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SCIENTIFIC ARTICLE

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Technical strategies and anatomic considerations for parapedicular access to thoracic and lumbar vertebral bodies

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Abstract *Objectives:* To investigate and illustrate a variation on the traditional percutaneous access to the vertebral body via a parapedicular approach. *Design:* An effective parapedicular access technique that could safely and reliably guide the needle tip into the center of the vertebral body was developed from cadaver dissection observations for the purpose of clinical use. *Patients:* A total of 102 vertebral compression fractures from T-4 to L-5 were treated via the parapedicular access at our institution between July 2005 and March 2006. There were 72 patients between the ages of 17 and 96 years (mean age: 68.2 years) who underwent treatment. *Results:* The cadaver dissection revealed a relatively avascular and aneural portion of the vertebral body along the superior margin of the vertebral body-pedicle junction. A total 102 vertebral fractures were treated using the parapedicular access technique without any recognized clinical complications from the needle access or the instrumentation. *Conclusions:* The thoracic and lumbar vertebral bodies may be safely, reliably, and reproducibly accessed using a percutaneous parapedicular access technique. The technique presented represents a relatively avascular and aneural approach to vertebral body.

Keywords Lumbar · Parapedicular · Paraspinal · Spine · Thoracic · Vertebral body · Vertebroplasty

Introduction

Percutaneous access to the vertebral body may be utilized to obtain a sample of the contents of the vertebrae in case of infection or tumor and can be used as a pathway to repair vertebral compression fractures via the injection of polymethylmethacrylate (PMMA) or allograft bone. Percutaneous vertebroplasty was first reported in 1987 for the treatment of vertebral hemangiomas and has subsequently been used to treat osteoporotic and neoplastic compression fractures of the spine [1–4]. Osteoporotic vertebral compression fractures (VCF's) most often occur in the lower thoracic and lumbar spine, and the typical access for this region has been via a transpedicular approach [5]. The primary shortcoming of the unilateral transpedicular approach for vertebroplasty is that the desired needle location tends to be too far lateral toward the ipsilateral side as the path is directed by the pedicle. The parapedicular approach enables a more favorable needle trajectory that may allow for a more predictable and consistent approach to the center of the vertebral body.

As with any approach to the vertebral body, potential clinical complications of the parapedicular approach include nerve root injury, hematoma, rib fractures, and injury to surrounding organs. An additional clinical complication possibility when performing an approach that is farther lateral than the typical transpedicular vertebral body approach is a pneumothorax or pleural tear. The development of a parapedicular access technique that would provide the safest possible route to the center of the vertebral body would be one possibility option to reduce the risk of complications to the lowest possible rate.

In this article we present our results on cadaver dissection that demonstrate the parapedicular anatomy specifically as it relates to the neurovascular and osseous structures. We also report our complication rate related to the parapedicular access technique as described.

Patients

A total of 102 vertebral compression fractures were treated using the parapedicular access technique between July 2005 and March 2006. A total of 72 patients between the ages of 17 and 96 years (mean age: 68.2 years) underwent vertebral compression fracture treatment. All patients underwent preoperative imaging assessment using a combination of conventional radiography, magnetic resonance (MR) imaging, computed tomography (CT), and nuclear scintigraphy. The typical workup consists of MR imaging for those patients who are able to undergo this examination and a combination of CT and nuclear scintigraphy for those patients who are not able to undergo a MR imaging examination. Conventional radiographs were also obtained on the majority of the patients.

All patients were examined prior to their VCF treatment and their strength, neurological status, and musculature were assessed by physical exam and compared to the postoperative evaluation. All patients were kept overnight and released the following day.

Parapedicular approach-technical description

After the patient has undergone a physical examination and informed consent is obtained, they are placed prone on the special procedures table and sterilely prepped and draped. Conscious sedation is then initiated with a combination of midazolam and fentanyl in 1-mg and 50-mcg increments, respectively, and titrated to effect. A sedation nurse monitors blood pressure and oxygen saturation and administers oxygen via an oxygen mask. A combination of antibiotics is given, including a single periprocedural dose of 1 gm of cefazolin and 400 mg of gentamycin. Clindamycin (600 mg) is given for patients that have had a documented reaction to penicillin.

The affected vertebral level is then identified using fluoroscopy (General Electric, Milwaukee, Wis.), and the image intensifier (II) is positioned to view the vertebral body in a direct anteroposterior (AP) orientation with the endplates parallel to the X-ray beam and the spinous process centered between the pedicles. After the II is adjusted to view the vertebral body from an AP dimension, a line is drawn from the contralateral inferior vertebral body corner to the ipsilateral superior vertebral body corner and extended out of the vertebral body for a distance equal to the width of the mid portion of the vertebral body (Fig. 1). The entry point is marked with a skin marker in this location, and a small incision is made. The needle is then inserted into this incision and placed at a 45° angle relative to the floor. Immediately after inserting the needle into the skin incision, the proceduralist has the option of assessing the trajectory of the needle by rotating the II 20–40° ipsilateral (along the pathway of the needle) to ensure that the needle tip is directed toward the parapedicular entry point just anterior to the upper portion of the pedicle. The insertion through the soft tissue is monitored with the II in an AP position, and the mallet is used to tap the needle tip into the outermost portion of the vertebral cortex, just enough to seat the needle into the cortex. The II is then rotated 20–45° ipsilateral, and the tip of the needle is identified. The needle tip should be located just anterior to the ipsilateral pedicle and adjacent to the upper one half of the pedicle (Fig. 2). After the parapedicular location of the

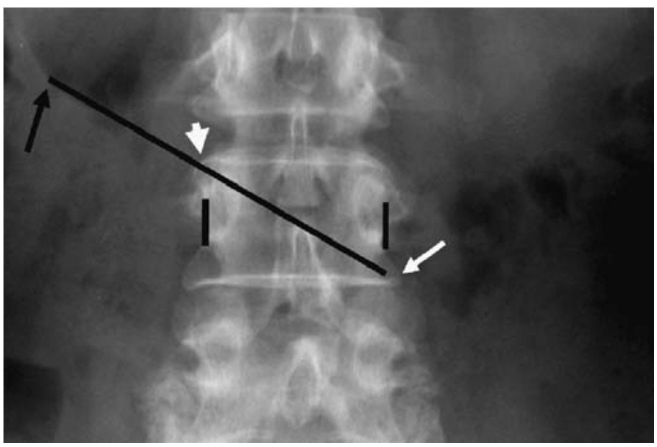

Fig. 1 Anteroposterior view of the lumbar spine demonstrates a line drawn from the contralateral inferior vertebral body corner (*white arrow*) to the ipsilateral superior vertebral body wall corner (*white arrowhead*). The line extends one vertebral body width (distance between the *black vertical hashmarks* shown on each side of the vertebral body) ipsilateral and superior to a point that serves as the skin entry point for the parapedicular access (*black arrow*)

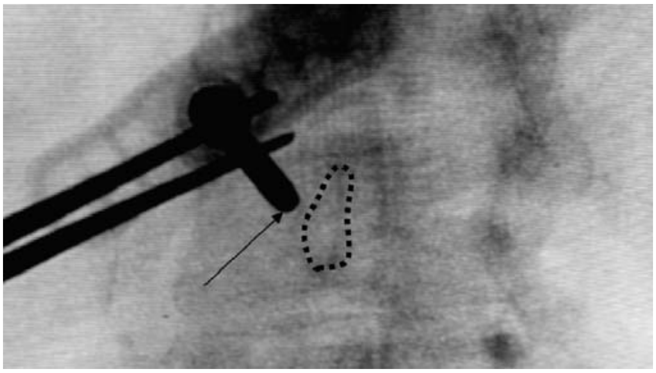

Fig. 2 Ipsilateral oblique (left posterior oblique) of the vertebral body being accessed shows the needle tip (*black arrow*) immediately anterior and adjacent to the upper half of the pedicle (outer portion indicated by *dashed black line*). The needle tip, in this region, is parapedicular. The needle is also held by a clamp (*white arrow*) to minimize the radiation exposure to the proceduralist

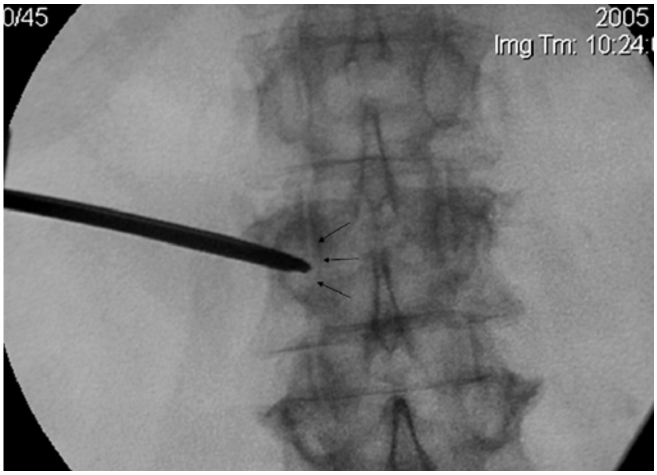

Fig. 4 Anteroposterior (AP) fluoroscopic view of the vertebral body shows the needle tip approaching the medial wall of the pedicle (*black arrows*). The medial wall should not be transgressed until the needle tip is seen to be located within the posterior portion of the vertebral body (Fig. 5)

needle tip is confirmed, the II is then returned to the AP position, and the needle is advanced into a position where the needle tip projects over the center of the ipsilateral pedicle on the AP view. The II is then positioned laterally, and the trajectory of the needle is adjusted to ensure that the needle tip is directed into the correct portion of the vertebral body (Fig. 3). The II is then positioned back to the AP view, and the needle tip is advanced just proximal to the medial wall of the pedicle but not across the medial wall (Fig. 4). A lateral fluoroscopic view is then obtained prior to crossing the medial wall of the pedicle. At this point, the needle tip should be located within the posterior portion of the vertebral body (Fig. 5). With this trajectory and entry point the needle tip will be away from the structures within the spinal canal and will not contact the exiting nerve roots. It is critically important to visualize the tip of the needle within the posterior portion of the vertebral body prior to the tip crossing medial to the medial wall of the pedicle. The needle can then be safely directed into the center portion of the vertebral body.

Anatomic correlation for parapedicular approach

Anatomically, the pedicle divides the exiting and traversing nerve roots, and the exiting spinal nerve root quickly divides into the ventral and dorsal rami (Fig. 6). The ventral ramus courses inferiorly and obliquely across the lateral portion of the vertebral body and does so slightly more

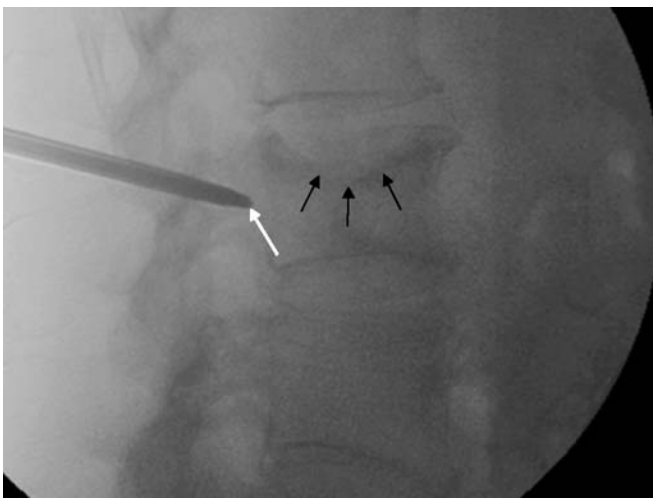

Fig. 3 Lateral fluoroscopic view of the fractured vertebrae in the lumbar spine shows the needle tip (*white arrow*) directed toward the center portion of the vertebral body inferior to the depressed superior endplate (*black arrow*)

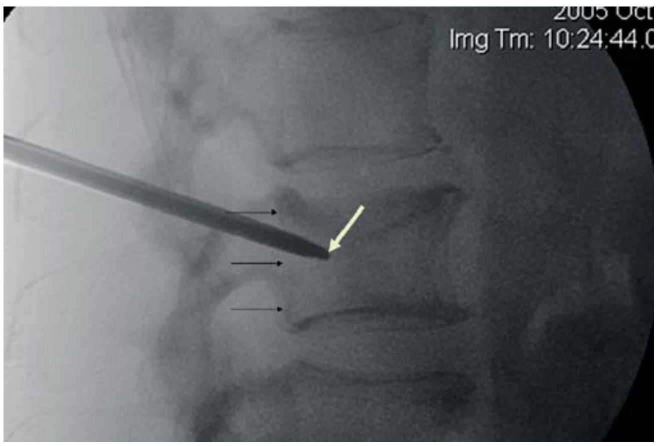

Fig. 5 Lateral fluoroscopic view of the lumbar spine shows the needle tip (*white arrow*) anterior to the posterior portion of the vertebral body (*black arrows*). The position of the needle tip anterior to the posterior vertebral body wall prior to the needle tip transgressing the medial wall on the AP view is necessary to avoid unnecessary injury to the contents of the spinal canal and/or the nerve roots

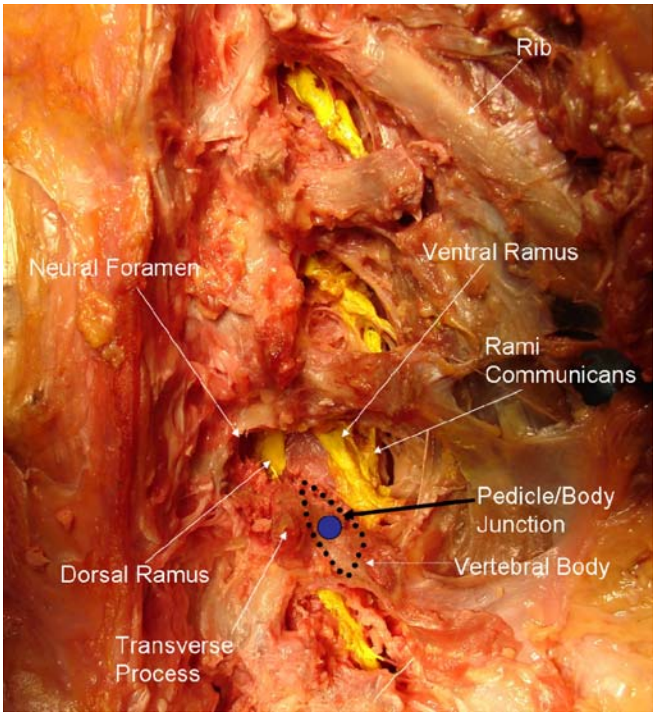

Fig. 6 Lateral view of a cadaver thoracic spine shows the structures labeled above with the mid and lower ribs removed for the purpose of demonstrating the underlying anatomy. The start point is indicated by the *blue mark* at the pedicle/body junction (*black arrow*). The needle is angled caudally along the trajectory of the nerve roots, and the entry point is between the exiting ventral rami. The borders of the safe entry zone are indicated by the *area within the dotted line*

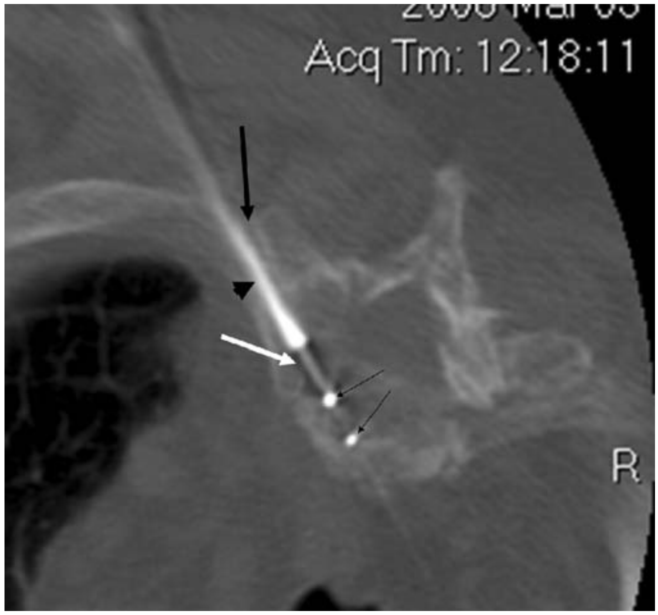

Fig. 7 Axial computed tomography image displayed with bone windows demonstrates the parapedicular pathway of the 11-gauge needle (*black arrowhead*) as it travels along the superior margin of the costotransverse junction (*large black arrows*) and the costovertebral junction (*white arrow*). A catheter has been placed through the needle, and the marker bands for the inflatable bone tamp can be seen within the vertebral body (*small black arrows*)

horizontally in the thoracic spine than in the lumbar spine. The ventral rami communicate with the sympathetic chain (present at T-4–T-12 on the left) via the rami communicantes and receive the postganglionic non-myelinated fibers from the sympathetic trunk. The fibers then join both the dorsal and ventral rami and supply the effector organs.

The entry point target for the parapedicular approach is the pedicle body junction of the vertebral level of interest. In the thoracic spine, the needle entry point is just anterior and superior to the ventral ramus of the exiting nerve root above it (i.e., at T-8, the entry point will be anterosuperior to the ventral ramus of the T-7 exiting ramus). The needle penetrates the superolateral portion of the vertebrae at the pedicle-body junction. In the thoracic spine this avoids contact with the pleura which, in cadaveric studies, has been found to be immediately adjacent to the inferolateral pedicle [6, 7]. The trajectory of entering the superior portion of the pedicle-body junction is effective at avoiding the dorsal nerve root ganglion that is located inferior to the entry point, the aorta (T-5–T-10 on the left) and the azygos vein (T-5–T-11 on the right). The superior to inferior trajectory allows the needle to pass superior to the transverse process and along the superior margins of the costotransverse and the costovertebral junctions (Fig. 7). These osseous structures and articulations provide a natural path of least resistance into the center of the vertebral body.

In the lumbar spine, the ventral rami course more vertically and the needle entry point is just anterior to the exiting ventral ramus of the vertebral level above (Fig. 8). The optimal entry point in the lumbar spine, as in the thoracic spine, is just below the superior vertebral endplate at the junction between the superior portion of the pedicle and the posterior portion of the adjacent vertebral body.

Discussion

Although the parapedicular access to the vertebral body is somewhat controversial due to the perceived higher risk of complications, the rate of clinically significant complications is low, and most of the parapedicular access reports are from the orthopedic and neurosurgical literature and describe the parapedicular insertion of pedicle screws [8, 9]. In retrospective evaluations, Chiras reported complication rates of 1% in patients with osteoporotic vertebral fracture and between 2.5 and 10% in patients with benign and malignant spinal tumors, respectively [10, 11].

The parapedicular pathway has been found to be generally clear of important soft tissue structures, but certain rules of thumb should be considered when performing parapedicular access of the vertebral body. In the thoracic spine, aligning the needle with the medial rib

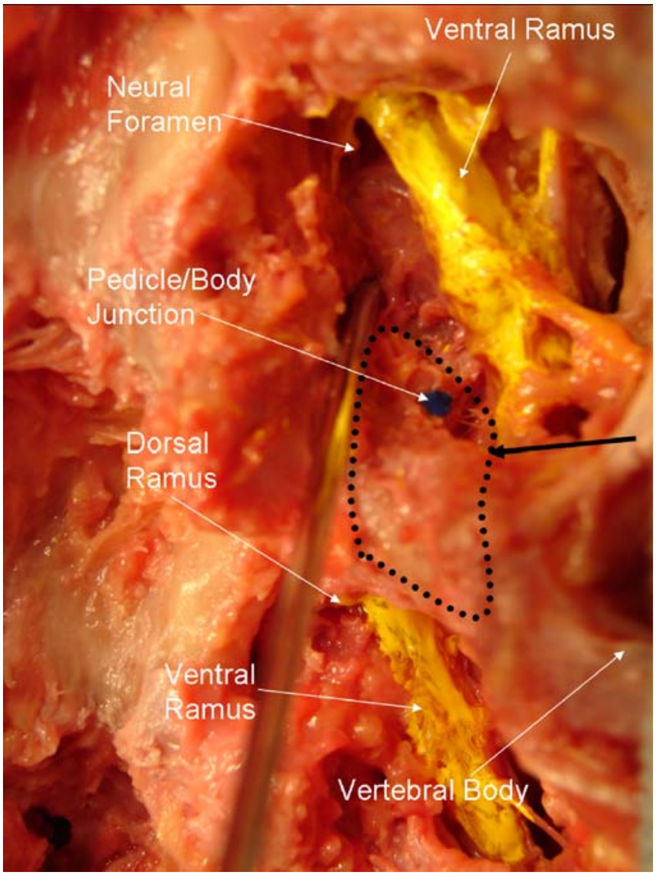

Fig. 8 Lateral view of a cadaver lumbar spine shows the structures identical to those labeled in Fig. 6. A probe is placed at the junction between the superior portion of the pedicle and the posterior portion of the vertebral body. The entry point is indicated by the *blue mark* at the pedicle/body junction (*black arrow*). The borders of the safe entry zone are indicated by the *area within the dotted line*

insertion is beneficial as the needle will pass immediately adjacent to the costotransverse and the costovertebral junction. These junctions provide a path of least resistance toward the center of the vertebral body, and the optimal entry point is at the superior costal facet along the superior portion of the pedicle at the pedicle-vertebral body junction.

The natural anteroinferior angulation of the needle in the thoracic spine is optimal to avoid the adjacent intervertebral disk and the neural foramen above the access point. The needle must also be placed at the pedicle-body junction (the pedicle rib unit in the thoracic spine) to avoid the spinal nerves. The rib may be used as a reliable guide to access the thoracic vertebral bodies and to prevent the transgression of the important neural structures in this region. The neural structures (ventral rami) in the thoracic spine have a more horizontal orientation than do the ventral rami in the lumbar spine, thereby providing a wide berth of osseous area that is available for parapedicular access.

The paravertebral vessels in the lumbar spine are larger than those found in the thoracic spine and are located near the mid portion of the vertebral body. If the appropriate superoinferior orientation is maintained the posterior entry point will be superior to the majority of the paravertebral vessels in a relatively avascular region. The psoas musculature lies immediately adjacent to the vertebral bodies and had to be manually removed from its attachment to the vertebral body during cadaver dissection. This close muscular attachment likely limits hemorrhage from the paravertebral access point by providing anatomic tamponade.

The limitations of the parapedicular access include the upper thoracic spine and the lower lumbar spine, particularly the L-5 vertebral body. The costotransverse and costovertebral junctions in the upper thoracic spine typically directs the trajectory of the needle more ipsilateral, thereby making the access to the center of the vertebral body with a unilateral approach more difficult. The wide pedicles at the L-5 level make the transpedicular approach the naturally favored method for accessing the L-5 vertebral body. A parapedicular access at this level is difficult due to the challenge of navigating around the large pedicles.

We have performed the parapedicular approach in 102 patients with vertebral compression fractures from July 2005 to March 2006, including 63 spineoplasty procedures where a 7-mm cannula was placed into the vertebral body in a parapedicular manner. No complications (nerve root injuries, hematomas, or injuries to spinal canal contents) were identified in any of these patients undergoing this procedure. No cases were identified where the fill material (either morselized allograft bone or PMMA) extruded proximally around the needle at its entry point.

Conclusion

The parapedicular approach may be used as an alternative approach to the vertebral body in both the thoracic and lumbar spines. The needle approach is easily planned using landmarks that are fluoroscopically identifiable, and the trajectory places the entry point through a relatively avascular and aneural portion of the vertebral body. The parapedicular approach offers a more favorable route to the center of the vertebral body and may be used to obtain tissue from the vertebral body or treat vertebral compression fractures. When the vertebral level is acceptable for a parapedicular approach, our experience supports this method of access as a safe and effective technique that allows percutaneous access to the vertebral body.

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