The "Canoe" Technique to Insert Lumbar Pedicle Screws: Consistent, Safe, and Simple

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Abstract
Pedicle screw instrumentation has become standard fixation for a variety of spinal disorders. Traditionally, the landmarks for screw insertion have been described as the junction of the pars interarticularis, with the superior articular process of the corresponding facet and the transverse process. Consistent and reproducible insertion remains challenging specifically when faced with anatomic patient variations and superimposed pathology. We describe a novel method to approach pedicle screw fixation using primarily the transverse process.

In 1959, Boucher[1] described the use of a long facet screw that occasionally obtained oblique purchase across the pedicle as a method of spinal fusion. His screws were not aimed intentionally down the long axis of the pedicle; as a result the first deliberate attempt to put pedicle screws through the isthmus of the pedicle has been credited to Harrington and Tullos[2] in 1969, who described the attempted reduction of 2 cases of high-grade spondylolisthesis in children.

The use of pedicle screw-based spinal instrumentation for the management of spinal fractures, deformities, and degenerative conditions has become a standard part of a spine surgeon's armamentarium. Pedicle screws are inserted according to anatomic landmarks, which vary considerably among different regions of the spine and among different individuals. Roy-Camille and colleagues[3,4] described an entry point 1 mm beneath the facet joint in line with the lateral margin of the facet joint. This entry point is to be used with a straight-ahead direction for the screw. Others have described a more lateral entry point, which is located at the nape of the neck of the superior articular process, adjacent to the pedicle.[5] It is used with a more oblique passage of the screw angled toward the midline, along the axis of the pedicle. Screw malpositioning rates that have been reported vary between 28.1% and 39.9% in clinical studies with postoperative computed tomography evaluation and between 5.5% and 31.3% in cadaver studies.[6-8] The danger of neurovascular complications associated with screw malplacement is obvious, and severe complications have been described.[5,9,10] The inferior mechanical stability of a misplaced screw may cause early loosening and breakdown of the construct.

Gaines[11] described the medial-based funnel technique in which a 1 cm-diameter section of cortical bone is removed over the presumptive top of the pedicle with a burr or Lexel rongeur. A Kerrison rongeur is used to remove the cortical bone peripherally so that the isthmus of the pedicle can be seen. Once the isthmus of the pedicle is directly palpated, a small 2-mm pedicle probe is passed through the isthmus into the vertebral body. Subsequently, a larger, 5 mm probe, then is used to en-

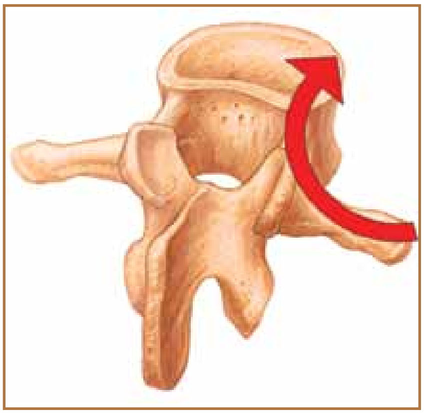

Figure 1. Pedicle approach pathway with the canoe technique. Note how the anatomy of the transverse process merges with the pedicle at that level.

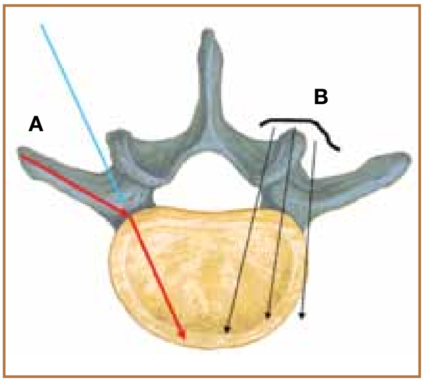

Figure 2. Pedicle approach pathway with the canoe technique (A) that uses the ventral surface of the transverse process as a guide to the pedicle allowing reproducible access to the pedicle. Compared with the Roy-Camille/lateral entry point technique, the pedicle approach can be used at any point along region (B).

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Figure 3. Preoperative AP (A) and lateral (B) radiograph of a 55-year-old man with degenerative spondylolisthesis/stenosis at L4-L5. Note the AP radiograph demonstrates the mid-transverse axis of the transverse process of L4 and L5 leading to the mouth of the ipsilateral pedicle.

large the path through the isthmus of the pedicle. Kirschner wires are placed into the probed pedicles as radiographic markers. Biplanar fluoroscopic imaging is used to verify wire positions. Threads then are cut into the pedicle with progressively larger taps until firm cortical purchase is achieved. Finally, a ball-tip probe is used to feel the pedicle in all directions: the bottom of the pedicle (in the vertebral body) and the superior, inferior, medial, and lateral inner walls of the pedicle. The screw then is inserted into the pedicle with a screwdriver.

The anatomy of the human lumbar spine pedicle has been studied. Wide individual variations within common patterns of anatomy exist exhaustively.[12-13] The basis of current techniques of pedicle screw insertion relies solely on diverse medial anatomic landmarks, including the morphology of the pars interarticularis, junction of the transverse process to the facets, presence or absence of a mamillary process. These landmarks are prone to distortion depending on facet joint hypertrophy, degree of decompression performed, lumbar level of pedicle screw placement and potential posterior element disruption in cases of spine trauma.

In an attempt to negate these anatomic inconsistencies, we describe a novel method to insert pedicle screws based on a path derived from the long axis of the transverse process: the canoe technique.

The Canoe Pedicle Screw Insertion Technique

At this point in the surgical procedure, the spinous process, lamina, facet joint, and the transverse process of the level to be instrumented have been exposed and confirmed with intraoperative posteroanterior radiography.

Bone from facet joint hypertrophy is carefully removed along the lateral edge of the facet joint at the level of the pars interarticularis and the mouth of the transverse process. The typical lumbar transverse process is flat laterally and has a central ridge that is contiguous with the mamillary process of the corresponding superior facet.

Using a Lexel rongeur, a unicortical breach, or "canoe", is made along the long axis of the transverse process at the level of the central ridge. Using a long handled sharp curette, a trough is created and propagated from lateral to medial towards the pars interarticularis and the mamillary process. As the cortical bone along the transverse process is sequentially removed taking care to retain the ventral surface of the transverse process the mouth of the ipsilateral pedicle is heralded with the appearance of spongy cancellous bone. At this point the isthmus of the pedicle is exposed using the curette in a sweeping fashion (**Figures 1, 2**).

A sharp gearshift pedicle probe is then used to penetrate the long axis of the pedicle in the direction of the pedicle depending on the vertebral level. A ball-tip probe is then used to feel the pedicle in all directions: the bottom of the pedicle and the superior, inferior, medial, and lateral inner walls of the pedicle. If there is concern as to the quality of screw fixation, a threaded tap is used and finally the pedicle screw is inserted.

Discussion

Weinstein and colleagues[5] explored the safety of pedicle screw placement and demonstrated that even in an experimental situation consistent screw malposition occurs if standard anteroposterior and lateral radiographic views are used for monitoring screw placement. There was a 21% failure rate with most screws placed medially into the spinal canal. The failure rate was not related to the approach used or the experience of the surgeon. The Roy-Camille approach was satisfactory in the upper lumbar spine, where the pedicle axis is more sagittal. It was less accurate in the lower lumbar spine, where the pedicle axis is more oblique.

Robertson and colleagues[14] evaluated 2 entry points (Roy-Camille vs lateral entry point at lateral margin of superior articular facet) for pedicle screws placement in the lumbar spine. Their results indicated that both were not reliable and tended to direct screw placement medial to the pedicle axis enough to lead to a substantial frequency of pedicle breakthrough for screws parallel to this axis.

The canoe technique for pedicle screw insertion does not use either the articular processes of the facet joint or the facet joint line itself to approach the pedicle axis. We primarily use a single consistent anatomic landmark (transverse process) rather then a combination of variable landmarks (pars interarticularis, superior articular facet, mamillary process, and transverse process).

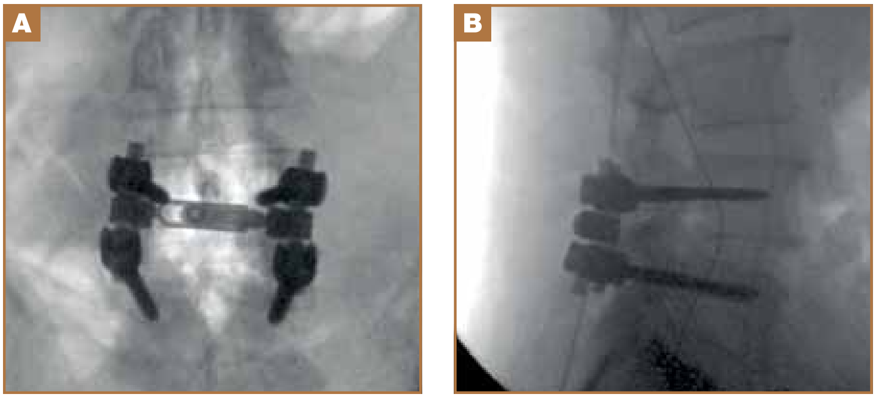

Figure 4. Intraoperative final fluoroscopic images (A, B) of the construct. Pedicle screws were inserted using the canoe technique.

The benefit of this approach is that the facet hypertrophy that accompanies degenerative spinal disorders may cause distortion of the lateral facet anatomy at the pedicle screw entry site. In addition, rotation of the vertebral body in the coronal and sagittal plane in deformity cases leads to additional variation in regional morphology. By using a pathway from lateral to medial along the long axis of the transverse process that is directed specifically towards the mouth of the pedicle, we have obtained excellent results (**Figure 3**).

There are several limitations associated with this technique. Initiating the canoe at the mid-point of the transverse process relies on peeling the paraspinal muscles leading to further dissection and stripping. In some cases, this may lead to further blood loss and increased operative time. However, in cases where a posterolateral spinal fusion is contemplated, such an exposure of the transverse processes is expected. Another limitation may be in cases of obese patients where retraction of the soft tissues and exposure of the bony anatomy is challenging. As a result, when the starting point is more lateral, the trajectory of the pedicle screw is more lateral, and a lateral wall breech may be encountered. In this situation, we always confirm screw placement/trajectory with antero-posterior/lateral fluoroscopy (**Figure 4**). Another limitation is in complex rotational deformities where the transverse axis of the transverse process does not always line up with the mouth of the pedicle. Finally, if during the preparation of the canoe, the transverse process is iatrogenically fractured, the utility of using this method of screw placement is diminished.

Vertebral body fixation with pedicle screws relies on surgeon experience, topological landmarks, tactile feel, as well as knowledge of 3D anatomy. Intraoperative imaging techniques with real-time fluoroscopy may be used to assist in proper screw pathways. The canoe technique is one method of ensuring appropriate pedicle screw placement and trajectory. We have obviated the need for intraoperative real-time fluoroscopy and only perform postoperative posteroanterior radiographs just prior to closure. This decreases surgeon radiation exposure, time, and cost.

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