and limited widespread availability, it is the author's opinion that the improvements in accuracy, safety, and overall surgical quality support the use of these technologies when available. To the author's knowledge, this current case report represents the first description of a fully executed navigated robot-guided Bertolotti joint resection. A key advantage of this technique is the ability to perform computerized preoperative surgical planning using three-dimensional CT imaging to define optimal bone-cut locations, surgical trajectories, and the desired extent of resection. Preplanned trajectories may also facilitate optimization of

incision placement and minimize the required skin incision. It is the author's opinion that this level of preoperative planning offers advantages beyond the intraoperative use of navigation alone, particularly when navigation is obtained before skin incision.

The importance of precise retractor placement for tubular MIS spine surgery is well documented, and this holds true for Bertolotti resection as divergent trajectories may be needed to cut across the transverse process and the articulation with the sacrum/pelvis and to dissect the fragment free [17]. Oh et al. previously described the use of robotic guidance for tubular retractor placement during Bertolotti resection [18]. In this report, the authors used a robotic system to plan a robotic trajectory to the Bertolotti articulation and to guide placement of the tubular retractor. In this report, the tubular retractor was then secured to the operating table using a standard bed-mounted attachment and the actual resection procedure was performed using standard handheld navigation instruments, including a navigated burr and navigated pointer. While this early description demonstrates the potential benefits of preoperative surgical planning for optimizing incision placement and retractor positioning, the actual resection of the Bertolotti articulation was performed using standard navigated instruments without robotic involvement in the bone cuts, dissection or fragment excision.

The current report is the first description of a fully robotic-guided Bertolotti resection in which the robotic system was used not only for incision planning and retractor placement, but also for planning and executing the bone cuts and removing the Bertolotti fragment. Robotic-guided bone cuts were executed using the 7.5 mm robotic bone cutting bur and robot-guided osteotome, resulting in an entirely robot-guided surgical procedure. We believe this evolution offers even greater promise by enabling precise preoperative planning and execution of the entire surgical resection. It is the author's opinion that it is ideal for all bone cuts to be planned before any cuts are performed and that performing the cuts across the articulation with sacrum and/or ilium may facilitate a more complete resection of the Bertolotti fragment and reduce the risk of retained bone when compared to cutting only the transverse process and then pulling on the cut end to remove the distal fragment without direct release of its articulation with the sacrum and/or ilium.

Conclusion

This paper describes the feasibility and workflow of preoperative planning and intraoperative execution for a novel minimally invasive navigated robot-guided Bertolotti resection technique. To the authors' knowledge, this is the first report of a fully robotic procedure completing all major operative steps, including planning, skin incision, surgical exposure, bone cuts, osteotomy across the Bertolotti articulation, and removal of the resected fragment. This technique further expands the indications for navigated robotic procedures and represents one of the first examples of a spine surgical procedure in which the robotic arm is utilized throughout all critical steps of the operation, not just for implant placement. This approach represents another step in the evolution of robotic spine surgery toward a future in which robotic systems may be used throughout the entirety of a spinal procedure, extending well beyond their traditional role in implant placement.

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Figures:

Fig 1. Pre-operative images showing bilateral Bertolotti's articulations at L5/S1. (A) AP x-ray view with Bertolotti's articulation (white line / arrow). (B) Coronal CT showing Bertolotti's articulation. (C) Axial CT scan. (D) Coronal MRI demonstrating L5/S1 articulation.

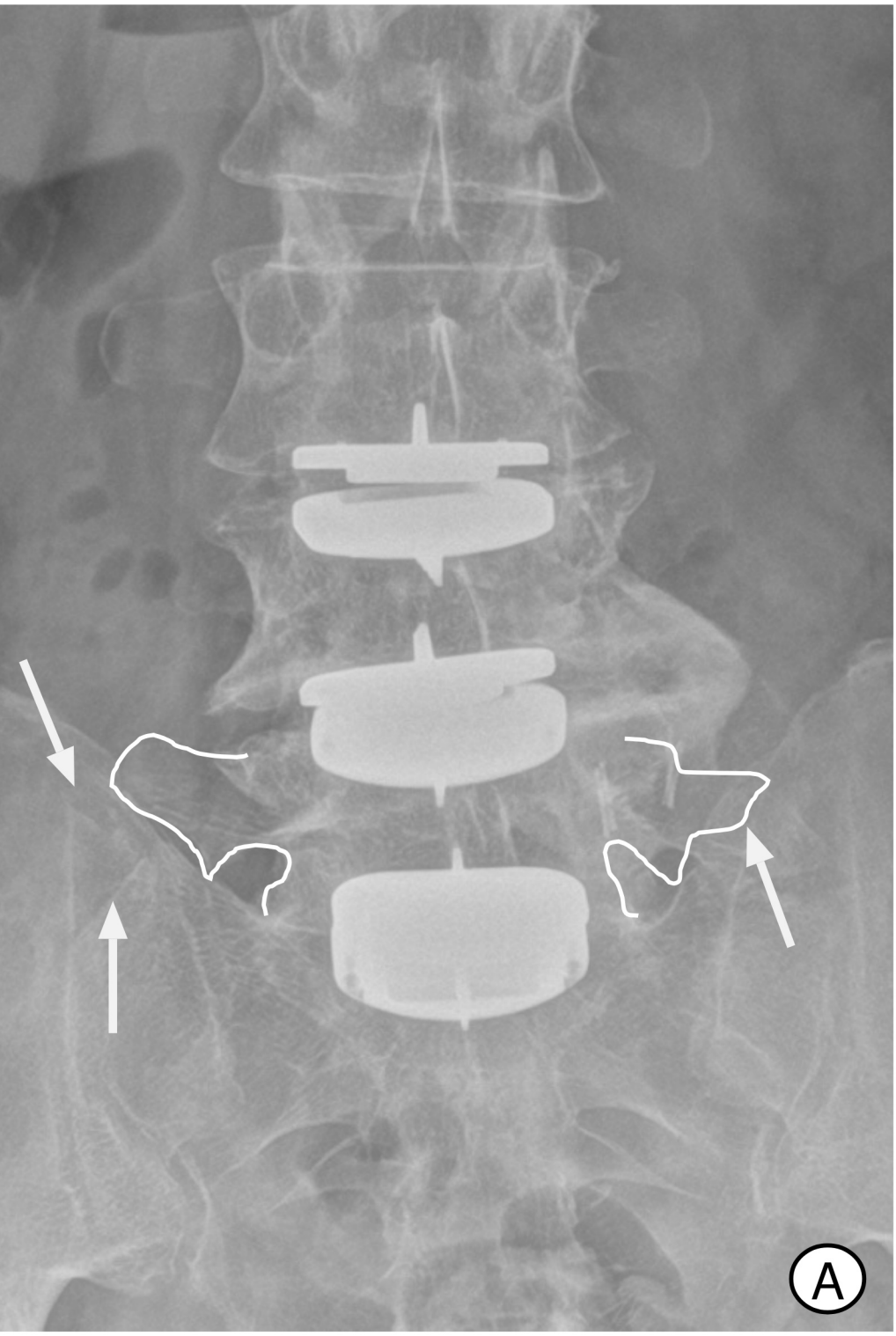
Fig 2. Pre-operative robotic surgical CT plan. (A) Coronal and (B) Axial view showing planned 7.5mm bone cut trajectories across the transverse process. (C) Coronal and Sagittal CT plan showing stacked bone cut trajectories. (D) Coronal and Sagittal CT plan showing resultant skin convergence for incision planning.

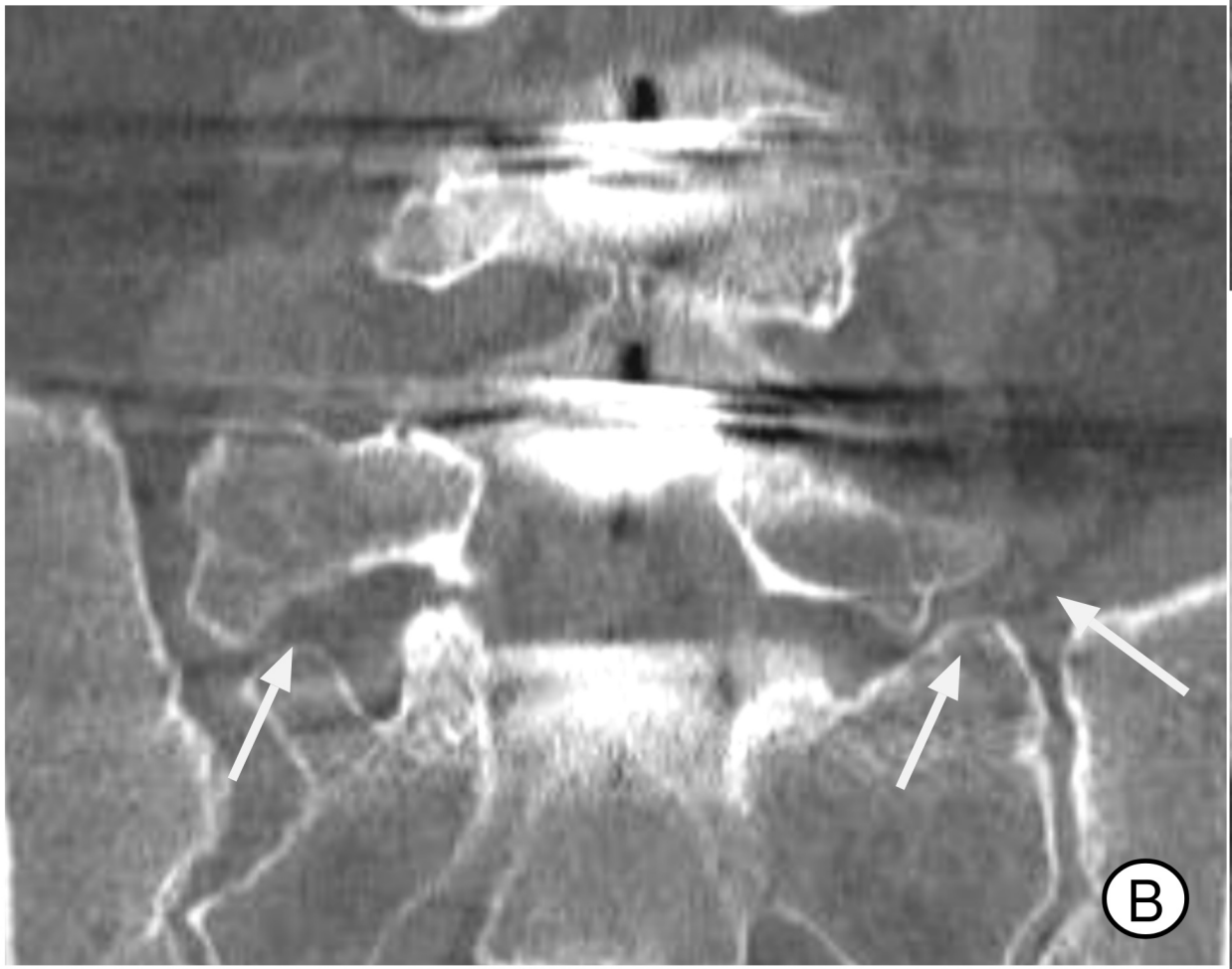
Fig 3. Axial and Sagittal Intra-operative navigation views showing planned bone cut and robot guided burr (A) before cut and (B) final depth of cut. Notice planned trajectory does not violate

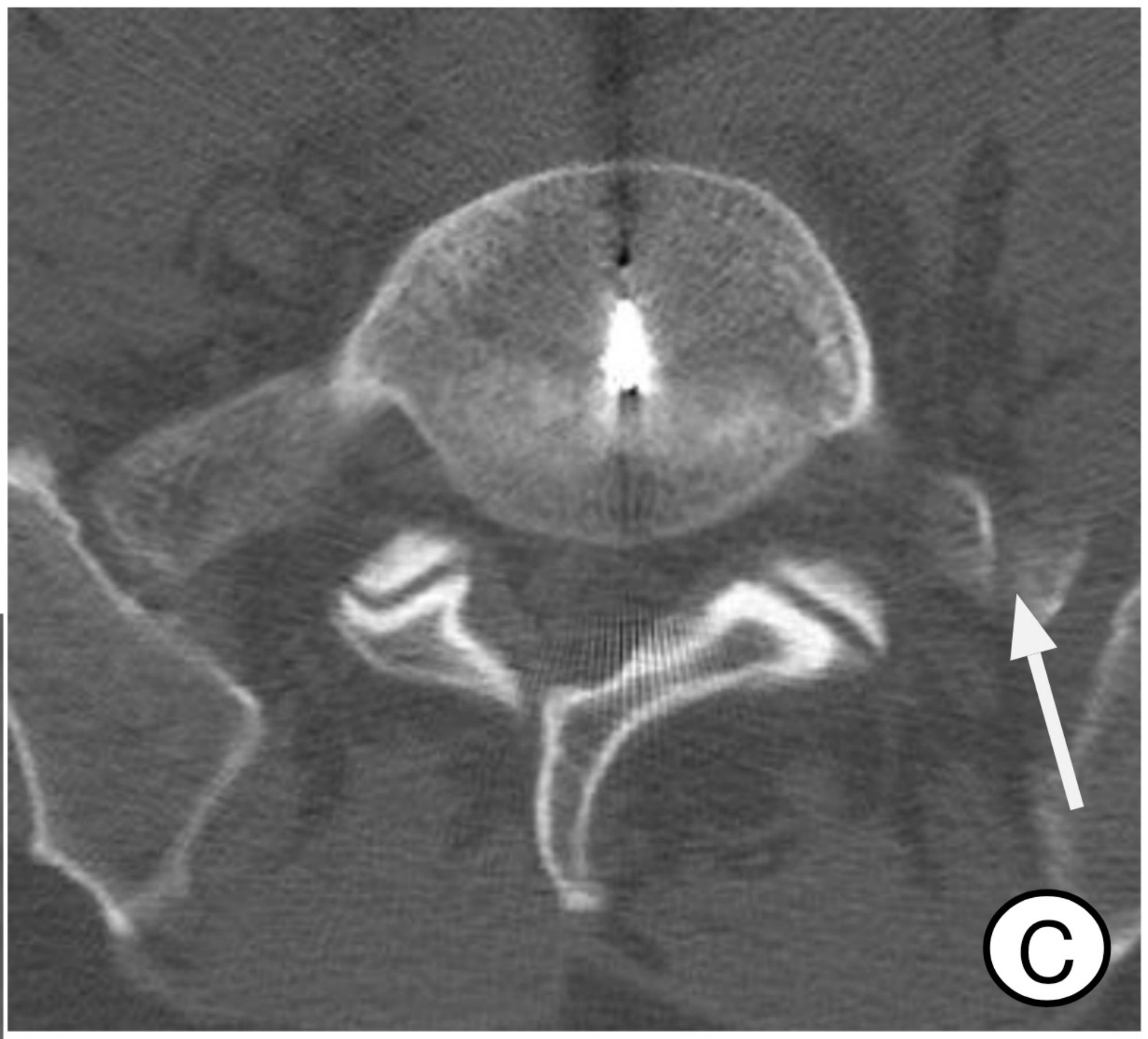
ventral bone cortex. (C) Intra-operative photo showing MIS tubular placement and robotic arm holding bone cutting burr with navigation frame attached.

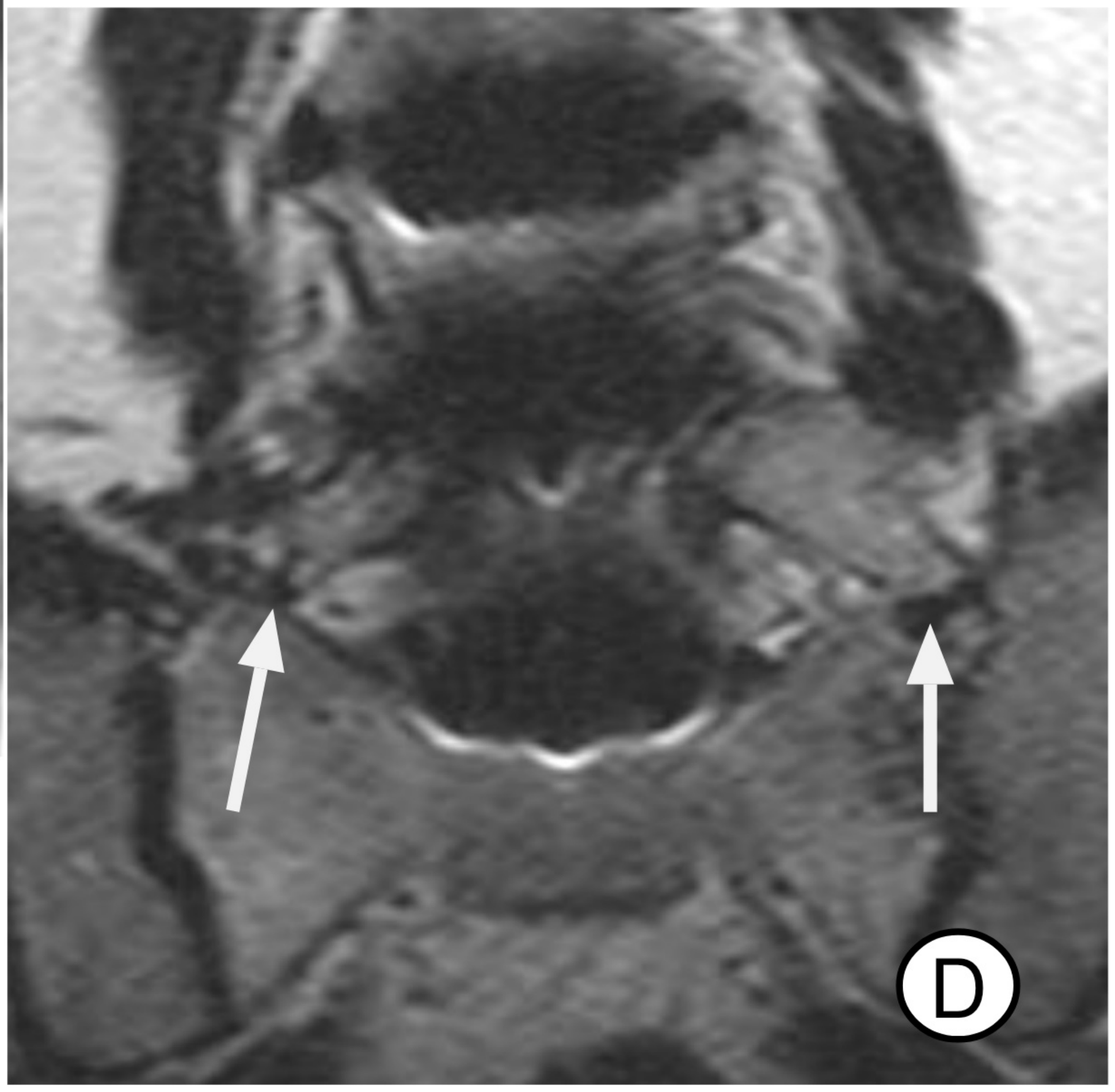
Fig 4. (A) Axial and Sagittal intra-operative navigation views showing final bone cut with robot guided osteotome. (B) Intra-operative photo showing MIS tubular placement and robotic arm holding osteotome with navigation frame attached. (C) Axial intra-operative navigation views showing curette to remove resected bone fragment (D) Final bone fragments resected from right and left side. (E) Axial and Sagittal intra-operative navigation views showing navigation probe outlining area of bone removal after resection to verify full resection.

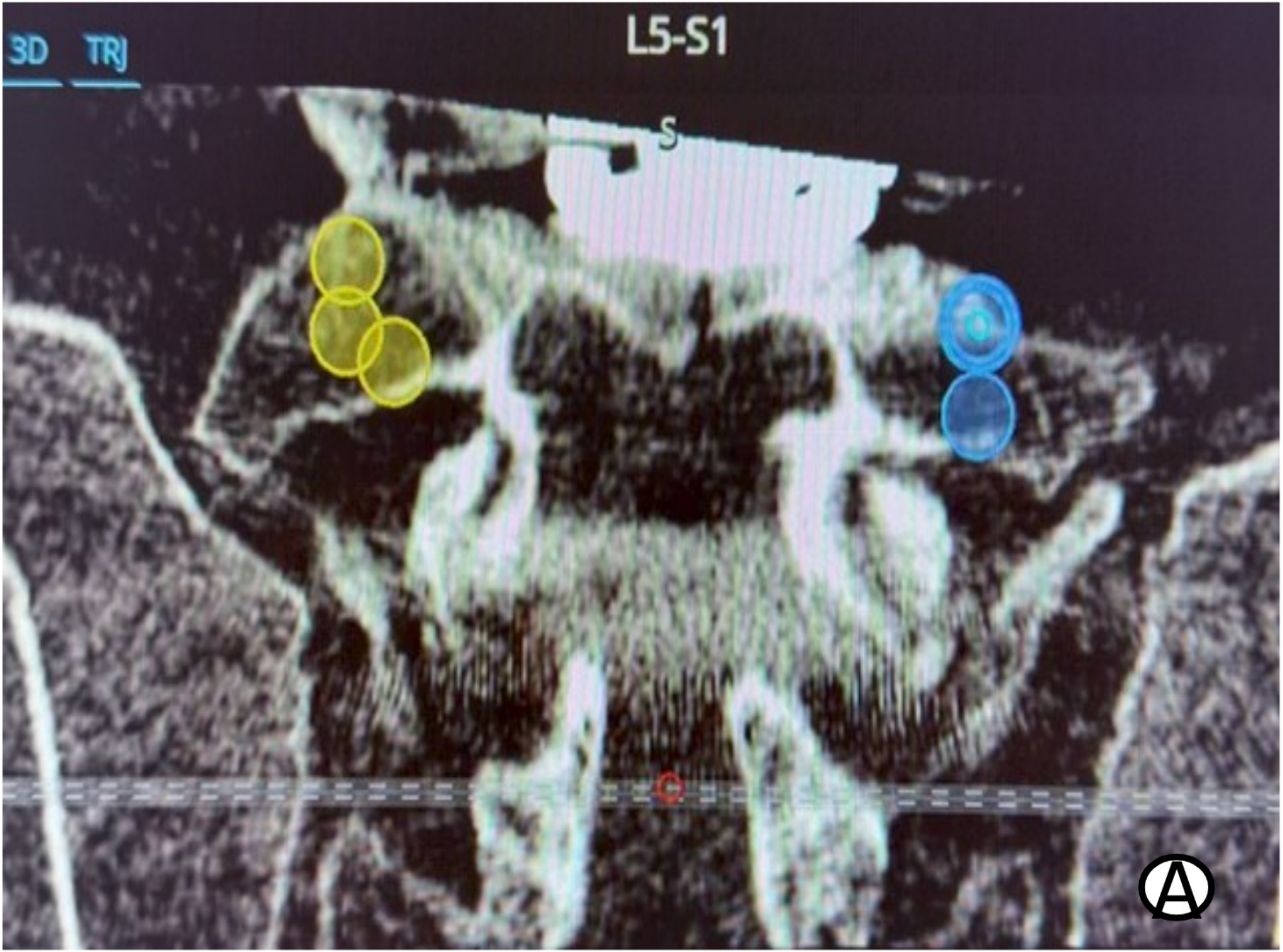
Fig 5. Post-operative images after complete resection. (A) Ferguson x-ray and (B) Axial CT showing complete resection of transverse process at L5 bilateral (arrows). (C) Pre-operative coronal CT to compare with (D) Post-operative coronal CT demonstrating complete resection of Bertolotti's fragment bilateral.

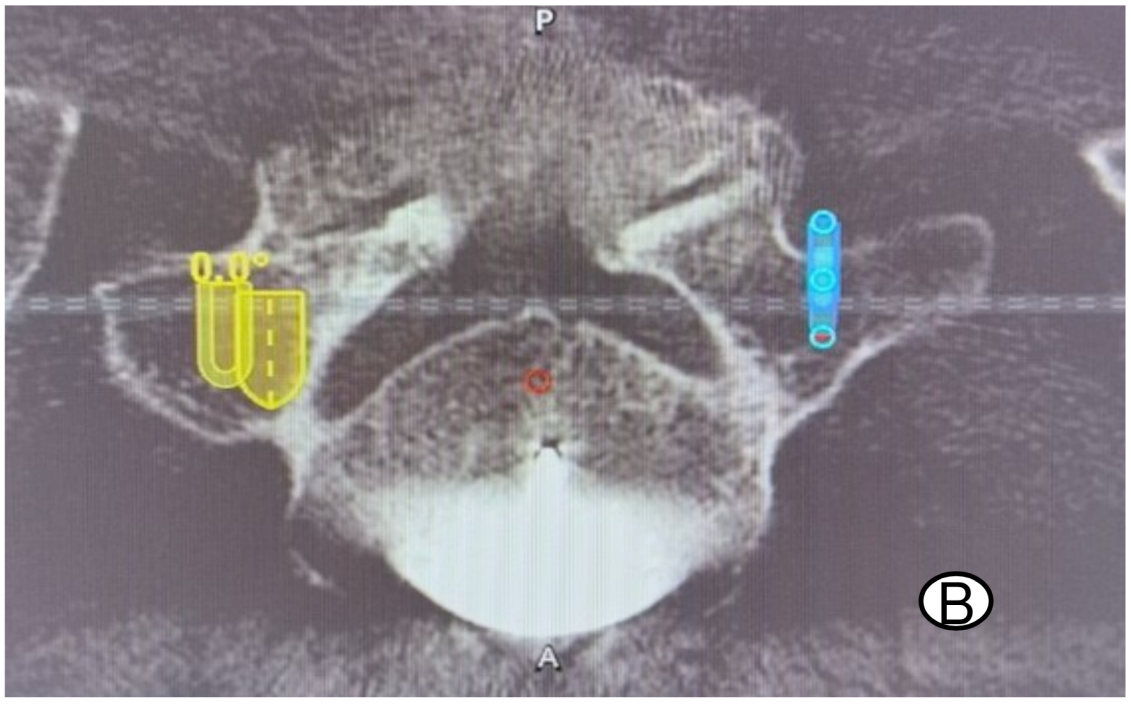

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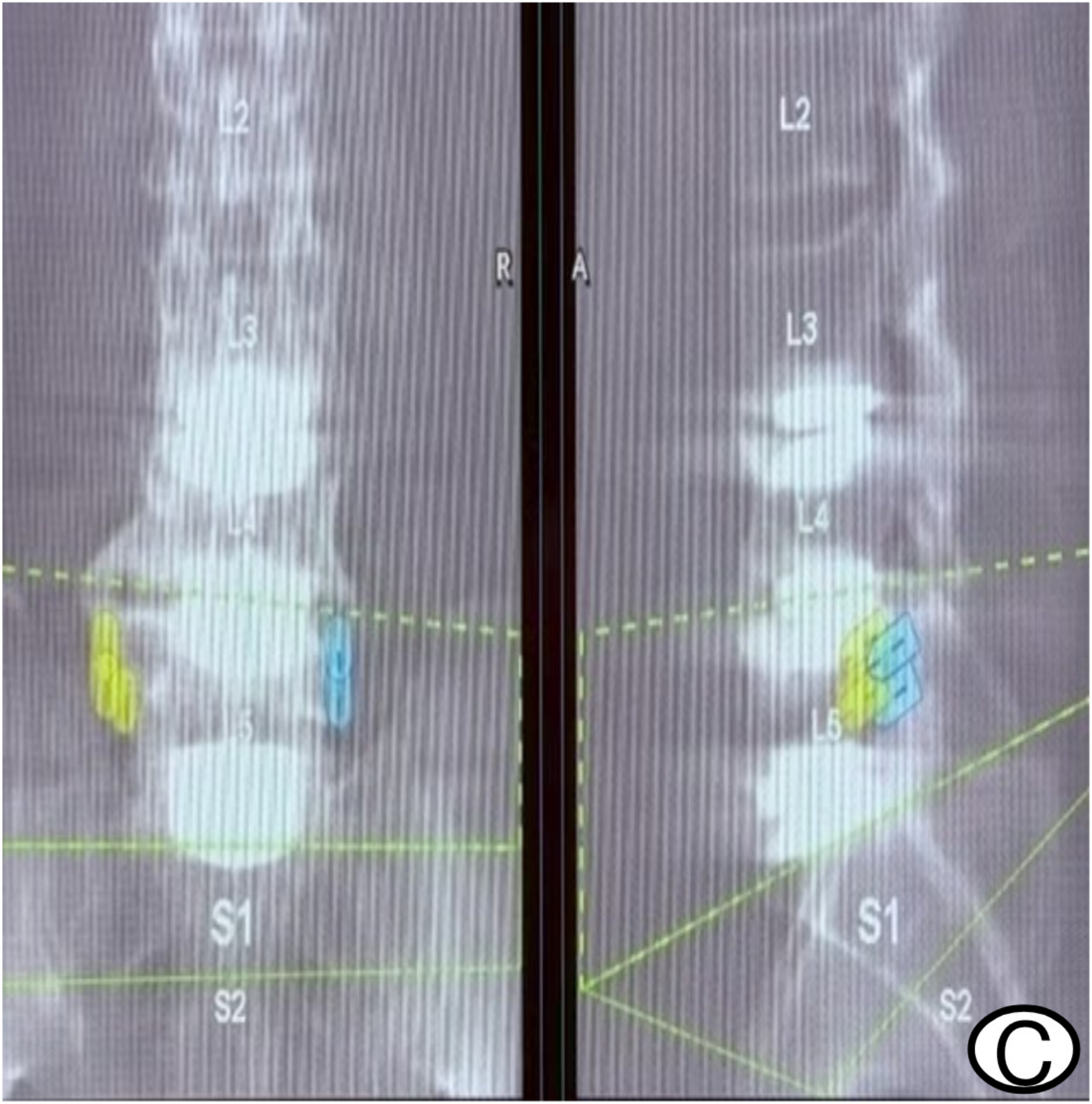

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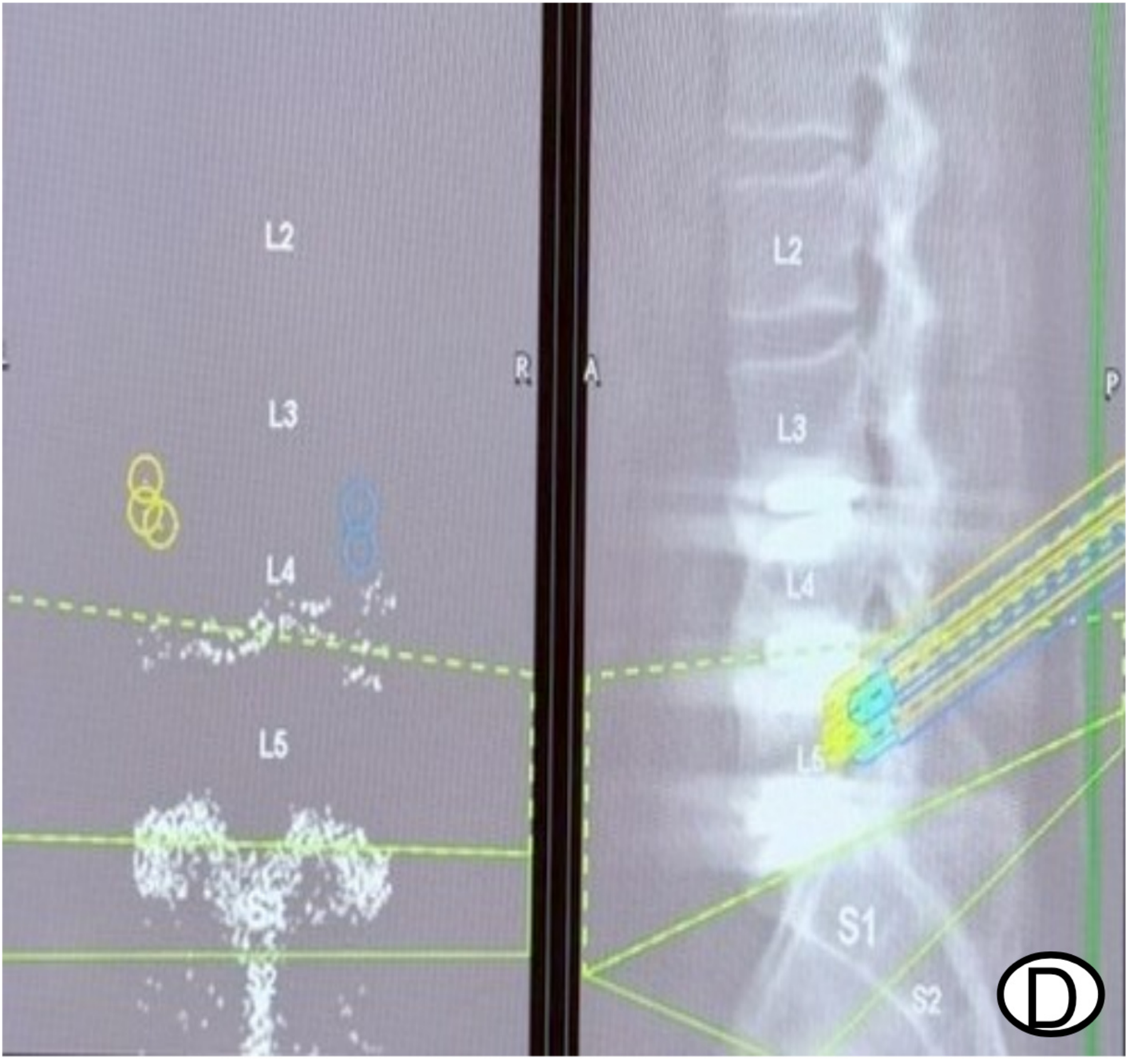

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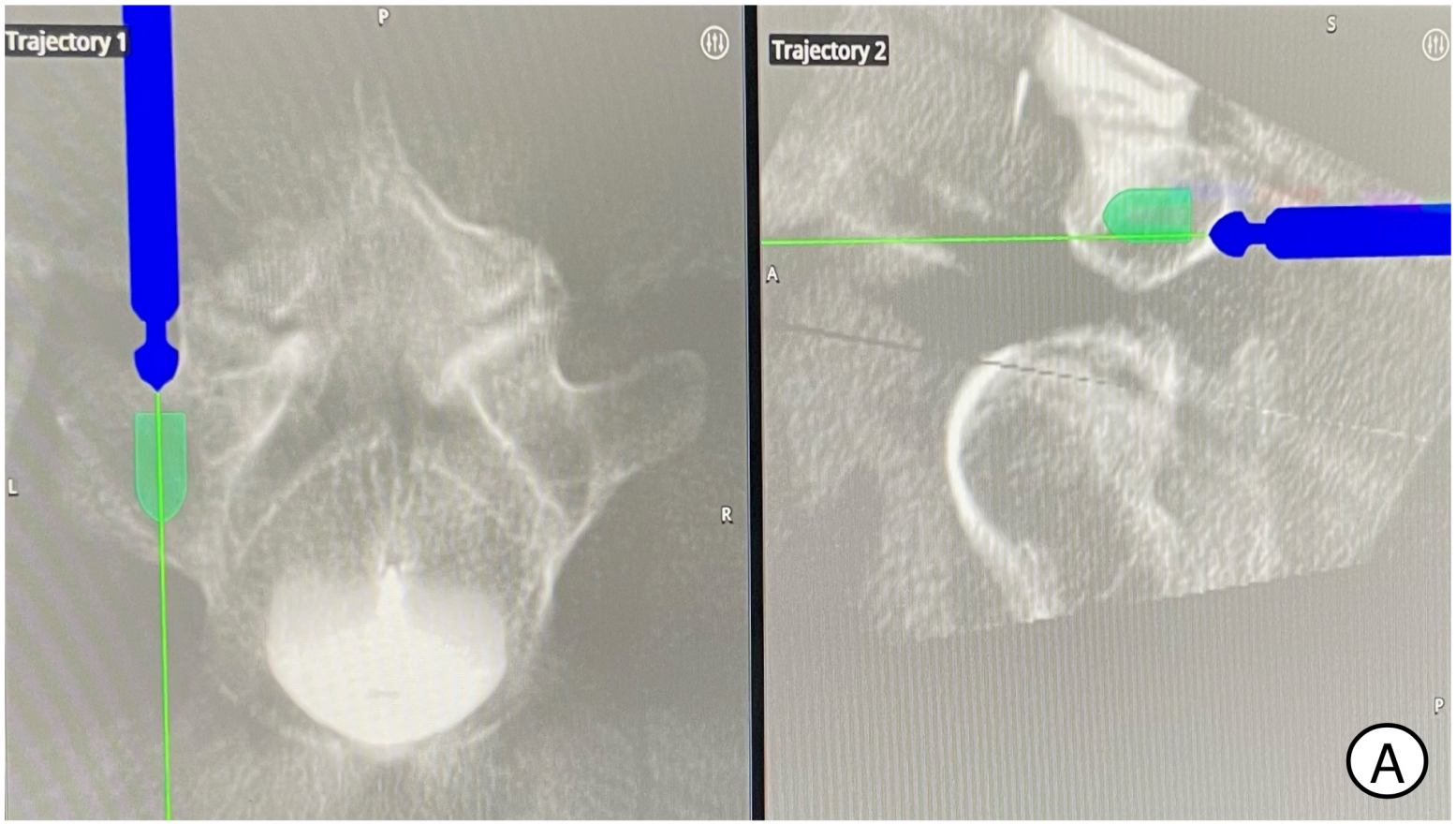

D

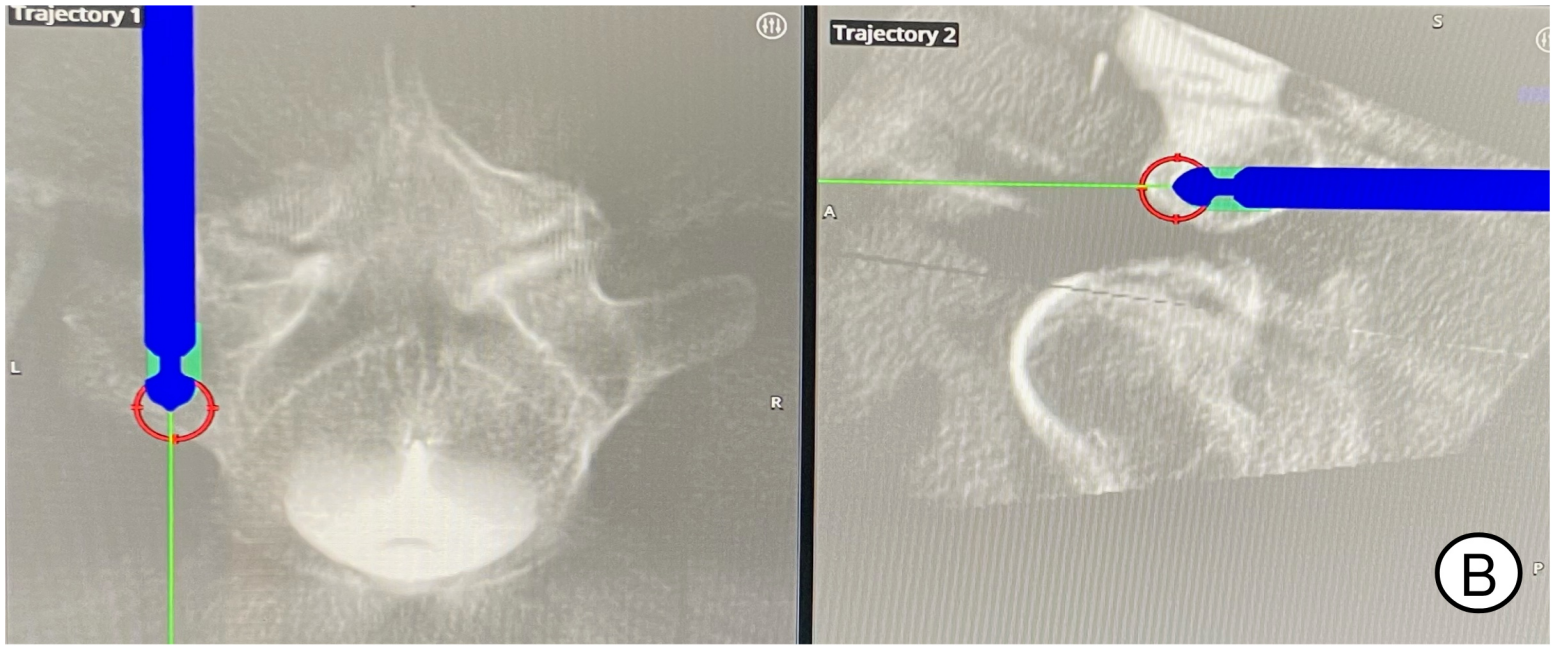

3D
TRJ
L5-S1
S


P
0.0°
A
B

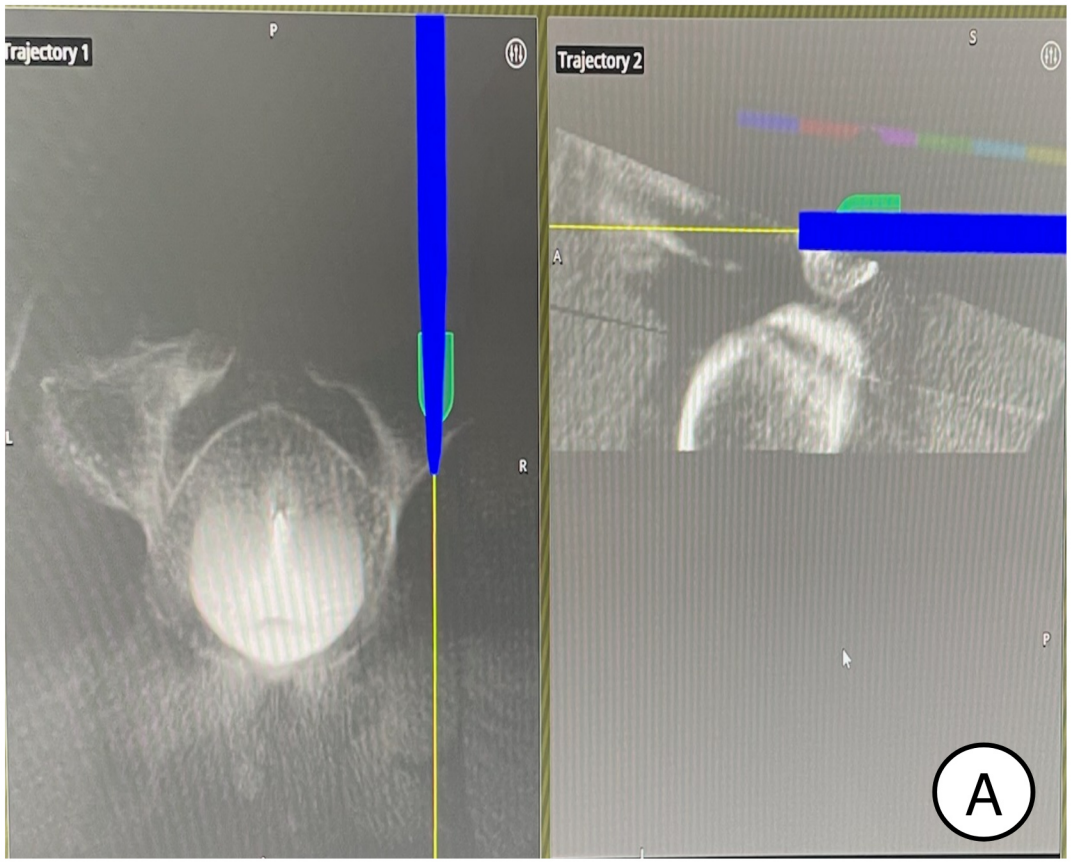

L2
L3
L4
L5
S1
S2
R
A
L2
L3
L4
L5
S1
S2

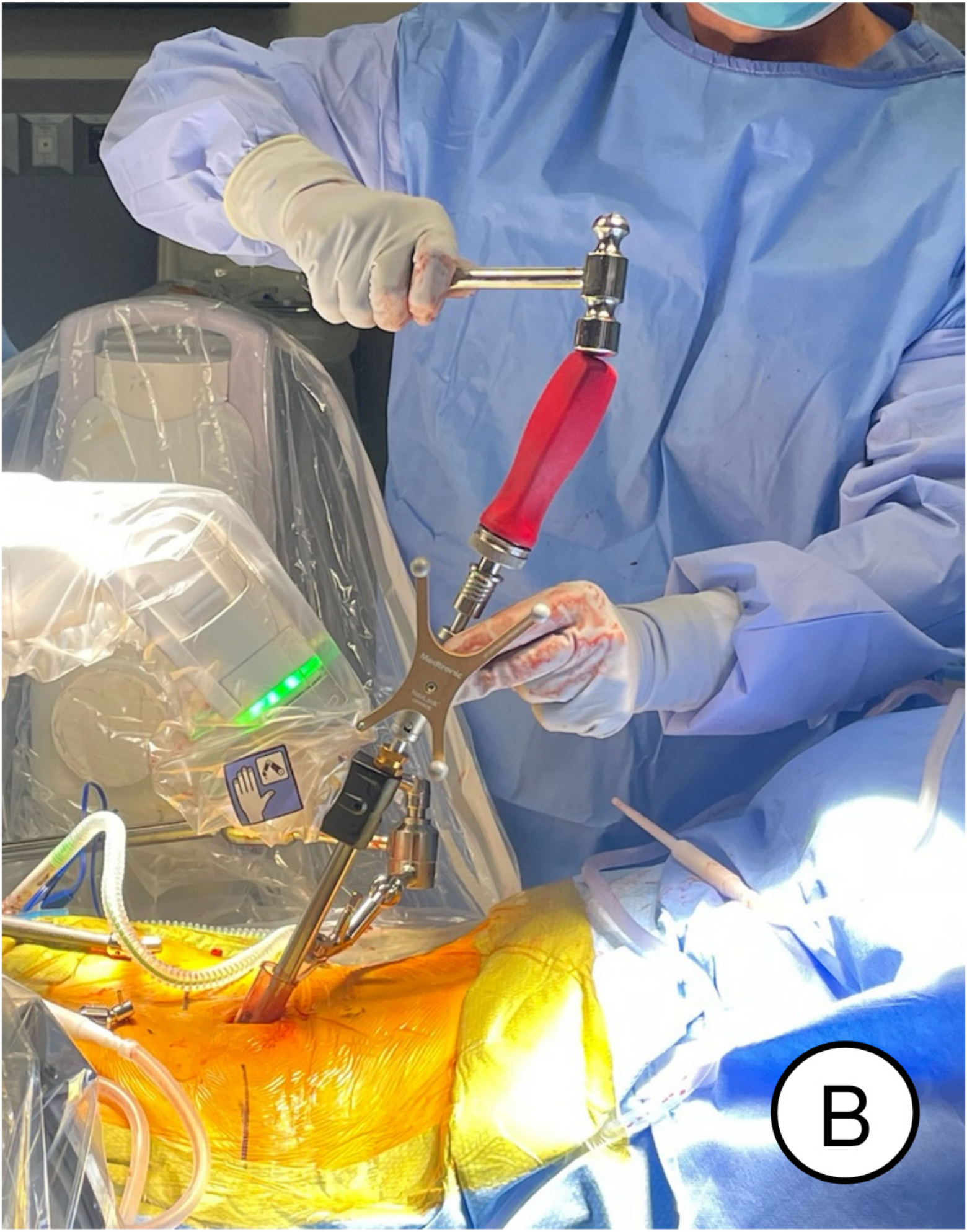

L2
L3
L4
L5
S1
S2
R
A
P
L2
L3
L4
L5
S1
S2
D

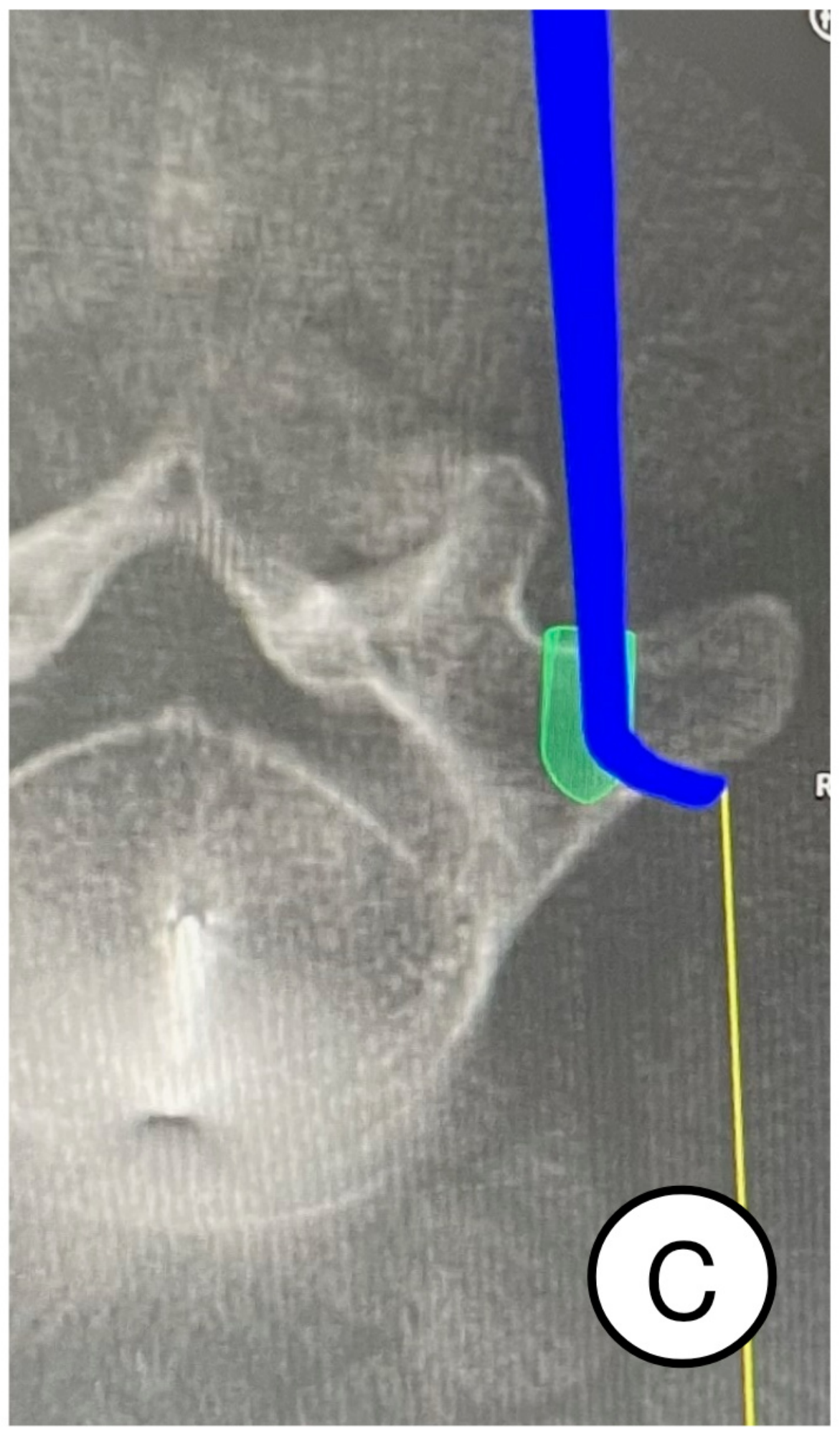

Trajectory 1
P
L
R
Trajectory 2
S
A
P
A


Trajectory 1
L
R
Trajectory 2
S
A
P
B

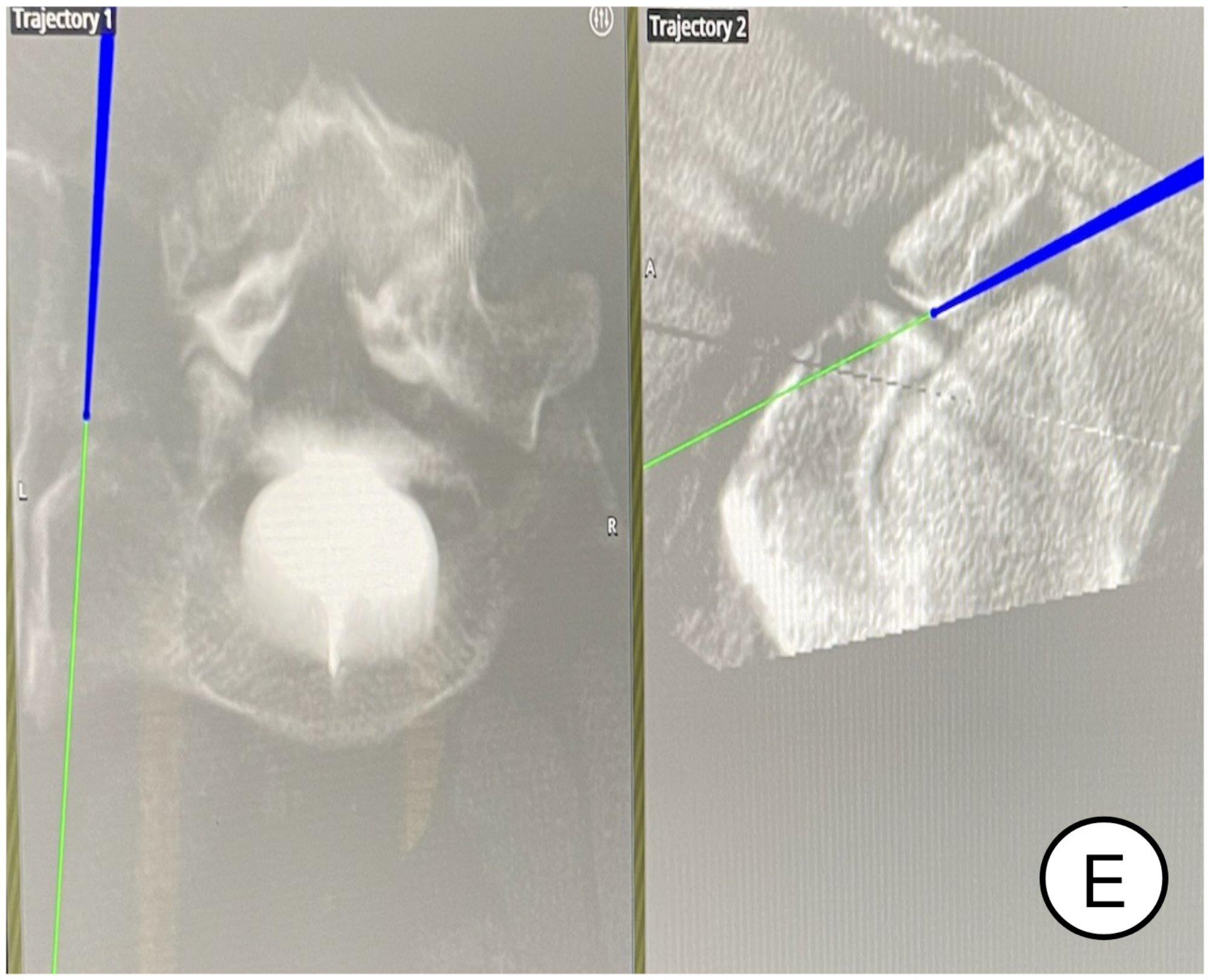


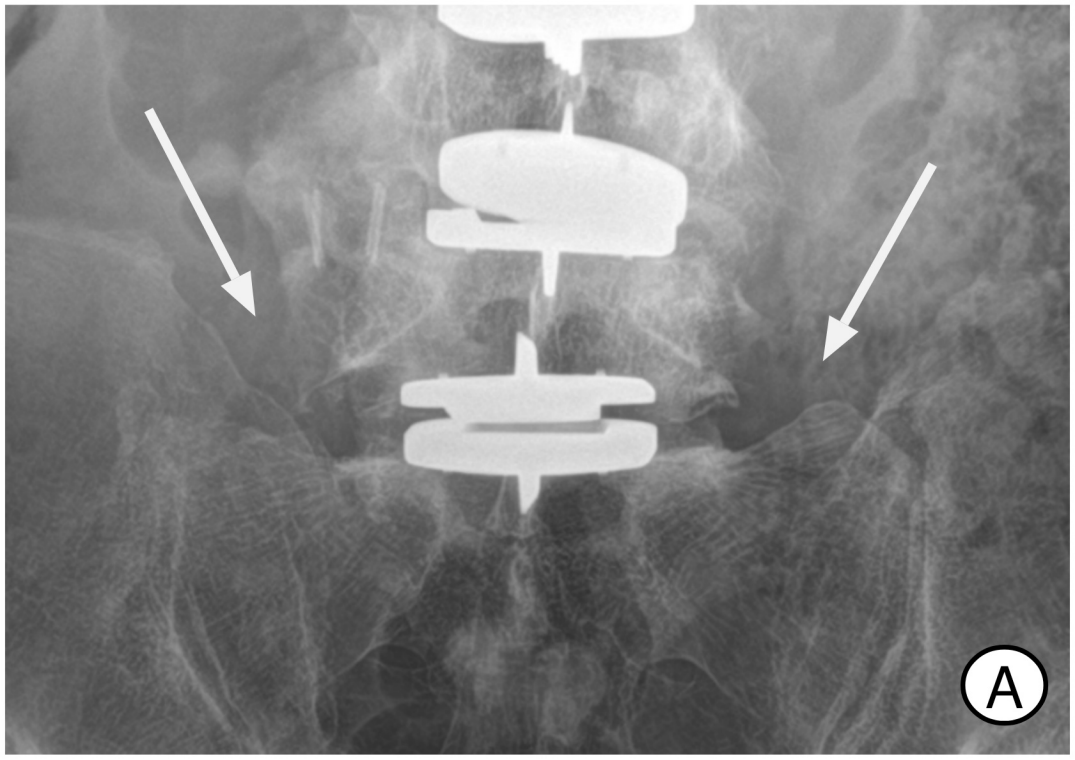

Trajectory 1
P
L
R
Trajectory 2
S
A
P
A

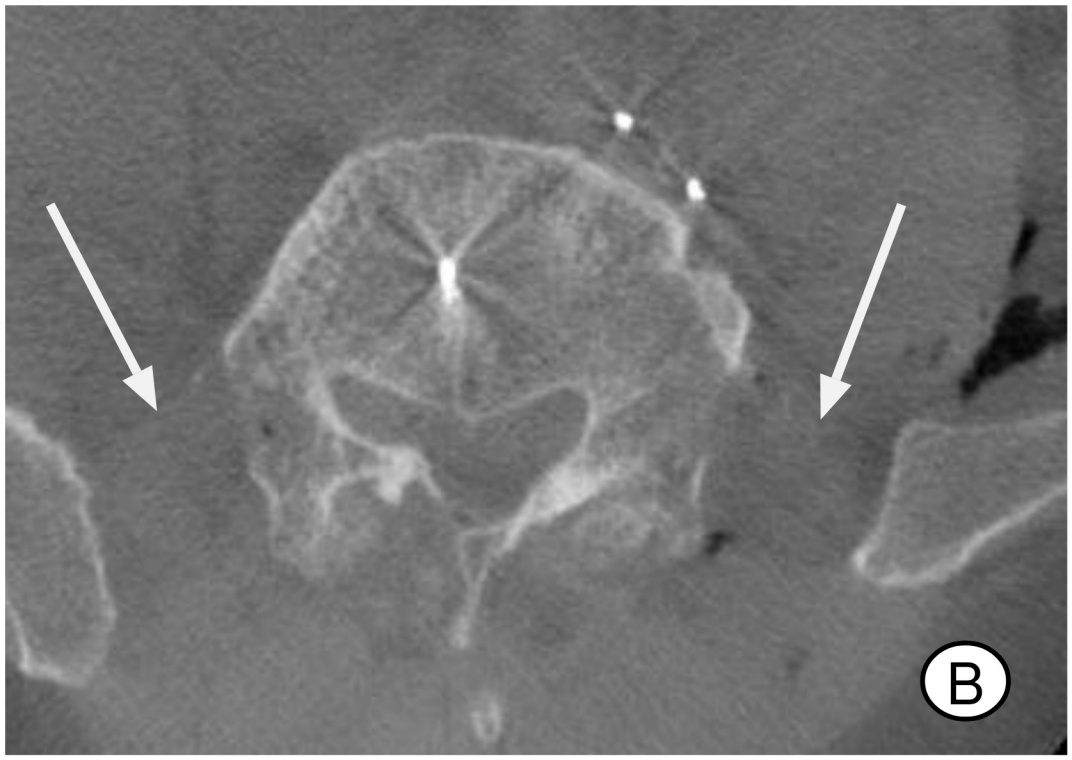

Medtronic
B

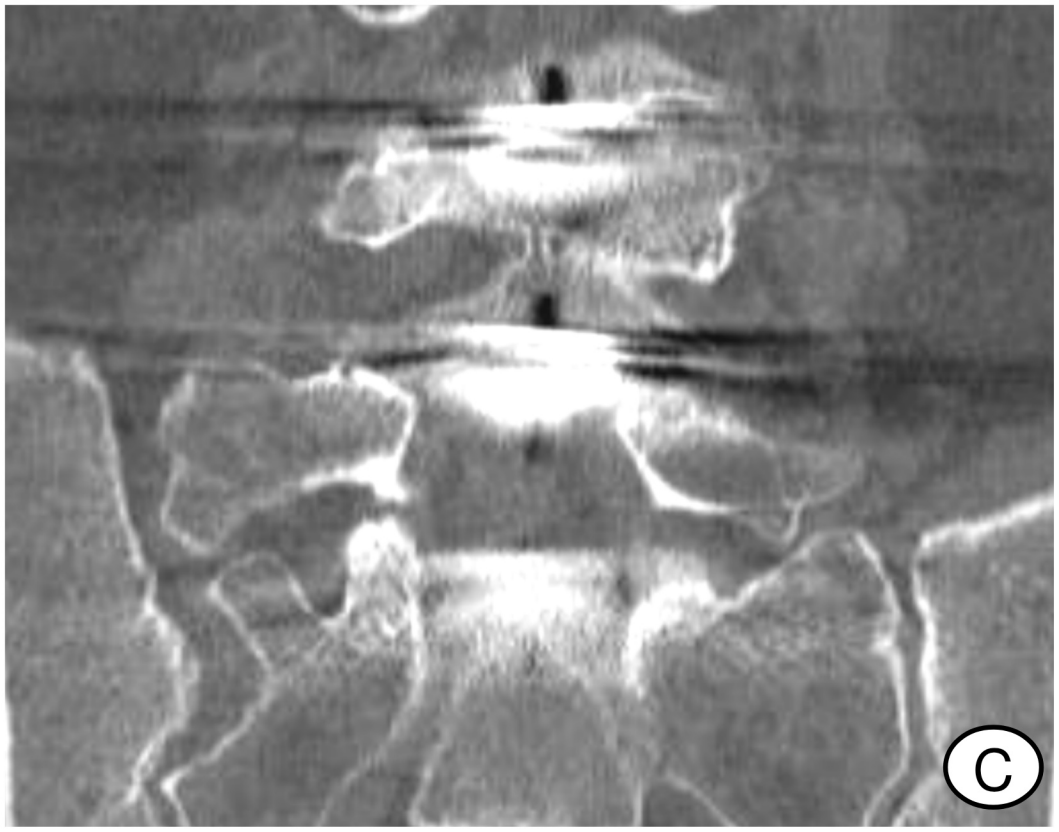

C

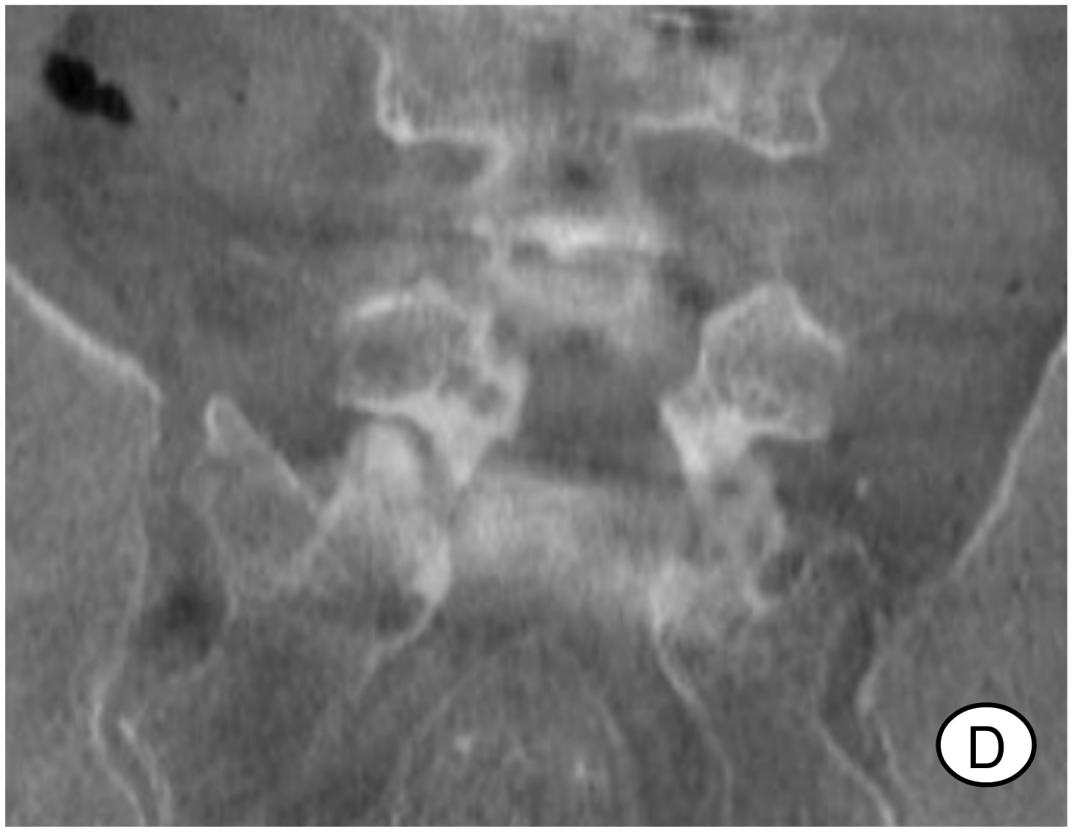

CM
1
2
3
4
5
6
INCHES
1
2
D


Trajectory 1
L
R
Trajectory 2
A
E


A


B


C


D