




# Proposal of a Route Map for Cervical Spinal Ultrasonography: A Simple and Clear Learning Tool for Beginners

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Received: May 14, 2023 / Accepted: July 18, 2023 / Published online: July 30, 2023  
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## ABSTRACT

Spinal ultrasonography has increasingly been used to image axial structures from the cervical to sacral region in recent years. In this work, we propose a comprehensive, systematic cervical scanning protocol that we refined as a route map, especially for beginners, to facilitate teaching, learning, diagnosis, and treatment in clinical pain practice. As a simple and clear tool to demonstrate the scanning protocol, the route map is delineated with rectangles, lines, and arrows. The rectangles represent the positions of the transducer, the arrows indicate route directions, and the lines show the routes of transducer movement. In this article, we describe cervical spinal ultrasonography to illustrate the route map interpretation, scanning protocol and target anatomical structures in detail. We believe that this comprehensive, clear, systematic, and portable route map will be beneficial for inexperienced pain clinicians and ultrasound beginners.

**Keywords:** Spinal ultrasonography; Route map; Learning tool; Teaching efficiency

## Key Summary Points

This article introduced the novel idea of a route map that was refined from a comprehensive, systematic scanning protocol for cervical spinal ultrasonography.

The route map is delineated with concise rectangles, lines, and arrows.

The route map may be a simple, clear, systematic, comprehensive, and portable tool for cervical spinal ultrasonography beginners and pain practitioners to learn quickly, scan precisely, and operate safely.

We believe the route map has potential for application in bedside teaching, learning, ultrasound diagnosis, ultrasound-guided interventions, text curricula, and training workshops, among other areas.

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## INTRODUCTION

Ultrasonography can be cost-effective and affordable, especially in resource-constrained settings. It has recently become used to image axial structures and guide procedures for spinal interventions because of its ease of use, good success rates, and lack of radiation. For spinal pain, most typical imaging examinations and interventional procedures performed under fluoroscopy have also been reportedly performed under ultrasound guidance [1]. For certain types of cervical pain injection therapy, there is also evidence that ultrasound provides noninferior guiding effects when compared with computed tomography [2]. Ultrasonography guidance has many advantages: no ionizing radiation, real-time guidance, high spatial resolution, excellent soft tissue contrast, and the ability to identify and avoid critical structures [3]. Moreover, shear-wave elastography has recently been introduced on clinical scanners, with a promising role in determining the severity of disease and treatment follow-up of various musculoskeletal tissues, including muscles, nerves, and ligaments [4].

Currently, ultrasound-guided techniques are well established for demonstration of the lumbar anatomy, intraspinal anesthesia of the lumbar canal [5], and treatment of lumbar spondyloarthropathy [6, 7]. However, ultrasound guidance has not been widely implemented in other regions of the spine. For untrained beginners and intermediate practitioners, spinal ultrasonography involves abundant sonographic sections and rich details, which are challenging to organize mentally and memorize. To simplify spinal ultrasonography and create a more methodical approach, making it easier to teach and learn, by summarizing clinical experience and reviewing previous literature, we extracted a systematic scanning protocol for the cervical spine and then refined and delineated it as a route map using rectangles, lines, and arrows.

The purpose of this article is to introduce the route map as a novel tool for learning cervical spinal ultrasonography. In this article, we comprehensively describe the corresponding

approaches and propose the route map as a simple and clear learning tool for educational and practical use by inexperienced pain clinicians.

## METHODS

This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

### Overview of the Route Map

Figures 1 and 2 demonstrate programmed travel routes for the cervical ultrasound scan. Figure 1 includes both the anatomical diagram and the ultrasonography route map. Figure 2 is an express edition of the route map. In the route map, the rectangles represent the positions of the transducer. The black rectangles mark initial starting points, while the white rectangles mark transfer points or termini of transducer routes. The arrows indicate route directions. Full lines show the transducer route paths on the initial side of the body, while dashed lines indicate the paths in other orientations, i.e., anterior, posterior, anterolateral, posterolateral, or lateral.

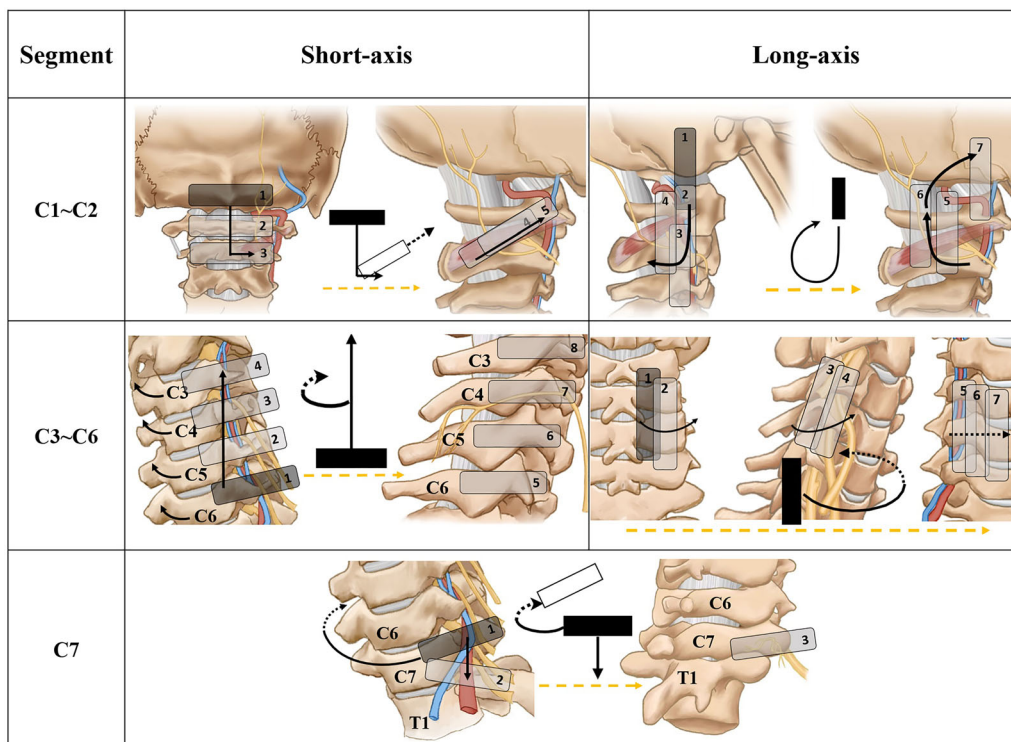
## RESULTS

### Scanning Protocol and Route Map Interpretation

On account of the different scanning protocols, the upper (C1 ~ C2), middle (C3–C6), and lower (C7) parts of the cervical region are described separately in the map. Ultrasonography for each region is summarized along both the short and long axes of the cervical spine.

### OVERVIEW OF THE UPPER CERVICAL REGION (C1–C2)

Ultrasonography of the atlas (C1) and axis (C2) is unique because of their characteristic anatomical structures [8]. The transverse



**Fig. 1** The programmed travel routes for the cervical ultrasound scan route map, including both the anatomical diagram and the simple ultrasonography route map

Segment	Short-axis	Long-axis
C1~C2		
C3~C6		
C7		

**Fig. 2** The express edition of the ultrasonography route map

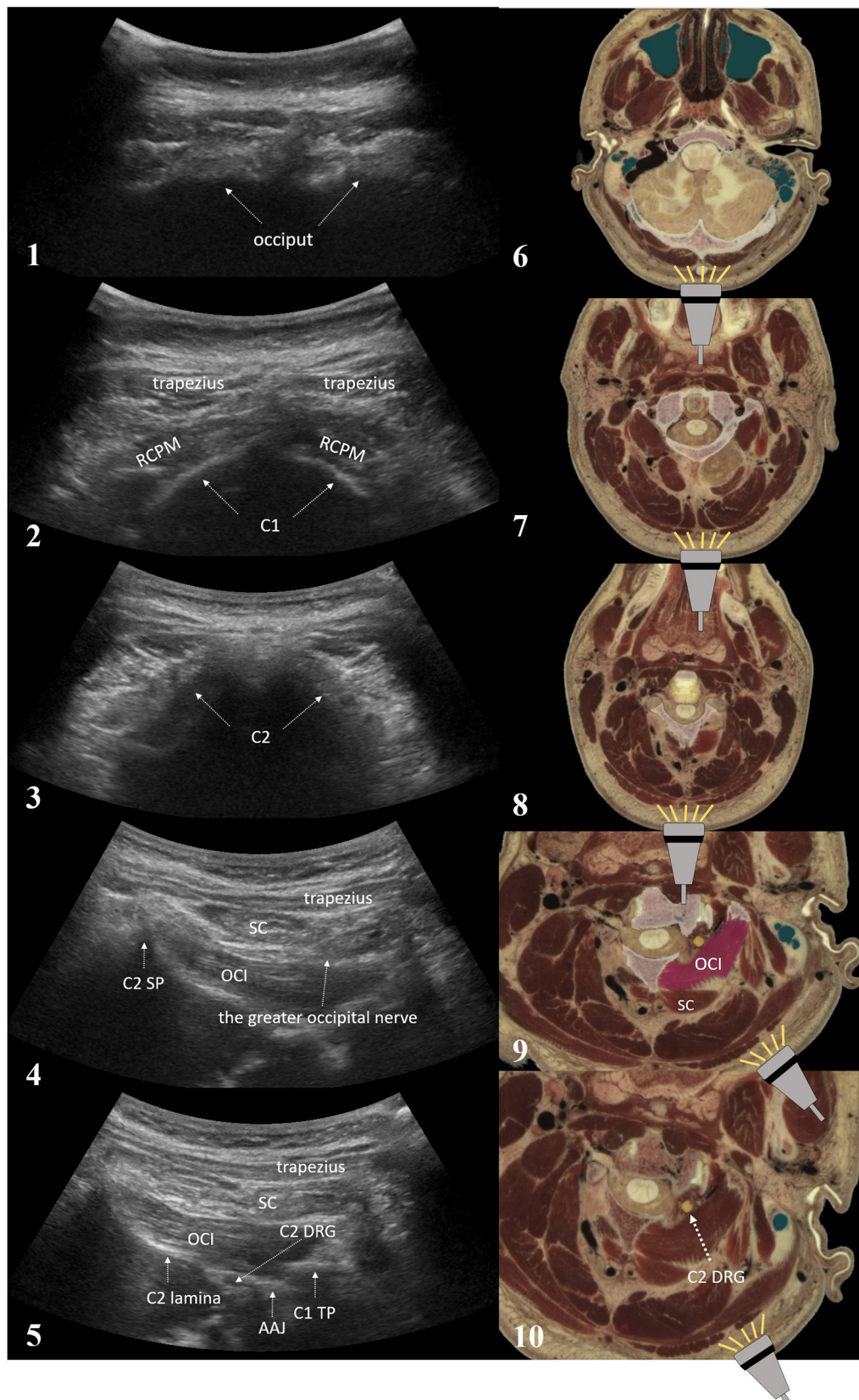
process of C1 is large and convex, and its spinous process is replaced by a posterior tubercle, which is a unique feature among all other

vertebrae. The vertebral body and lamina of C1 are absent. Because of the thinness of its anterior and posterior arches, there are relatively wide spaces between the atlas, occiput, and axis. Moreover, the atlantoaxial joint is near the C2 dorsal root ganglion and vertebral artery.

In this area, five short-axis and seven long-axis scanning sections are summarized in the route map. A linear array probe is usually used in this region. A convex array probe may also be considered for long-axis ultrasonography in particular sections.

**Short-Axis Ultrasonography (Fig. 3)**

Patients take a prone or sitting posture with their head lowered. As shown in Figs. 1 and 3, the transducer is initially placed in the middle of the occiput at position 1 and then moved caudally to positions 2 and 3 to visualize the posterior arch of C1 and the spinous process of C2. The transducer is relocated obliquely to position 4, in parallel with the obliquus capitis



◀**Fig. 3** Ultrasound images and anatomical illustration along the short axis regarding the route map of the upper cervical vertebral region (C1–C2). 1–5, ultrasound images at positions 1–5; 6–10, transducer positions and anatomical illustration at positions 1–5. *RCPM* rectus capitis posterior minor muscle, *SC* semispinalis capitis, *OCI* obliquus capitis inferior muscle, *SP* spinous process, *DRG* dorsal root ganglion, *AAJ* atlantoaxial joint, *TP* transverse process. The anatomical images were generated using VH Dissector software (Touch of Life Technologies, <http://www.toltech.net>)

inferior muscle. At this point, the trapezius, semispinalis capitis, and obliquus capitis inferior muscles can be seen from shallow to deep. Within the fascia between the semispinalis capitis and obliquus capitis inferior muscles, a long-axis view of the greater occipital nerve can be obtained for use in guiding various pain treatments [9]. Then, the transducer is moved slightly anterolaterally to position 5 to view the atlantoaxial joint and C2 dorsal root ganglion, which lies on the surface of the atlantoaxial joint [10]. The vertebral artery can also be seen on the lateral edge of the display [11].

### Long-Axis Ultrasonography (Figs. 4 and 5)

Patients take a lateral or sitting posture with their head lowered. As shown in Figs. 4 and 5, the transducer is initially placed at the caudal end of the mastoid process at position 1. Then, the transducer is moved caudally to position 2 to locate the transverse process of C1 and C2 and obtain a view of the C2–C3 facet joint at position 3. Over the surface of the C2–C3 facet joint, the third occipital nerve passes, which can be visualized as a hypoechoic oval structure. The transducer is then brought headward to position 4 to detect the C2 nerve root or the initiation site of the C2 dorsal rami at the C2 vertebral pedicle. Then, the transducer is moved to position 5 for scanning of the C2 dorsal root ganglion, which lies on the atlantoaxial joint and beneath the obliquus capitis inferior muscle. Injury of the vertebral artery or entry of the spinal canal must be carefully avoided when pain interventions are performed nearby. The

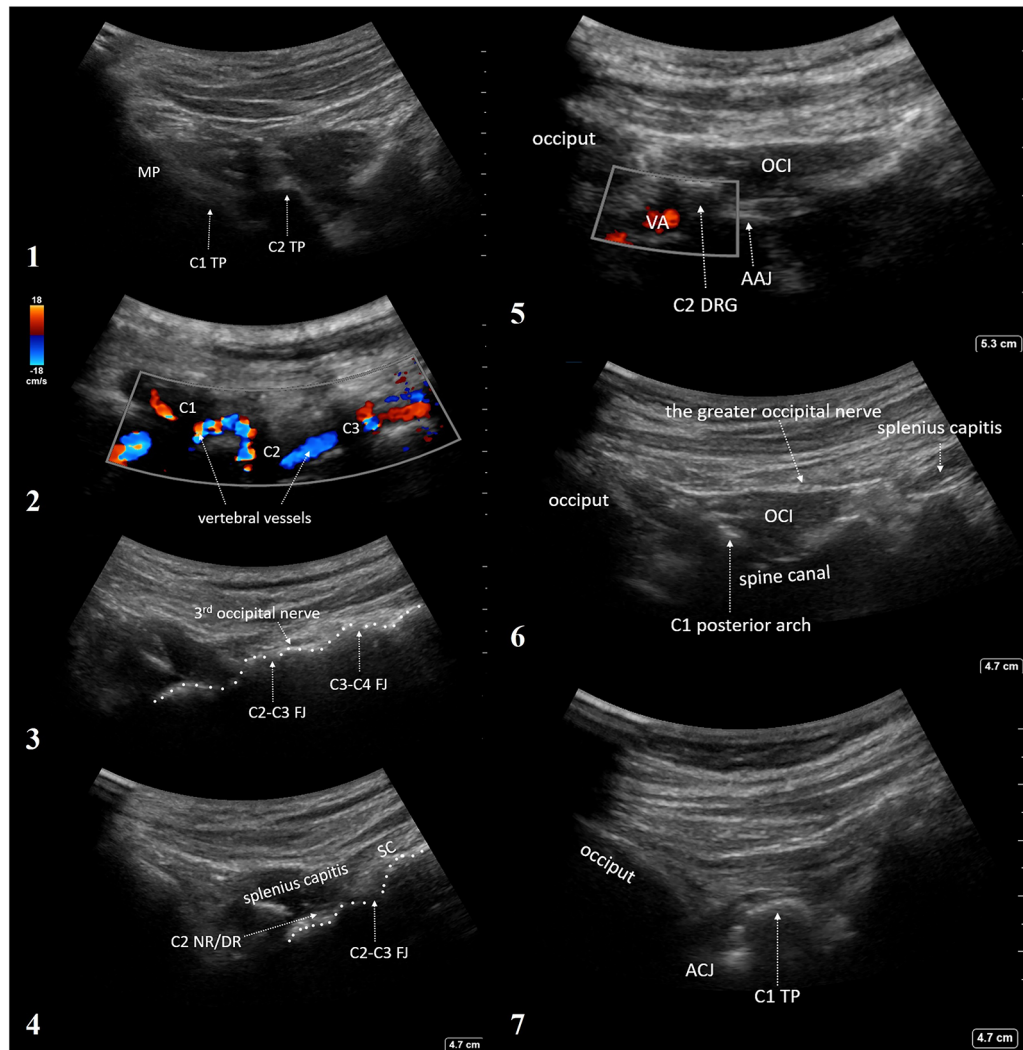
transducer is relocated dorsad to position 6, where the greater occipital nerve can be observed on top of the obliquus capitis inferior muscle and blocked. Finally, the transducer is shifted cephalad to position 7, with the head end of the transducer between the mastoid process and occipital protuberance. Here, the atlanto-occipital joint can be observed between the occipital bone and C1 transverse process [12]. Note that operators must carefully identify the nearby vertebral blood vessels and spinal canal structure before performing injections into the atlanto-occipital joint. Color Doppler examination is highly recommended.

### Overview of Middle Cervical Vertebrae (C3–C6)

Middle cervical vertebrae (C3–C6) share similar anatomical structures and ultrasonography. It is the most commonly involved part in the clinical setting. In this region, eight short-axis and seven long-axis (Fig. 1) scanning sections are summarized in the route map.

### Short-Axis Ultrasonography (Fig. 6)

Patients are placed in a lateral posture or supine position with their head rotated to the contralateral side. Check each of the four TPs from bottom to top, as shown in Figs. 1 and 6. C7 TP is easily recognized because it has no anterior but only a posterior tubercle. As the transducer moves up from position 1 to 4, the anterior and posterior tubercles of the TPs from the C6 to C3 vertebral levels appear, and the ventral rami can also be seen as a hypoecho section as they run above the TPs after exiting the intervertebral foramen [13]. The cervical plexus passing through the prevertebral fascia and envelope fascia and superior cervical ganglion can be located at positions 3 and 4 [14]. Rotate the transducer 90° to position 5–8; here are targets for the injection therapy of the medial branch of the spinal nerves' dorsal rami.



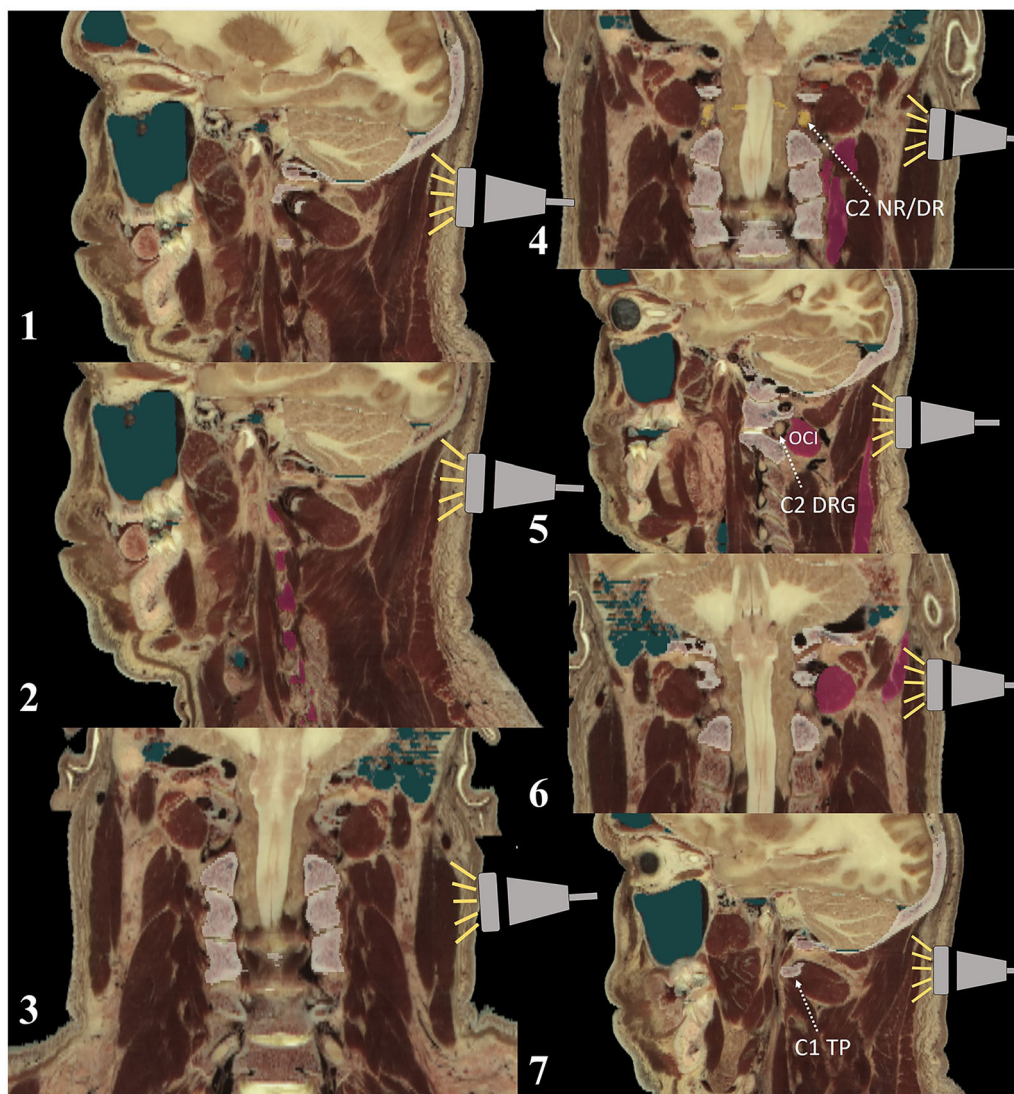
**Fig. 4** Ultrasound images along the long axis regarding the route map of the upper cervical vertebral region (C1–C2). 1–7, ultrasound images at positions 1–7. *MP* mastoid process, *TP* transverse process, *FJ* facet joint, *NR/DR* nerve

root/dorsal rami, *SC* semispinalis capitis, *OCI* oblique capitis inferior muscle, *AAJ* atlantoaxial joint, *DRG* dorsal root ganglion, *VA* vertebral artery, *ACJ* atlanto-occipital joint

### Long-Axis Ultrasonography (Figs. 7 and 8)

As a scan from dorsally to ventrally (Fig. 1), patients may take a prone posture with their heads lowered, lateral and supine posture successively. As shown in Figs. 7 and 8, start from the paraspinous scan at position 1 to check the ligamentum flavum and spinal dura. Slide to position 2 to locate the imbricate facet joint. Then, move laterally to position 3 to obtain the plane of “wave”, in which the joint space lies in

the crest and medial branch of the dorsal rami in the trough [15]. Moving ventralward to position 4, a long, hypoechoic ventral ramus can be observed emerging from the intertubercular grooves of the TP. Place the transducer at position 5 to check the vertebral artery beside the anterior tubercle. Then, advancing to position 6, the “waves” seen here are the uncovertebral joints. Finally, shift the transducer inward to position 7, press to obtain images of the anterior vertebrae and intervertebral discs.



**Fig. 5** Anatomical illustration along the long axis regarding the route map of the upper cervical vertebral region (C1–C2). 1–7, transducer positions and anatomical illustration at positions 1–7. *NR/DR* nerve root/dorsal

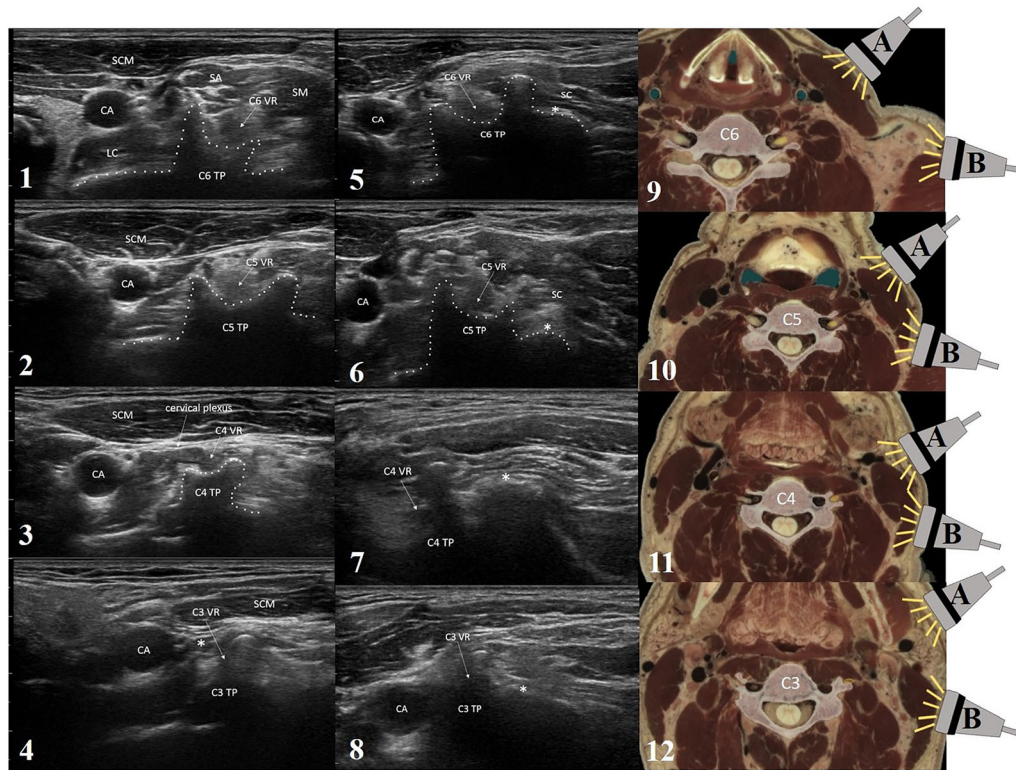
rami, *DRG* dorsal root ganglion, *OCI* obliquus capitis inferior muscle, *TP* transverse process. The anatomical images were generated using VH Dissector software (Touch of Life Technologies, <http://www.toltech.net>).

### Overview of the Lower Cervical Vertebra (C7)

The structure of the lower vertebra C7 is different from that of other cervical vertebrae; the SP of C7 is unforked, and the TP is broad without an anterior tubercle. The scanning protocol of the lower cervical vertebra is described differently as well.

### Ultrasonography (Fig. 9)

The ultrasonography scanning protocol includes one dorsal plane and two ventral planes (Fig. 1). First, patients take supine posture with their head rotated to the contralateral side. As shown in Fig. 9, put the transducer on the supraclavicular fossa, move upward to recognize the C7 TP, which has only a posterior tubercle at position 1. Hypoechoic C7 ventral



**Fig. 6** Ultrasound images and anatomical illustration along the short axis regarding the route map of the middle cervical vertebral region (C3–C6). 1–8, ultrasound images at positions 1–8; 9A, 10A, 11A, 12A, transducer positions and anatomical illustration at positions 1–4; 9B, 10B, 11B, 12B, transducer positions and anatomical illustration at

positions 5–8. *SCM* sternocleidomastoid, *CA* carotid artery, *LC* longus colli, *SA* scalenus anterior, *VR* ventral rami, *SM* scalenus medius, *TP* transverse process. The anatomical images were generated using VH Dissector software (Touch of Life Technologies, <http://www.toltech.net>)

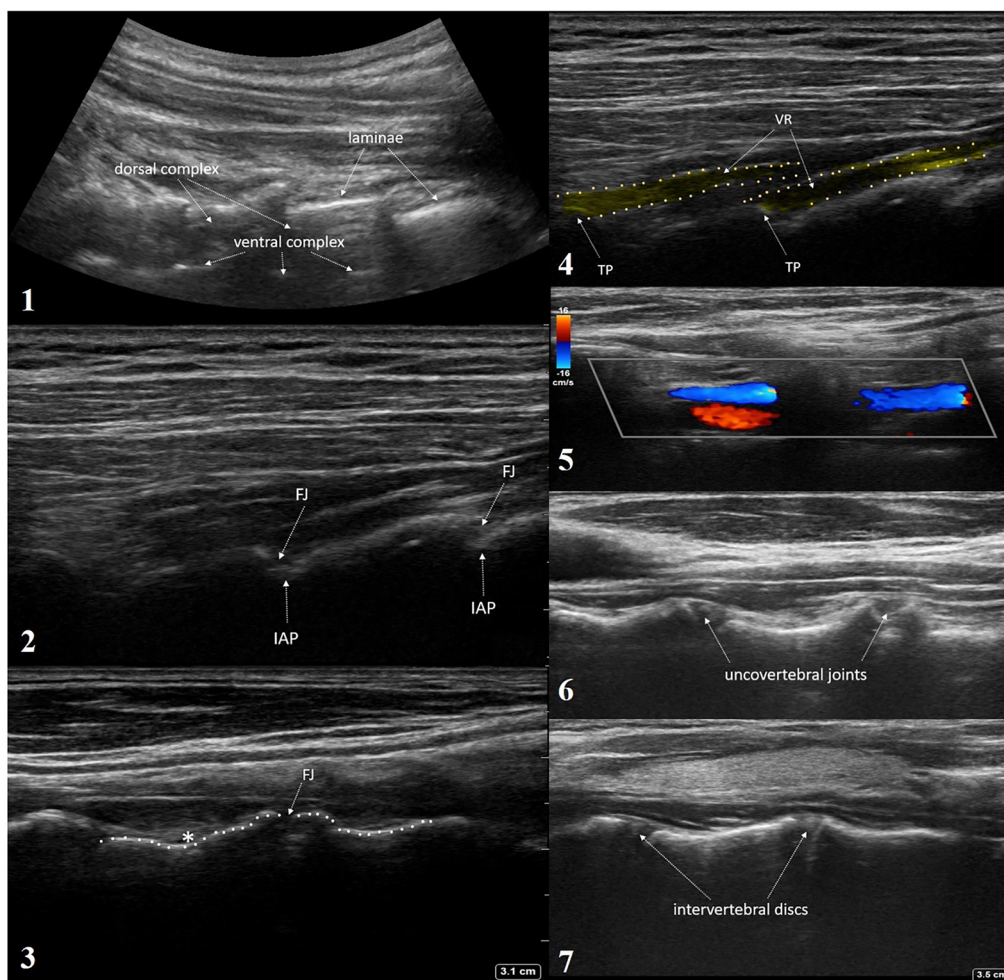
ramus can be seen between the TP and vertebral artery. Injection of the C7 ventral ramus or cervical sympathetic ganglion can be performed at position 1. Then, slide caudalward until the C7 TP disappears, and the C8 ventral ramus and 1st rib emerge at position 2 [16]. Doppler imaging is recommended to enhance the vertebral artery since most of them have not entered the foramen transversalis of the TP at the C7 level. Shift patients to side-lying or sitting posture. Position 3 is designed to see the medial branch of the dorsal rami. It can be located at the waist of the cervical facet column, as shown in Figs. 1 and 9.

## DISCUSSION

As indicated above, we introduced the route map for spinal ultrasonography in the cervical region to help beginners accomplish clinical scanning and interventional therapy.

Previous literature has described the anatomical relationships and probe positions for corresponding ultrasound images of commonly scanned spinal structures, aiming to provide a standardized approach for spinal ultrasonography [17]. Starting from this integrated framework, we have made further refinements to this scanning protocol; for instance, we introduced more scanning planes and detailed the cervical region into three distinct partitions regarding different segments, namely, the upper, middle, and lower regions.



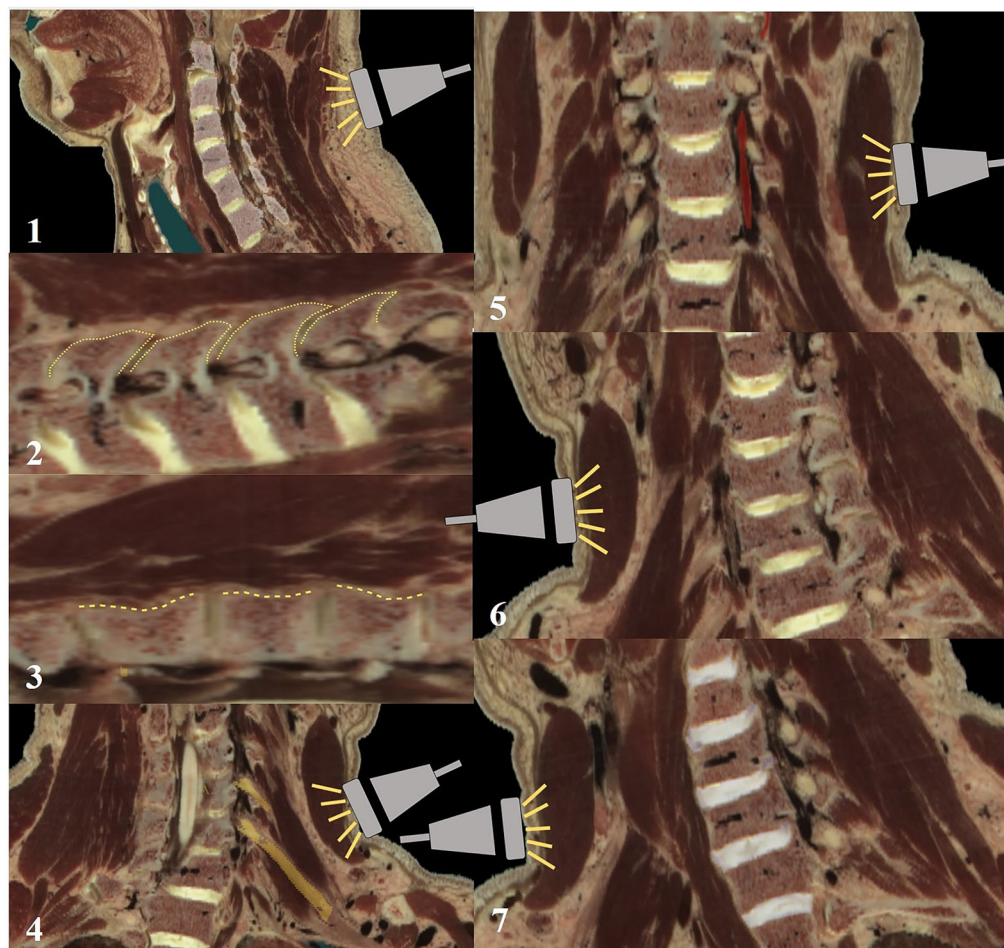


**Fig. 7** Ultrasound images along the long axis regarding the route map of the middle cervical vertebral region (C3–C6). 1–7, ultrasound images at positions 1–7. *FJ* facet joint, *IAP* inferior articular process, *VR* ventral rami, *TP* transverse process

The concise route map, which was then summarized and integrated, indicates not only the probe positions but also the routes of probe movement. In addition, to verify the reliability and reproducibility of the ultrasound scan technique described in this article, we dissected the neck region using human anatomy modeling software (VH Dissector, Touch of Life Technologies, <http://www.toltech.net>). The related dissected sectional images are shown in the article figures. Similarly, the route map can be further generalized and used in all other regions of the spine, including the thoracic, upper/middle/lower lumbar and sacrococcygeal regions. We believe this route map may contribute to pain clinicians' dynamic, coherent

clinical thinking when learning and performing spinal ultrasonography.

Specifically, there are several advantages of the route map. First, it is comprehensive, clear, systematic, and portable. The route map may help guide the operator back to the starting point or one of the transfer points upon the operator losing their orientation during scanning. Second, the comprehensive and coherent route map may help clinicians achieve objectives through other anatomical landmarks to avoid omission. Third, the ultrasonographic sections are adjacent to each other in the neck region. Beginners are prone to mistaking one section for another, for example, mistaking the lamina for the facet joint. From this perspective,



**Fig. 8** Anatomical illustration along the long axis regarding the route map of the middle cervical vertebral region (C3–C6). 1–7, transducer positions and anatomical illustration at positions 1–7. The anatomical images were

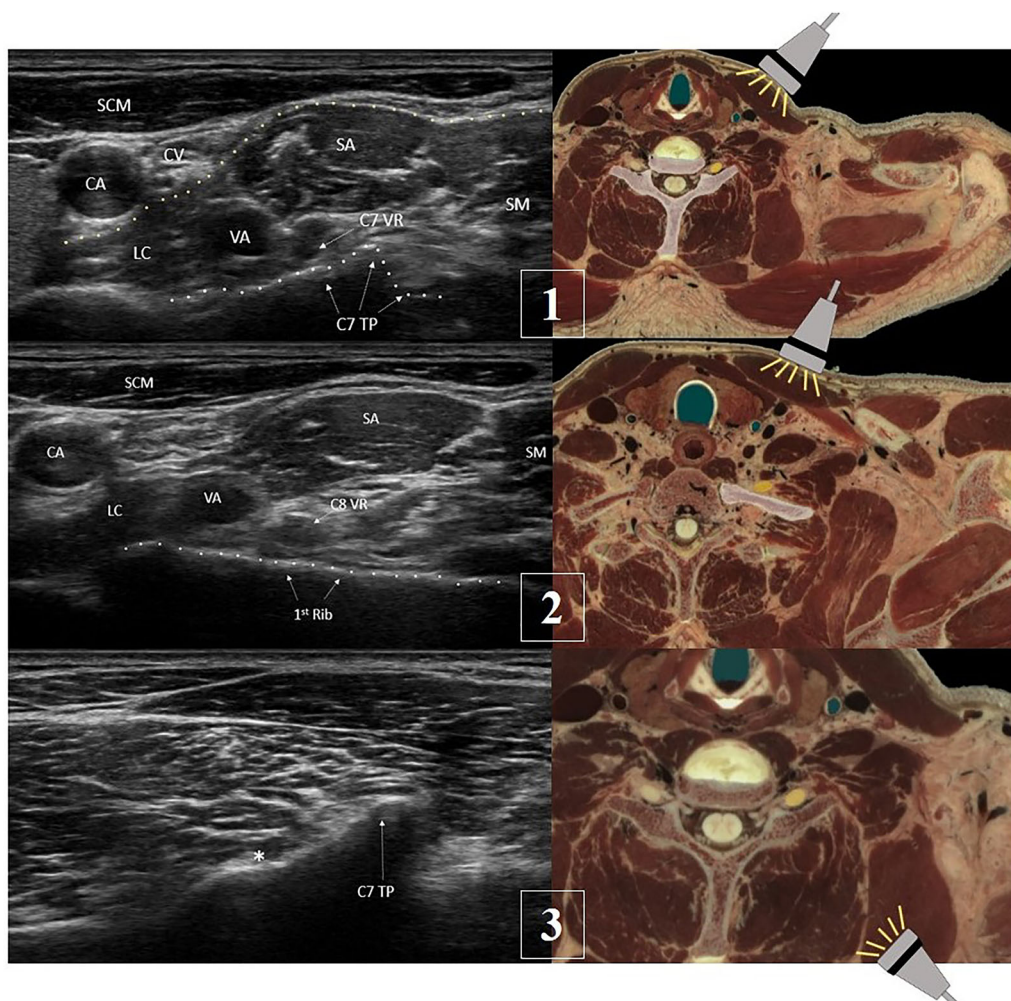
generated using VH Dissector software (Touch of Life Technologies, <http://www.toltech.net>)

the route map may help beginners operate more safely. Additionally, the portability of the map allows it to be posted on ultrasound equipment or a classroom wall or carried around in one's pocket.

The route map has potential for application in bedside teaching, learning, ultrasound diagnosis, ultrasound-guided interventions, text curricula, and training workshops, among other areas. We hope that with the help of this route map, the learning curve for inexperienced beginners in spinal ultrasonography can be improved, and the rates of missed diagnosis and misdiagnosis can be decreased.

Notably, although spinal ultrasonography has certain advantages, pain physicians should be aware of its limitations, particularly the challenges in sonographic visualization of deep and bony structures. Advantages and disadvantages should be weighed carefully when deciding between ultrasound and other methods of visualization [18]. Further studies are needed to evaluate the safety and efficacy of ultrasound guidance compared with fluoroscopy and computed tomography guidance in spinal procedures.

Applications of the route map may have limitations considering the following aspects. First, the proposed map is based on normal



**Fig. 9** Ultrasound images and anatomical illustration regarding the route map of the lower cervical vertebral region (C7). [1]~[3] [1]–[3], the ultrasound images, the transducer positions and anatomical illustration at positions 1–3. *SCM* sternocleidomastoid, *CA* carotid artery,

*CV* carotid vein, *LC* longus colli, *VA* vertebral vessels, *SA* scalenus anterior, *SM* scalenus medius, *TP* transverse process, *VR* ventral rami. The anatomical images were generated using VH Dissector software (Touch of Life Technologies, <http://www.toltech.net>)

anatomical structures of the spine. The utility of the route map in patients with abnormal spinal anatomy, especially severe spinal malformations or a history of spinal surgery, may be partly limited. Recently, we reported ultrasound-guided location and nusinersen administration for spinal muscular atrophy patients with severe scoliosis [19]. Second, since the spinal anatomy of children/newborns is slightly different from that of adults [20], the route map and methods for its clinical use in children may require further modification. Finally, we regard

the route map as a simple and clear tool for spinal ultrasonography beginners to learn. However, as an exploratory study, we did not accomplish the verification of usefulness in teaching and learning. Future research to evaluate the efficacy of this learning tool is warranted.

## CONCLUSIONS

The route map can be used as a simple and clear learning tool in cervical spinal ultrasonography. Its comprehensiveness, clarity, systematic organization, and portability allow pain clinicians and ultrasound beginners to learn quickly, scan precisely, and operate safely.

## ACKNOWLEDGEMENTS

We would like to thank Dr. Shaofeng Pu for his valuable consultations. We would also like to thank Touch of Life Technologies (<http://www.toltech.net>) for granting permission to use images from VH Dissector software in this manuscript.

**Author Contributions.** Si Chen, methodology and writing. Jiao Zhang, methodology and software. Yuda Fei, study coordination. Xulei Cui, conceptualization, supervision and funding acquisition. Le Shen, critical revision and funding acquisition. Yuguang Huang, critical revision.

**Funding.** This work was supported by National High Level Hospital Clinical Research Funding (Grant Number: 2022-PUMCH-B-007) and the Chinese Academy of Medical Sciences Innovation Fund for Medical Sciences and Health (Grant Number: 2021-I2M-C&T-B-015). The funding organizations had no role in the study design, data collection and analysis, decision to publish, or manuscript preparation. The journal's Rapid Service Fee was provided by the authors.

**Disclosures.** Si Chen, Jiao Zhang, Yuda Fei, Xulei Cui, Le Shen and Yuguang Huang have nothing to disclose.

**Compliance with Ethics and Guidelines.** This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

**Data Availability.** Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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## REFERENCES

1. Hurdle MF. Ultrasound-guided spinal procedures for pain: a review. *Phys Med Rehabil Clin N Am.* 2016;27(3):673–86.
2. Yue L, Zheng S, Hua L, Li H, Yang Y, Li J, He L. Ultrasound-guided versus computed tomography fluoroscopy-assisted cervical transforaminal steroid injection for the treatment of radicular pain in the lower cervical spine: a randomized single-blind controlled noninferiority study. *Clin J Pain.* 2023;39(2):68–75.
3. Lin JS, Gimarc DC, Adler RS, Beltran LS, Merkle AN. Ultrasound-guided musculoskeletal injections. *Semin Musculoskelet Radiol.* 2021;25(6):769–84.
4. Wee TC, Simon NG. Ultrasound elastography for the evaluation of peripheral nerves: a systematic review. *Muscle Nerve.* 2019;60(5):501–12.
5. Perlas A, Chaparro LE, Chin KJ. Lumbar neuraxial ultrasound for spinal and epidural anesthesia: a systematic review and meta-analysis. *Reg Anesth Pain Med.* 2016;41(2):251–60.

6. Loizides A, Peer S, Plaikner M, et al. Ultrasound-guided injections in the lumbar spine. *Med Ultrason*. 2011;13(1):54–8 (Erratum in: *Med Ultrason*. 2011; Jun;13(2):178).
7. Wang Y, Wang AZ, Wu BS, et al. Chinese Association for the Study of Pain: experts consensus on ultrasound-guided injections for the treatment of spinal pain in China (2020 edition). *World J Clin Cases*. 2021;9(9):2047–2057.
8. Waxenbaum JA, Futterman B. Anatomy, back, cervical vertebrae. In: StatPearls. Treasure Island: StatPearls Publishing; 2019.
9. Vanderhoek MD, Hoang HT, Goff B. Ultrasound-guided greater occipital nerve blocks and pulsed radiofrequency ablation for diagnosis and treatment of occipital neuralgia. *Anesth Pain Med*. 2013;3(2):256–9.
10. Li J, Yin Y, Ye L, Zuo Y. Pulsed radiofrequency of C2 dorsal root ganglion under ultrasound guidance for chronic migraine: a case report. *J Pain Res*. 2018;11:1915–9.
11. Kariya K, Usui Y, Higashi N, et al. Anatomical basis for simultaneous block of greater and third occipital nerves, with an ultrasound-guided technique. *J Anesth*. 2018;32(4):483–92.
12. Won SJ, Lee UY, Cho SU, Rhee WI. Feasibility of ultrasound-guided atlanto-occipital joint injection. *Ann Rehabil Med*. 2012;36(5):627–32.
13. Jee H, Lee JH, Kim J, Park KD, Lee WY, Park Y. Ultrasound-guided selective nerve root block versus fluoroscopy-guided transforaminal block for the treatment of radicular pain in the lower cervical spine: a randomized, blinded, controlled study. *Skelet Radiol*. 2013;42(1):69–78.
14. Narouze S. Ultrasound-guided stellate ganglion block: safety and efficacy. *Curr Pain Headache Rep*. 2014;18(6):424.
15. Chang KV, Wu WT, Özçakar L. Ultrasound-guided interventions of the cervical spine and nerves. *Phys Med Rehabil Clin N Am*. 2018;29(1):93–103.
16. Karmakar MK, Pakpirom J, Songthamwat B, Areeruk P. High definition ultrasound imaging of the individual elements of the brachial plexus above the clavicle. *Reg Anesth Pain Med*. 2020;45(5):344–50.
17. Chang KV, Kara M, Su DC, et al. Sonoanatomy of the spine: a comprehensive scanning protocol from cervical to sacral region. *Med Ultrason*. 2019;21(4):474–82.
18. Chi M, Chen AS. Ultrasound for lumbar spinal procedures. *Phys Med Rehabil Clin N Am*. 2018;29(1):49–60.
19. Zhang J, Cui X, Chen S, Dai Y, Huang Y, Zhang S. Ultrasound-guided nusinersen administration for spinal muscular atrophy patients with severe scoliosis: an observational study. *Orphanet J Rare Dis*. 2021;16(1):274.
20. Alvarado E, Leach J, Caré M, Mangano F, Hara SO. Pediatric spinal ultrasound: neonatal and intraoperative applications. *Semin Ultrasound CT MR*. 2017;38(2):126–42.