FactFinders for Patient Safety

Minimizing Risk with Basivertebral Nerve Radiofrequency Neurotomy: Preprocedural Imaging Recommendations

Gerry Yeung, MD[1]; Ben Laplante, DO, MS[2]; David Hao, MD[3]; Paul Kitei, MD[4,5]; Reza Ehsanian, MD, PhD[6]; and David Levi, MD[7] on behalf of the International Pain and Spine Intervention Society's Patient Safety Committee

[1]Stanford University Medical Center, Stanford, California, USA;
[2]University of Rochester Medical Center, Rochester, New York, USA;
[3]Massachusetts General Hospital, Boston, Massachusetts, USA;
[4]Rothman Orthopaedic Institute, Philadelphia, Pennsylvania, USA;
[5]Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania, USA;
[6]University of New Mexico, Albuquerque, New Mexico, USA;
[7]Jordan-Young Institute, Virginia Beach, Virginia, USA

MYTH: Basivertebral nerve radiofrequency neurotomy (BVNRFN) can be performed safely and effectively at all levels in a standardized fashion using only a transpedicular approach.

FACT: BVNRFN can be performed safely and effectively at the L3 through S1 vertebral levels. Scrutiny of preprocedural imaging may minimize risk. Although the transpedicular approach is preferred, patient anatomy may dictate a non-transpedicular trajectory.

Overview

BVNRFN selectively disrupts pain signaling from vertebral endplates to treat vertebrogenic chronic axial back pain with concurrent Modic type 1 or type 2 changes on MRI. BVNRFN involves accessing the pedicle, introducing a curved cannula to create a channel, inserting a radiofrequency probe, and ablating the basivertebral nerve [1]. An extrapedicular/parapedicular trajectory for vertebral body access has been described and may be considered depending on pedicular width or presence of pedicle screws [2]. While the reported rate of complications is low with both transpedicular and extrapedicular approaches, those described to date include nerve root injury and radicular pain and/or neurological deficit, incisional pain, urinary retention, lumbar and sacral fractures, retroperitoneal hemorrhage, hemorrhage posterior to the vertebral body, new-onset back pain in a different location, and lateral femoral cutaneous neuropraxia [1,3-7].

Minimizing the risk of lumbar artery, segmental artery, and nerve root injury involves avoiding direct vascular or neural contact, minimizing thermal injury to nerve root with final probe placement, preventing pedicle breach or fracture, and reducing the likelihood of vertebral body compromise. Scrutiny of available MRI and CT imaging can aid in preprocedural planning to minimize neurovascular injury.

Vascular

Amongst the most serious complications associated with BVNRFN is vascular injury, which carries the potential for subsequent hemorrhage and shock. In the literature, this has been documented once due to misdirected pedicle access [1,3-6]. An excessively lateral position resulted in a psoas hematoma, and the resulting compressive lesion caused transient neuropraxia on the femoral nerve [3]. An additional case of a hematoma was reported posterior to the vertebral body with tenting of the posterior longitudinal ligament [7]. However, lumbar artery iatrogenic injury has been described in the literature with other percutaneous vertebral access procedures (vertebroplasty/kyphoplasty) with both transpedicular and extrapedicular puncture [8]. A thorough review of available imaging can focus on visualizing the pertinent vascular structures to avoid when planning the trajectory of the introducer trochar. The lumbar arteries originate from the abdominal aorta, typically distributing in pairs from the L1 to L4 levels, and rarely from the L5 level. They then traverse to the posterolateral side of the vertebral body, dividing into three branches (anterior, posterior, and middle branches) anterior to the neuroforamen. However, significant anatomic variation may occur, including differences in size and width, the number of arteries present, whether a common trunk is present, variations in branching patterns, and differences in their anatomical course [8-11].

Neural
Spinal cord injury would potentially also be amongst the most serious complications that may be associated with BVNRFN. Given the termination of the spinal cord above levels usually targeted for BVNRFN with on-label use (L3-S1), direct spinal cord trauma has not been reported. However, spinal cord injury has been associated with other vertebral body access procedures and may be secondary to epidural hematoma [12].

The most frequently reported adverse events include transient motor/sensory disturbances and/or radiculopathy [1,3-6]. As mentioned above, it is important to review and consider the pertinent neural anatomy to minimize direct contact with pedicular breach and/or thermal injury during final probe placement when performing the ablation portion of the procedure. The lumbar nerve roots run near the pedicles and vertebral bodies, with the pedicles forming the roof and floor of the neuroforamen, and the dorsal root ganglion often lying directly beneath the pedicles [13,14]. More specifically, the traversing nerve root lies in the lateral recess just medial to the pedicle, and the exiting nerve root runs just inferior to the mid-portion of the pedicle within the superior aspect of the foramen. Given the anatomical structures abutting the pedicles, careful evaluation of pedicular morphology is essential to minimize the risk of pedicular breach during the transpedicular approach.

Pedicular Breach
To minimize pedicular breach, evaluate the pedicle diameters and access the larger of the two pedicles available at any given vertebral body level if one is too small to access with the available instrument. In the spine surgery literature, an 80% pedicle screw diameter-to-pedicle width ratio is generally considered a conservative threshold to reduce the risk of pedicle breach, so consider the size of the pedicle to the pedicular access instrument used in basivertebral nerve ablation. It is additionally recommended to maintain a minimum cortical margin of 0.5 mm on both the medial and lateral aspects of the pedicle to minimize the risk of pedicle fracture [15]. However, in the spine surgical literature, it is known that transpedicular intervention can reduce the axial resistance force of the pedicle, which may lead to pedicle fracture [16]. While the risk of fracture may not be the same for proceduralists with a single trochar compared to maintaining margin for placing pedicle screws, when considering pedicular access versus extrapedicular vertebral body access, proceduralists should carefully determine which side of the pedicle offers the greatest safety margin for trochar insertion based on width and cortical margin. One may consider extrapedicular access when pedicle width is inadequate for the trochar on either side, when there are preexisting pedicle screws, or when there is presence of vasculature in the trajectory with pedicular access [2]. Thus, it is important to scrutinize MRI for pedicular width, prior instrumentation, and neurovasculature. However, it is important to consider the limitations of MRI. A comparative observational study comparing MRI and CT in the lumbar spine found that pedicle diameters on CT were 0.4-0.5 mm wider than on MRI [17]. Thus, if MRI shows adequate pedicle diameter, further imaging is not required. However, if there is any doubt about whether the pedicle can accommodate

the trochar, obtaining a CT scan could be considered to evaluate bony anatomy best when planning for pedicle access [18]. Otherwise, this may be a time to defer to an extrapedicular approach to avoid the possibility of accessing a pedicle without adequate width.

Pedicle transverse angulation and width typically increase from L1 to L5 [19]. Ideally, the C-arm should be obliqued to at least 30 degrees to allow the trochar to enter the pedicle and vertebral body at an angle that facilitates the accurate placement of the radiofrequency probe. However, the precise C-arm angle required varies depending on individual anatomical variations. Some patients may have pedicles oriented in the sagittal plane and/or exhibit extremely narrow pedicles at mid-to-upper lumbar levels. In patients with markedly sagittal pedicle orientation, accurate probe placement can be challenging, increasing the risk of procedural failure due to anterior radiofrequency probe placement. Conversely, in patients with very narrow pedicles, there is an elevated risk of pedicular breach or fracture. When pre-procedural imaging reveals a pedicle angulation significantly less than 30 degrees, an off-label parapedicular or extra-pedicular approach may be considered.

Access to the S1 segment is typically achieved using a Ferguson view (with the S1 superior endplate squared off). Iliac crest anatomy can complicate S1 pedicular access, particularly in male patients with high and narrow iliac crests. Pre-procedural X-ray imaging can assist the interventionalist in selecting the pedicle that allows for a more favorable oblique trajectory. In patients whose anatomy would otherwise result in excessively ventral probe placement, increasing the rostral tilt beyond the Ferguson view may permit greater obliquity. However, care must be taken to avoid excessively caudal positioning of the instrument within the vertebral body in such scenarios.

The lumbar basivertebral nerve is generally located at the midpoint of the vertebral body, between the superior and inferior endplates [20], whereas the S1 basivertebral nerve is often situated slightly closer to the superior endplate [21]. Nonetheless, significant anatomical variability exists at S1, particularly in patients with transitional anatomy. Although the basivertebral nerve itself cannot be directly visualized, it travels with the basivertebral vessels [20], which are often visible on sagittal MRI. A thorough review of imaging is essential to account for individual anatomical differences and to try to ensure accurate lesioning of the basivertebral nerve.

Fracture

BVNRFN has not been strongly associated with long-term adverse effects on the vertebral body in the initial trials with normal bone density study patients [22]. However, BVNRFN may transiently weaken the bone in patients with existing osteoporosis, with vertebral compression fractures (VCFs) presenting on average two months after the procedure. VCFs in the SMART Trial (n = 225) were found to have an exceedingly low prevalence of 0.4%; however, the study excluded patients with scoliosis, spondylolisthesis, and osteoporosis [3]. Notably, the lone fracture was in a sham patient who crossed over to active treatment at one year and was only found to have osteopenia on subsequent evaluation. A subsequent observational study (n=74) without the previously noted exclusions found a higher incidence of VCFs at 12%, at an average interval of 69 days following BVNRFN [23]. Of note, the mean age of these patients with VCFs was 78 years, and all of the patients with VCFs had osteoporosis with a mean T-score of -3.0. Thus, interventionalists should consider reviewing T-scores in patients with advanced age. For those with significant osteoporosis, it is important to have a risk-benefit discussion regarding BVNRFN and VCF risk.

Summary

- A review of MRI for pedicle width, pedicle orientation, and basivertebral nerve location is recommended.
- MRI may underestimate pedicle width; therefore, if there is any doubt about whether the pedicle width can accommodate the trochar, consider CT imaging.
- While off-label with Intracept, a parapedicular or extrapedicular approach with BVNRFN could be considered when the pedicle is too narrow to minimize the risk of pedicle breach or if the pedicles are too sagittally oriented to avoid a final probe position that is too ventral.
- When pursuing a parapedicular approach, it is crucial to review the locations of the lumbar artery and segmental arteries to minimize the risk of vascular injury.
- Reviewing T-score in patients with advanced age and having a risk-benefit discussion regarding BVNRFN and VCF risk for patients with significant osteoporosis are recommended.

References

1. Conger A, Schuster NM, Cheng DS, Sperry BP, Joshi AB, Haring RS, et al. The effectiveness of intraosseous basivertebral nerve radiofrequency neurotomy for the treatment of chronic low back pain in patients with modic changes: a systematic review. *Pain Medicine*. 2021 May 21;22(5):1039-1054. doi: 10.1093/pm/pnab040. PMID: 33544851.
2. Stolzenberg D, Kitei PM, Tran D, Pfeifer R. Intracept technique at adjacent levels to fusions with pedicle screws. *Interv Pain Med*. 2023 Jun 14;2(2):100261. doi: 10.1016/j.inpm.2023.100261. PMID: 39238666; PMCID: PMC11372909.
3. Fischgrund JS, Rhyne AL, Franke J, Sasso RC, Kitchel SH, Bae HW, et al. Intraosseous basivertebral nerve ablation for the treatment of chronic low back pain: 2-year results from a prospective randomized double-blind sham-controlled multicenter study. *Int J Spine Surg*. 2019 Apr 30;13(2):110-119. doi: 10.14444/6015. PMID: 31131209; PMCID: PMC6510180.
4. Khalil JG, Smuck M, Koreckij T, Keel J, Beall D, Goodman B, et al. A prospective, randomized, multicenter study of intraosseous basivertebral nerve ablation for the treatment of chronic low back pain. *Spine J.* 2019 Oct;19(10):1620-1632. doi: 10.1016/j.spinee.2019.05.598. Epub 2019 Jun 20. PMID: 31229663.
5. Becker S, Hadjipavlou A, Heggeness MH. Ablation of the basivertebral nerve for treatment of back pain: a clinical study. *Spine J.* 2017 Feb;17(2):218-223. doi: 10.1016/j.spinee.2016.08.032. Epub 2016 Sep 1. PMID: 27592808
6. Truumees E, Macadaeg K, Pena E, Arbuckle J, Gentile J, Funk R, et al. A prospective, open-label, single-arm, multi-center study of intraosseous basivertebral nerve ablation for the treatment of chronic low back pain. *Eur Spine J.* 2019 Jul;28(7):1594-1602. doi: 10.1007/s00586-019-05995-2. Epub 2019 May 21. PMID: 31115683.
7. Fox S, Levin J. Hematoma formation after basivertebral nerve ablation. *Interv Pain Med.* 2025 Jul 30;4(3):100617. doi: 10.1016/j.inpm.2025.100617. PMID: 40786847; PMCID: PMC12332941.
8. Liu L, Li N, Wang Q, Wang H, Wu Y, Jin W, et al. Iatrogenic lumbar artery injury in spine surgery: a literature review. *World Neurosurg.* 2019 Feb;122:266-271. doi: 10.1016/j.wneu.2018.10.219. Epub 2018 Nov 9. PMID: 30419401.
9. Liu L, Cheng S, Wang Q, Liang Q, Liang Y, Jin W, et al. An anatomical study on lumbar arteries related to the extrapedicular approach applied during lumbar PVP (PKP). *PLoS One.* 2019 Mar 5;14(3):e0213164. doi: 10.1371/journal.pone.0213164. PMID: 30835754; PMCID: PMC6400376.
10. Iwamoto S, Takao S, Harada M. Visualization of Lumbar artery variations by contrast-enhanced multi-detector row computed tomography. *J Med Invest.* 2016;63(1-2):45-8. doi: 10.2152/jmi.63.45. PMID: 27040051.
11. Cho SM, Nam YS, Cho BM, Lee SY, Oh SM, Kim MK. Unilateral extrapedicular vertebroplasty and kyphoplasty in lumbar compression fractures: technique, anatomy and preliminary results. *J Korean Neurosurg Soc.* 2011 May;49(5):273-7. doi: 10.3340/jkns.2011.49.5.273. Epub 2011 May 31. PMID: 21716899; PMCID: PMC3115147.
12. Fang M, Zhou J, Yang D, He Y, Xu Y, Liu X, et al. Management and outcomes of spinal epidural hematoma during vertebroplasty. *Medicine (Baltimore)*. 2018 May;97(21):e10732. doi: 10.1097/MD.0000000000010732. PMID: 29794750; PMCID: PMC6393141.
13. Ebraheim NA, Xu R, Darwich M, Yeasting RA. Anatomic relations between the lumbar pedicle and the adjacent neural structures. *Spine* (Phila Pa 1976). 1997 Oct 15;22(20):2338-41. doi: 10.1097/00007632-199710150-00003. PMID: 9355213.
14. Cohen MS, Wall EJ, Brown RA, Rydevik B, Garfin SR. 1990 AcroMed Award in basic science. Cauda equina anatomy. II: Extrathecal nerve roots and dorsal root ganglia. *Spine* (Phila Pa 1976). 1990 Dec;15(12):1248-51. PMID: 2281367.
15. Solitro GF, Whitlock K, Amirouche F, Mehta AI, McDonnell A. Currently adopted criteria for pedicle screw diameter selection. *Int J Spine Surg.* 2019 Apr 30;13(2):132-145. doi: 10.14444/6018. PMID: 31131212; PMCID: PMC6510178.
16. Meisterhans M, Hagel V, Spirig JM, Fasser MR, Farshad M, Widmer J. The biomechanics of the transpedicular endoscopic approach. *Spine* (Phila Pa 1976). 2024 Aug 1;49(15):1052-1058. doi: 10.1097/BRS.0000000000004871. Epub 2023 Nov 7. PMID: 37942817; PMCID: PMC11232940.

17. Pacha TO, Omar M, Graulich T, Suero E, Mathis SchrÖder B, Krettek C, Stubig T. Comparison of preoperative pedicle screw measurement between computed tomography and magnet resonance imaging. *Int J Spine Surg.* 2020 Oct;14(5):671-680. doi: 10.14444/7098. Epub 2020 Oct 23. PMID: 33097582; PMCID: PMC7671442..
18. Sarwahi V, Amaral T, Wendolowski S, Gecelter R, Sugarman E, Lo Y, et al. MRIs are less accurate tools for the most critically worrisome pedicles compared to CT scans. *Spine Deform.* 2016 Nov;4(6):400-406. doi: 10.1016/j.jspd.2016.08.002. Epub 2016 Oct 26. PMID: 27927568.
19. Goyal DKC, Tarazona DA, Segar A, Sutton R, Motto MA, Divi SN, et al. Lumbar pedicle morphology and vertebral dimensions in isthmic and degenerative spondylolisthesis—a comparative study. *Int J Spine Surg.* 2021 Apr;15(2):243-250. doi: 10.14444/8009. Epub 2021 Feb 18.
20. Bailey JF, Liebenberg E, Degmetich S, Lotz JC. Innervation patterns of PGP 9.5-positive nerve fibers within the human lumbar vertebra. *J Anat.* 2011 Mar;218(3):263-70. doi: 10.1111/j.1469-7580.2010.01332.x. Epub 2011 Jan 12. PMID: 21223256; PMCID: PMC3058212.
21. Degmetich S, Bailey JF, Liebenberg E, Lotz JC. Neural innervation patterns in the sacral vertebral body. *Eur Spine J.* 2016 Jun;25(6):1932-8. doi: 10.1007/s00586-015-4037-4. Epub 2015 Jun 16. PMID: 26077098; PMCID: PMC4681698.
22. Lorio M, Olivier Clerk-Lamalice, Beall DP, Julien T. International Society for the Advancement of Spine Surgery guideline—intraosseous ablation of the basivertebral nerve for the relief of chronic low back pain. *Int J Spine Surg.* 2020 Feb 29;14(1):18-25. doi: 10.14444/7002. PMID: 32128298; PMCID: PMC7043835.
23. Fogel G, Musie J, Phillips TR, Shonnard M, Youssef S, Hirsch JA, et al. Assessment and management of patients developing low energy vertebral compression fractures following basivertebral nerve ablation. *Pain Med.* 2024 Mar 1;25(3):249-251. doi: 10.1093/pm/pnad132. PMID: 37756701.