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REVIEW

Diagnosis and Treatment of Cervical Spondylotic Radiculopathy Using Selective Nerve Root Block (SNRB): Where are We Now?

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ABSTRACT

Cervical spondylotic radiculopathy (CSR) is one of the most common degenerative diseases of the spine that is commonly treated with surgery. The primary goal of surgery is to relieve symptoms through decompression or relieving pressure on compressed cervical nerves. Nevertheless, cutaneous pain distribution is not always predictable, making accurate diagnosis challenging and increasing the likelihood of inadequate surgical outcomes. With the widespread application of minimally invasive surgical techniques, the requirement for precise preoperative localization of the affected segments has become critical, especially when treating patients with multi-segmental CSR. Recently, the preoperative use of a selective nerve root block (SNRB) to localize the specific nerve roots involved in CSR has increased. However, few reviews discuss the currently used block approaches, risk factors, and other aspects of concern voiced by surgeons carrying out SNRB. This review summarized the main cervical SNRB approaches currently used clinically and the relevant technical details. Methods that can be used to decrease risk during cervical SNRB procedures, including choice of steroids, vessel avoidance, guidance with radiographs or ultra-sound, contrast agent usage, and other concerns, also are discussed. We concluded that a comprehensive understanding of the current techniques used for cervical SNRB would allow surgeons to perform cervical SNRB more safely.

Keywords: Cervical radiculopathy; Nerve block; Anesthesia; Nerve root compression

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Key Summary Points

This review classified the current approaches used for cervical nerve root blocks for diagnosis or treatment and ways to decrease the risk of complications.

The approaches involved in the reviewed articles were divided into four categories according to the respective needle trajectory: (1) the anterolateral approach; (2) the lateral approach; (3) the posterolateral approach; and (4) the dorsal approach. Each approach presented specific anatomic considerations for certain conditions and respective risks for injury.

Specifically, (1) use of small-particle steroids might reduce spinal cord or brain infarction; (2) increased familiarity with the anatomy of regional vessels results in fewer injections into critical arteries; (3) additional procedures such as the use of a lower needle trajectory in the anterolateral approach, the intraoperative lateral view of the cervical spine, and use of contrast agents might help improve the success of cervical nerve root blocks.

It is beneficial for surgeons to be proficient in multiple techniques, which allows successful management of a range of conditions that arise during selective nerve root blocks. Furthermore, the information provided in this review might allow surgeons to perform cervical nerve root blocks more safely.

INTRODUCTION

Cervical spondylotic radiculopathy (CSR) is a common degenerative disease that is usually treated with a nerve root block or surgery. Especially for minimally invasive cervical surgery, the accurate preoperative assessment of the affected nerve roots is strongly linked with positive postoperative outcomes. It has been reported that approximately 26% of patients tend to report persistent, significant pain during postoperative follow-up assessments [1]. Studies [2, 3] have revealed that atypical cutaneous pain distribution is commonly observed in many cases (24–50% of cases), which, in turn, may decrease the reliability of diagnosis using MRI and neurological examination.

Selective nerve root block (SNRB) is a treatment for CSR to relieve pain in the neck, arms, and shoulders resulting from compressed nerve roots within the cervical spine. Initially, SNRB was primarily used by anesthesiologists or radiologists. Due to its low risk of pharyngeal and esophageal structural damage, SNRB has also been increasingly used as a preoperative diagnostic method to determine affected nerve roots [4]. To our knowledge, few reviews have discussed cervical SNRB. Therefore, this narrative review summarized the brief history and technical details of the various cervical SNRB approaches that are in use currently and factors that could prevent complications, including choice of steroids, vessel avoidance, the guidance method used, use of contrast agents, and other concerns. The author searched PubMed, MEDLINE, and Google Scholar (1950–2021), using the terms “cervical” AND “radiculopathy” AND “nerve root block*”. Related supporting literature from the articles that were retrieved also were examined.

The first cervical spine epidural injection was performed by Dogliotti in 1933 [5]. The block was performed using an intervertebral approach to carry out surgical anesthesia. However, due to the narrow space between the ligamentum flavum and dura (1.5–2 mm in C7) [6], this approach has not been performed routinely for decades. Approximately 20 years later, Robechi and Livre reported using epidural cortisone injections to treat lower back pain [7, 8]. The advent of radiography significantly improved the accuracy and safety of spinal nerve root blocks. Since the 1980s, the clinical application of cervical epidural injections has increased gradually and has been used for CSR, neck pain, cervicogenic headache, and invalid sympathetic block complex regional pain syndromes [9–11].

Based on existing literature, we divided the predominant block approaches into an anterolateral approach, lateral approach, posterolateral approach, and dorsal approach. The classification criteria were based on the angle between the penetration trajectory and the horizontal plane of the patient when in the supine position. Specifically, 0° represents a lateral approach, a positive angle represents an anterolateral approach, and a negative angle represents a posterior lateral approach. The dorsal approach is relatively new. 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.

Anterolateral Approach

In 1988, Morvan et al. [12] described an anterolateral approach that was modified from cervical discography. With this approach, the contrasting bed is placed vertically, and the patient sits on a stool that can rotate, and the head is supported. Using radiography for guidance, the patient's body position is slightly tilted. The symptomatic side is positioned forward to obtain a complete image of the cervical intervertebral foramen, which is achieved using an oblique cervical view. The radiography projecting direction is adjusted so it is parallel to the target segment of the lamina. Then, the trachea, esophagus, carotid artery, and jugular vein are manually pushed medially (Fig. 1), and the needle is gently advanced to the intervertebral foramen under radiographic guidance. Next, the needle tip is placed at the posterior aspect of the intervertebral foramen against the anterior edge of the superior articular process or the posterior aspect of the uncinate process. The author [10] reported a successful completion rate for the procedure of only 14% using this approach. One of the 73 patients reported a headache, which disappeared within several hours. In another patient, who suffered from dizziness, the symptoms disappeared within 24 h. No other serious complications were reported.

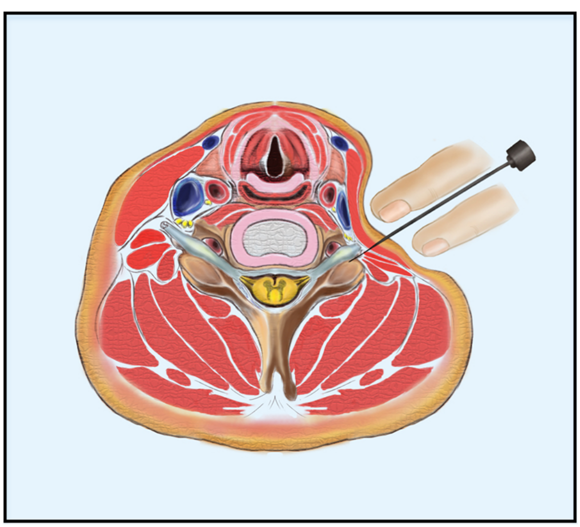

Fig. 1 The anterolateral approach performed by Morvan (1933)

Subsequently, the anterolateral approach has been used widely in cervical SNRB. Schellhas et al. [13] reported on 4612 patients that received cervical vertebral SNRB using the anterolateral approach (diagnostic + therapeutic) in 13 years without incidence of cerebral infarction, spinal cord injury, or other severe complications. In one patient, seizures were reported, but the patient recovered within 30 min. The author speculated that this might have been due to injection into an artery. No serious complications have been reported in other studies [14, 15].

Lateral Approach

In 1996, Bush et al. [9] reported a lateral approach for cervical SNRB in 68 patients. The authors discussed two approaches, in addition to the anterolateral approach described by Morvan; the author also used the lateral approach described by Moore et al. and Zenz et al. [16]. Briefly, patients were placed in a supine position. The needle was gently advanced towards the target segment until a bony docking site was attained (such as the C7 transverse process). Then the needle was slowly withdrawn; if no blood or cerebrospinal fluid were observed, 1 ml of 1% lidocaine and 1 ml 40 mg triamcinolone acetonide were injected. Later, Slipman et al. [17] also used the lateral

Table 1 Summary of the studies of cervical SNRB

Author	Time	Sample size	Patient position	Approach	Guidance	Contrast agent
Morvan et al. [12]	1988	71	Sitting	Anterolateral	X-ray	No
Bush et al. [9]	1996	170	–	Lateral/anterolateral	Partially X-ray	Yes
Slipman et al. [17]	2000	44	Supine	Lateral	X-ray	Yes
Vallee et al. [19]	2001	41	Siting	Lateral	X-ray	No
Cyteval et al. [65]	2004	30	Supine	Anterolateral	CT	Yes
Wagner et al. [66]	2005	~ 200	Supine	Anterolateral	CT	Yes
Ma et al. [56]	2005	1036	Lateral	–	X-ray	Yes
Schellhas et al. [13]	2007	4612	Supine	Anterolateral	X-ray	Yes
Kumar et al. [21]	2008	33	Lateral	Posterolateral	X-ray	Yes
Wolter et al. [30]	2010	53	Prone	Dorsal	CT	Yes
Sutter et al. [31]	2011	108	Prone	Dorsal	CT	Yes
Miller et al. [20]	2013	116	Lateral	Lateral	CT	Yes
Jee et al. [50]	2013	120	Lateral	–	US	–
Park et al. [51]	2013	64/50	Supine/lateral	Anterolateral/–	X-ray/US	Yes/–
Bensler et al. [32]	2014	112	Prone	Dorsal	CT	Yes
Chen et al. [67]	2014	190	Supine	Anterolateral	CT	–
Desai et al. [14]	2014	50	Supine	Anterolateral	CT	Yes
Takeuchi et al. [48]	2014	41	Lateral	–	US	–
Ito et al. [15]	2015	104/161	Supine	Anterolateral	X-ray	Yes
Wakeling et al. [53]	2016	149	Supine	–	X-ray + US	Yes
Park et al. [42]	2019	61/51	Prone/supine	Interlaminar/–	X-ray/US	Yes/–
Jang et al. [54]	2020	78/44	Supine	–	X-ray/US	Yes/–
Wu et al. [47]	2021	32	Lateral	Posterolateral	US	Yes

US ultrasound

approach SNRB for 20 cases. They obtained a satisfactory rate of block of 60% and reported no complications (Table 1).

Valle et al. [18] reported several shortcomings associated with the anterolateral approach, including (1) risk of damage to vital structures (trachea, esophagus, jugular artery, and vein), which could be avoided by pushing these structures towards the midline; (2) risk of damage to the vertebral artery, which cannot be avoided by manual manipulation; (3) risk of spinal cord injury caused by deep penetration of the needle tip into the spinal canal, also which cannot be avoided. The author determined that the lateral approach under radiographic guidance was safer when the patient was in a seated position. Performance using this approach will not damage vital structures such as the carotid artery without pushing tissues below the level of C3. However, this approach can provide a safe bony docking site before the needle is finally positioned (Fig. 2A, needle tip against

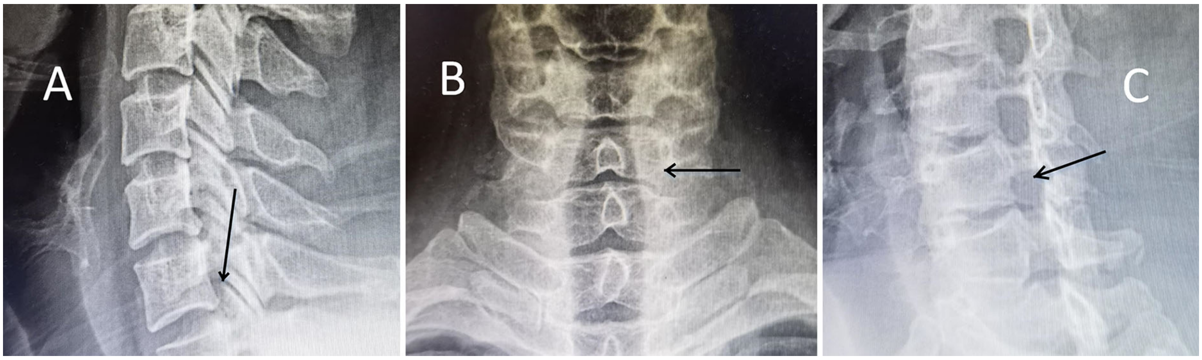

Fig. 2 Target needle position in the lateral approach for SNRB. **A** Lateral position. **B** Anteroposterior position. **C** Oblique position

the anterior edge of the superior articular process) [19]. It is noted that the patient's shoulder will probably be naturally lower when in a seated position, which facilitates manipulation. Thus, a contrast agent is not needed with cervical anteroposterior and oblique radiographs.

However, the lateral approach has been used rarely due to the inconvenient manipulation that is required. In 2013, Miller et al. proposed a modified lateral approach with the shortest penetration trajectory (Fig. 3). With this approach, the patient is placed in a lateral position. Then, under CT guidance, a needle is inserted in a near-vertical orientation. The author reported no severe complications in 116 cases that used this procedure. The author suggested that this modification increased safety and decreased the intraoperative radiation time [20]. This method could expand the clinical applicability of the lateral approach.

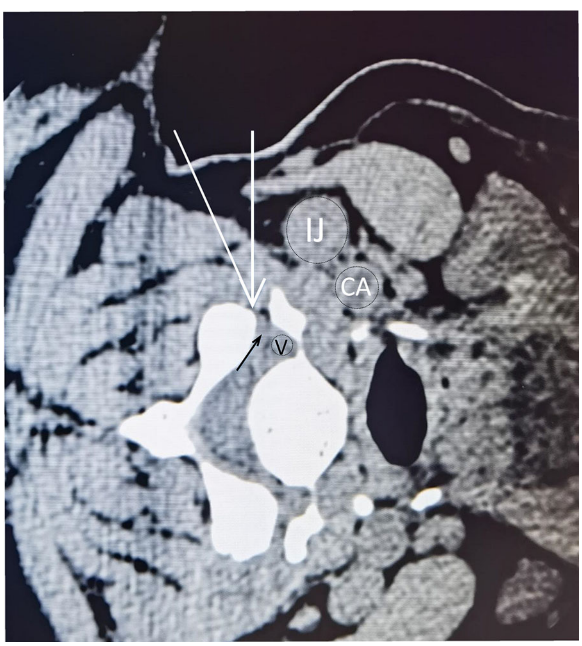

Fig. 3 Modified lateral approach. *White arrow*, target needle position against the anterior edge of the facet joint. *Black arrow*, venous plexus around the foramen. *IJ* internal jugular vein, *CA* carotid artery, *V* vertebral artery

Posterolateral Approach

The posterolateral approach was first described by Kumar et al. in 2008. When using this approach, the patient was placed in a lateral position with the affected side up. A pillow was placed beneath the neck to avoid lateral flexion, the neck was slightly stretched, and the patient's shoulders were pressed down to facilitate obtaining an entire intraoperative cervical radiograph. The C-arm was centered on the target segment, tilted 20°-30°, and the cervical oblique film was used to observe the foramen fully. The entry point was the intersection of the tangent line of the superior edge of the target segment foramen in parallel with the disc plane and the tangent line of the posterior edge of the two lateral masses of the target segment and the adjacent segment. The needle was inserted using imaging guidance until the needle tip was located on the anterolateral side of the posterior edge of the intervertebral foramen. After the needle entered the nerve root canal, it was withdrawn to ensure no blood vessels were penetrated. Subsequently, 0.2–0.5 ml of contrast agent was injected, and the diffusion along the nerve root was confirmed. Then, 1 ml of a long-acting steroid hormone (40 mg triamcinolone acetonide) and 1.0–1.5 ml of a long-acting local anesthetic were injected (0.25% bupivacaine) [21]. The authors observed that 28 of 30 patients exhibited significant improvements in their VAS and NDI scores. No severe complications were reported.

In the study [21], the author described a "safe zone" that was defined as the posterior-superior quadrant of the foramen (Fig. 4). It should not extend beyond the line connecting the midpoints of the articular processes in case of dural penetration [22]. Placement within this area can minimize the possibility of dura or blood vessel damage. Likewise, the SNRB guidelines suggest placing the needle tip on the dorsal side of the foramen, which is based on the assumption that the vertebral artery travels in front of the exiting nerve root [23]. However, Huntoon et al. [24] claimed that even if the needle was placed at the posterior area, there was still a 1% possibility of damage to the anterior spinal artery and suggested that a safe region did not exist.

Dorsal Approaches: Direct and Indirect

Previous studies have reported that severe complications related to cervical SNRB include cerebral edema, cerebral infarction, cervical spinal cord infarction, ventriculomegaly, subarachnoid hemorrhage, and hydrocephalus [25–27]. Even though these complications exhibit a relatively low incidence (less than 1%), if they do occur, they could be life-threatening [28]. In 2007, Drape et al. proposed a posterior facet joint block for patients with CSR that presented good outcomes. The injection to facet joints could indirectly affect the nerve root, which might be a safer approach. However, the sample size in this study was small (17 cases).

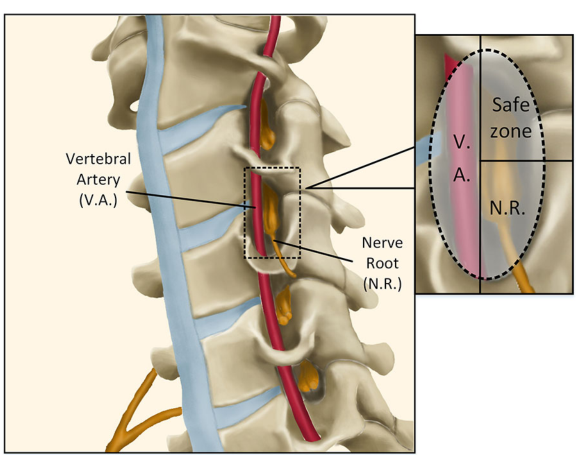

Fig. 4 Posterolateral approach and the "safe zone"

In 2009, Wolter et al. [29] first reported on the dorsal approach (Fig. 5A). A year later, they used the same approach to perform dorsal cervical SNRB in 53 patients [30]. In this approach, the patient is placed in a prone position. The needle is inserted at an angle of 10–45° to the sagittal plane to avoid cervical vessel penetration. Ideal needle insertion should occur against the lateral edge of the posterior wall of the intervertebral foramen. The facet joint capsule can serve as a guide to positioning the needle. In some cases, the patient may complain of induced analogous radicular pain when the tip of the needle is positioned correctly. When a satisfactory needle tip position is obtained, 0.5 ml of iopamidol and 0.75% bupivacaine (1:1 mixture) are injected. The author suggested that this approach can minimize the risk of accidental damage to the radicular artery (Table 2).

On the other hand, Sutter et al. suggested that the dorsal approach described by Wolter et al. is still a direct penetration technique that utilizes a dorsal approach to reduce the risk of inadvertent injection of a blood vessel. However, the needle tip placement is still within the intervertebral foramen area, which can potentially damage the nearby blood vessels. Sutter et al. established a new approach called an "indirect nerve root block" [31], during which the needle tip trajectory was far removed from the nerve roots and blood vessels to avoid related complications (Fig. 5B). With this approach, the patient is placed in a prone position. After the target segment is localized via a lateral cervical radiograph, the needle is inserted vertically into the dorsal skin, directly on the lateral surface of the facet joint, which is also adjacent to the target intervertebral foramen. After sterilization, the needle is advanced under imaging

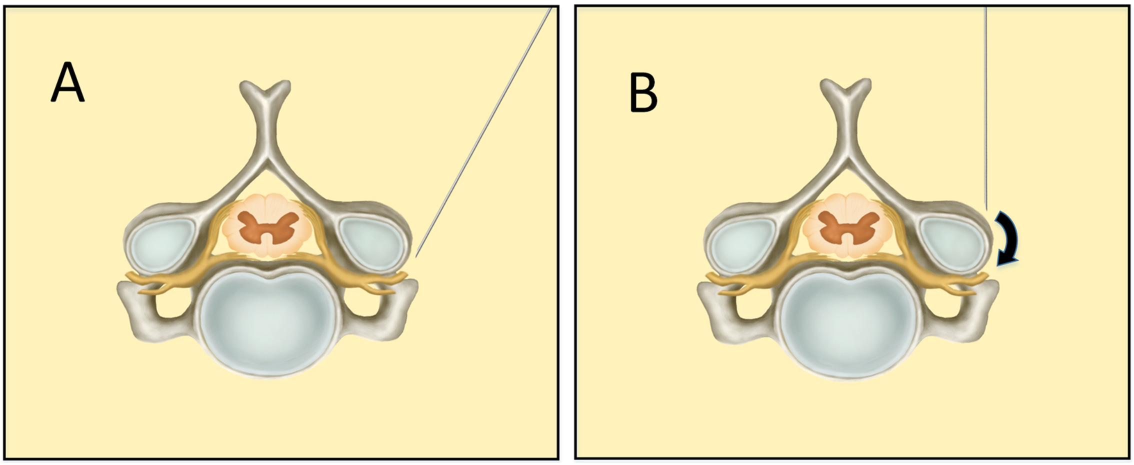

Fig. 5 **A** Direct dorsal approach. **B** Indirect dorsal approach. *Black arrow*, infiltration of the injected drugs

guidance until it reaches the bone at the facet joint, after which 0.5 ml of contrast agent is injected to verify whether the needle tip insertion is correct.

A contrast agent is used to visualize the distribution of drugs diffused around the dorsal and lateral sides of the facet joints and ventral to the facet joints, as well as the direct contact of the nerve roots. After contrast agent injection, 4 mg (1 ml) of a non-particulate corticosteroid (dexamethasone) and 1 ml of 0.2% bupivacaine are slowly injected. Bensler and Sutter et al. [32] examined a dorsal indirect approach in 112 patients and concluded that this approach is safer than the direct dorsal approach.

PROCEDURES TO DECREASE COMPLICATIONS

Use Non-particulate Steroids

Cervical SNRB has great value as a non-surgical treatment and a diagnostic method. However, the rare but catastrophic complications are an unavoidable dilemma that surgeons must face. In 2007, Scanlon et al. [33] published a cross-sectional study describing 78 critical neurological complications caused by cervical foramen blocks. In 2013, Hodler et al. [34] reported on two cases of tetraplegia after cervical SNRB. The surgeon in this study had performed more than 1000 cases of SNRB. The procedure was performed under the guidance of CT, and a contrast agent was used before drug injection.

Studies have revealed that critical complications after cervical SNRB, including quadriplegia, cerebral infarction, and cortical blindness, might be related to inadvertent arterial injection of a specific steroid. Some steroids contain large or small particles that may form larger aggregates and, consequently, create emboli. When an inadvertent arterial injection occurs, the spinal cord or brain may be infarcted, depending on which terminal blood vessels are blocked [27, 33, 35]. Scanlon and colleagues revealed a strong association between particulate corticosteroid usage and cerebral and spinal cord infarction [36]. A significant mortality rate (death of 4/4 animals) was observed in a porcine model in which animals received an injection of particulate steroids (methylprednisolone) into the vertebral artery. In contrast, animals injected with non-particulate steroids (dexamethasone, prednisolone) survived without MR or histological abnormality.

Table 2 The drugs and outcomes of the involving studies

Author	Drugs	Outcomes
Morvan et al. [12]	Therapeutic: 2.0–3.0 ml prednisolone acetate (50 mg)	7 (14%) satisfactory 31 (61%) fair
Bush et al. [9]	Therapeutic: 1.0 ml 1% lignocaine + 1.0 ml (40 mg) triamcinolone acetonide	32 (47%) partial relief 31 (46%) full relief
Slipman et al. [17]	Diagnostic: 0.5–0.75 ml 2% xylocaine Therapeutic: 1.0–1.5 ml betamethasone + 0.5 ml 1% xylocaine	12 (60%) pain relief > 50%
Vallee et al. [19]	Therapeutic: 2 ml (50 mg) prednisolone	21 (62%) pain relief > 50%
Cyteval et al. [65]	Therapeutic: 3 ml (15 mg) dexamethasone	11 (37%) excellent 7 (23%) good 2 (6%) fair
Wagner et al. [66]	Not mentioned	100% successful block
Ma et al. [56]	1 ml betamethasone + 0.5 ml 2% lidocaine	Not mentioned
Schellhas et al. [13]	Diagnostic: 1.0–1.6 ml mixture (steroid: lidocaine = 1:2 or 1:3) Therapeutic: repeat injection of 1.3–1.6 ml mixture (steroid: lidocaine = 1: 2 or 1: 3)	95% of 4612 cases improved
Kumar et al. [21]	Therapeutic: 1.0 ml (40 mg) triamcinolone acetonide + 1.0–1.5 ml 0.25% bupivacaine	100% improved
Wolter et al. [30]	Diagnostic: 0.5 ml mixture (1:1) of iopamidol and 0.75% bupivacaine	26 (68.4%) pain relief > 50%
Sutter et al. [31]	Therapeutic: 1.0 ml (40 mg) triamcinolone acetonide + 1.0 ml 0.2% ropivacaine–	43.2% pain decrease
Miller et al. [20]	Dexamethasone sodium phosphate	Not mentioned
Jee et al. [50]	Therapeutic: 2 ml dexamethasone (10 mg) and 1 ml 0.5% lidocaine	All significant improved
Park et al. [51]	Therapeutic: 2 ml dexamethasone (10 mg) + 1 ml 0.5% lidocaine	62.5% and 58% successful treatment
Bensler et al. [32]	Therapeutic: 4 mg dexamethasone + 1 ml 0.2% ropivacaine	68.1% improved at 1 year
Chen et al. [67]	Not mentioned	Not mentioned
Desai et al. [14]	Therapeutic: 1 ml 4 mg/ml dexamethasone + 1 ml 0.5% bupivacaine	77% pain relief immediately
Takeuchi et al. [48]	Therapeutic: 1.5 ml 1% lidocaine + 0.5 ml (2 mg) betamethasone	39 (95.1%) pain disappeared immediately

Table 2 continued

Author	Drugs	Outcomes
Ito et al. [15]	Therapeutic: 1.0 ml of 1:1 mixture of betamethasone and a 2% lidocaine	89% pain relief
Wakeling et al. [53]	Therapeutic: 0.25% bupivacaine + 1 mg/ml methylprednisolone	107 (71.8%) improved
Park et al. [52]	Therapeutic: 2 ml dexamethasone (10 mg) + 1 ml 0.5% lidocaine	80% and 77% successful treatment
Jang et al. [54]	Therapeutic: 2 ml dexamethasone (10 mg) + 1 ml 0.5% lidocaine	75.7–81.8% successful treatment
Wu et al. [47]	Therapeutic: 2 ml of a mixture of 0.2% ropivacaine + dexamethasone (4 mg)	72% symptom relief

GET FAMILIAR WITH THE VULNERABLE VESSELS' ANATOMY

The position of the carotid sheath is often a primary factor that affects the final choice of approach. When the carotid sheath is lower on a cross section, surgeons tend to choose a smaller angle with the horizontal plane to avoid the carotid sheath (e.g., lateral approach or posterolateral approach). Fitzgerald et al. [37] reported that the smaller the needle angle, the easier the needle tip trajectory intersects the vertebral artery. Therefore, it is essential to confirm the location of the vertebral arteries preoperatively.

Incorrect injection into the radicular artery and not the vertebral artery has been recognized as the cause of observed complications. The radicular artery (Fig. 6) originates from the vertebral artery and the ascending carotid artery. It accompanies the spinal nerve into the nerve root canal and connects with the anterior spinal artery and the medullary vascular network. Surgeons need to have a detailed understanding of the precise local anatomy for cervical SNRB. Still, only a few studies have investigated the precise local anatomy related to cervical SNRB, especially the relevant vascular anatomy. There

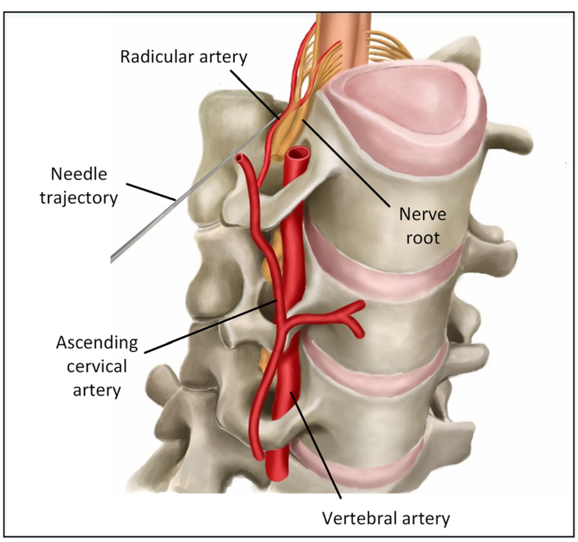

Fig. 6 Anatomy of the radicular artery

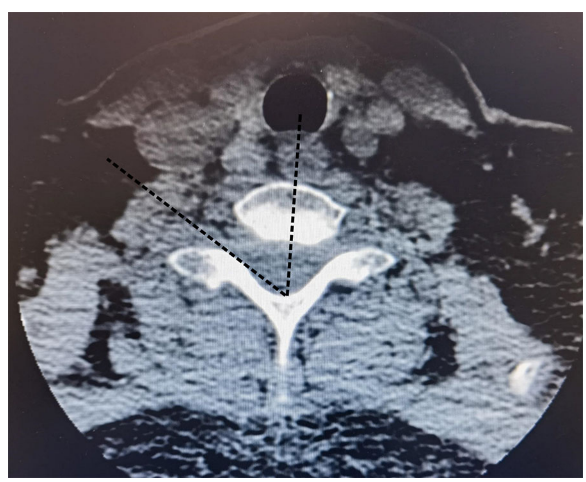

Fig. 7 Measurement of the degree of the needle trajectory in the anterolateral approach

also is confusion caused by the inconsistent naming of arteries. As mentioned above, the radicular artery has been called the “radicular artery,” or “radiculomedullary artery,” or “spinal branch” in different studies [38]. The artery is considered a high-risk vessel for incorrect injection and the cause of fatal complications during cervical SNRB (Fig. 6). A recent study of the optimal needle insertion angle for cervical SNRB using an anterolateral cervical approach (190 cases) concluded that the optimal needle insertion angle was between 33° and 68°, and the average was slightly less than 50° (Fig. 7). The authors concluded that maintaining the needle along the posterior wall of the foramen could minimize or even avoid accidental injury to the nerve root and vertebral artery. Still, it could not avoid entering the root canal or radicular artery. Thus, the risk of mistaken injection still exists.

Considerable anatomic variation of blood vessels around the cervical intervertebral foramen is another problem. A previous study revealed that unpredictable vascular anatomical variation is one of the main reasons for incorrect intravascular injections [39]. Huntoon et al. [24, 40] reported that critical structures, such as the ascending carotid artery and deep carotid artery pass through the posterior part of the intervertebral foramen, which is the needle tip placement area for conventional cervical SNRB. There are as many as 29% of vertebral artery variants that pass less than 2 mm to the posterior wall of the foramen. Recent research related to the distribution of vulnerable blood vessels that intersect the needle trajectory during cervical SNRB (C3-C7) with ultrasound (104 cases) [41] showed seven blood vessels (8.33%) at the level of C3, 14 blood vessels (13.86%) at the level of C4, 17 blood vessels (16.35%) at the C5 level, 27 blood vessels (25.96%) at the C6 level, and 31 blood vessels (29.81%) at the level of C7. The author reported [42] that 37.5% of 104 patients exhibited at least one vulnerable blood vessel, and approximately 14.89% of the 497 foramina had vulnerable blood vessels in the posterior half of the foramen. The author also reported that the risk of vascular injury in the lower cervical spine was greater than that of the upper region, which indicates the need for additional caution. This conclusion was supported by a recent study [43].

Apart from the localized anatomical considerations, the risk of cervical SNRB is also influenced by pathological changes due to the associated degeneration. A previous study showed that the severity of degenerative foraminal stenosis was positively correlated with the vertebral artery’s position. The osteophytes of the Luschka joint tend to push the vertebral artery towards the posterolateral foramen, and the osteophytes of the facet joints tend to push the posterior edge of the foramen towards the vertebral artery, thus causing the foramen to be covered by the vertebral artery. As a result, the vertebral artery may be extremely close to the conventional needle tip location during cervical SNRB in patients with cervical degeneration. Nearly all patients with CSR who need to receive SNRB may suffer from some degree of intervertebral degeneration. To design the safest needle trajectory and needle placement point, surgeons need to be aware of the possibility of a change in the position of the vertebral artery, especially for patients with Luschka joints or facet joint osteophytes.

CONSIDER ALTERNATIVE GUIDANCE WAY: ULTRASOUND

Recently, the clinical application of cervical SNRB combined with ultrasound has increased. In 2004, Galiano et al. [44] used cadavers to examine ultrasound-guided transforaminal injections on the lumbar spine. The CT results confirmed that the needle tip could be accurately positioned using ultrasound guidance. In 2009, Narouze et al. reported that ultrasound-guided cervical SNRB was a safe approach that could allow the needle tip to stay within 5 mm of the target, and the risk of blood vessel damage was minimized in the target area. This was later confirmed by Nakagawa et al. [45]. Both authors emphasized the advantage that was provided when the transverse process with nerve roots and vessels could be recognized under ultrasound guidance, which enables safer SNRB. The cadaver study revealed that a solution injected in SNRB under ultrasound spread in the extraforaminal direction, which would not cause an epidural block [46].

Other more recent studies have reported on the safety of cervical SNRB under ultrasound guidance [47–49]. Jee et al. [50] compared the clinical outcomes of cervical SNRB under ultrasound and radiographic guidance (120 cases). Five cases of intravascular injection in the radiographic guidance group were reported with no significant difference observed between the groups. Furthermore, Park et al. [51] reported on three cases of intravascular injection in a group that used fluoroscopy guidance in their cohort study. Moreover, a retrospective comparative study reported that ultrasound-guided SNRB might be safer and have similar pain relief compared with SNRB under fluoroscopy (seven cases of intravascular contrast injection were observed) [52]. Wakeling and colleagues [53] reported on the application of cervical SNRB under combined fluoroscopy and ultrasound guidance to avoid vessel damage when using only ultrasound and to avoid mistaken vascular injection when using only fluoroscopy. The author believed that this approach could reduce complications and irradiation exposure [41]. More recently, a retrospective comparative study compared interlaminar SNRB under ultrasound guidance with transforaminal SNRB under fluoroscopy guidance. The authors of this study concluded that SNRB guided by ultrasound had the lowest intravascular injection rate and similar pain relief in the lower cervical spine [54]. Moreover, the logistic regression analysis revealed that the guidance method, gender, age, and pain duration were not independent predictors of the block success [54].

Current evidence has not revealed any difference between cervical SNRB under ultrasound guidance and SNRB under fluoroscopy guidance. Thus, the unique advantage of real-time vascular visualization may help reduce intravascular injection.

VALUE THE INTRAOPERATIVE LATERAL CERVICAL VIEW

The International Spinal Injection Association and Windsoret et al. [55] recommended that the needle tip position should be confirmed with the aid of cervical anteroposterior and oblique radiographs. Consequently, Ma et al. [56] proposed lateral cervical spine division (Fig. 8). The author emphasized the importance of the lateral cervical view, which has been ignored in cervical SNRB. To avoid vertebral artery damage as much as possible, the authors suggested that the needle tip should be closely attached to the anterior surface of the lateral mass and that position can be determined only with a standard lateral cervical view. Even if the position of the needle tip on the oblique cervical radiograph appears to be appropriate on the lateral radiograph, the needle tip might be placed too anteriorly. According to their study of 1036 cases of cervical injection, the complication rate of injection in zone C was significantly higher than in zones A and B (complication rate of 6.06, 1.51, and 1.81%, respectively).

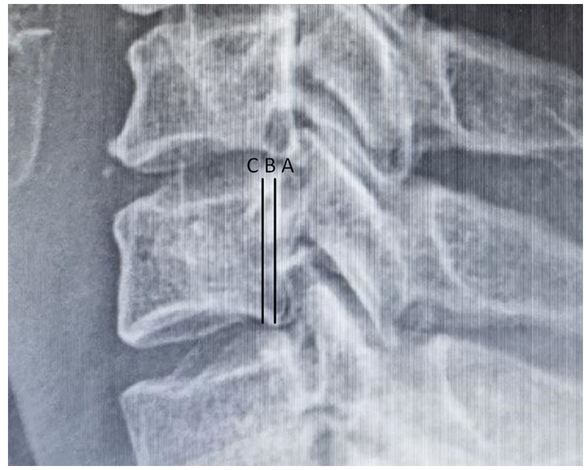

Fig. 8 Division boundaries of various lateral zones. **A** Ideal needle placement. **B** Zone within two needle tip diameters anterior to Zone A. **C** Zone further anterior than zone B

USE CONTRAST AGENTS

Initially [19], it was believed that contrast agents increase the infection risk, prolong the procedure time, and induce radicular pain due to locally increased pressure caused by the contrast agents. However, all subsequent studies have supported the use of contrast agents. First, Bush et al. [9] suggested that the reason for the poor outcomes (satisfaction rate of only 14%) in the study reported by Morvan et al. was because they did not use contrast agents. As a result, they could not be sure that the drugs were injected around the responsible nerve root appropriately or if they were flushed away by cerebrospinal fluid or blood flow. Also, the use of contrast agents can minimize inappropriate artery injections. If no contrast agent is used during surgery, inappropriate vessel injection is primarily determined by the appearance of blood in the syringe after withdrawal. However, it has been reported that the artery may be penetrated even if no blood is observed. When assessing if a vessel was incorrectly injected based on the presence of blood in the withdrawn syringe, the specificity is 97%, and the sensitivity is only 45.9% [57, 58]. Moreover, the contrast agent used in SNRB has been proved to be safe. A prospective study (504 cases of cervical SNRB) reported that in approximately 19% of the cases, contrast agents were observed to be injected into the bloodstream, but no severe complications were reported [57]. Also, the application of a contrast agent did not influence the effect of the nerve root block [59].

In conclusion, even if the needle is ideally placed and no blood is observed when the syringe is withdrawn, the possibility of inappropriate artery injection cannot be excluded. Furthermore, fast clearance of the contrast agent indicates the possibility of a mistaken artery injection, while slow clearance indicates the possibility of a mistaken vein injection. Rathmell et al. [60] reported on a case where, after injection of a contrast agent, a curved filament was observed medial to the nerve root. With digital subtraction angiography, a clear outline of the radicular artery could be identified. The author stopped further manipulation immediately, and the patient showed no adverse reaction. Therefore, the application of a contrast agent in cervical SNRB probably is advantageous.

SOME OTHER CONTROVERSIAL POINTS

a) Although multiple “direct approach” studies have reported that homologous radicular pain reappearance sometimes occurs when the needle is placed in the correct position, this “reappearance” does not influence the block effect [59].
b) There has been controversy related to blunt needle application in SNRB, and no evidence has proven that use of a blunt needle provides better safety [24, 61].
c) Ryan et al. [62] claimed that CT guidance might not be sufficient to identify the intravascular injection due to the following reasons: (1) once injected, the contrast agents are washed away before the CT is performed; (2) the vessels enter the cord at a different level, and therefore, are not properly imaged.
d) It has been proposed that a narrow intervertebral foramen might impact the effectiveness of SNRB. A recent retrospective study [63] reported an unexpected conclusion that patients with severe foramen narrowness respond well to SNRB. On the other hand, the response of a patient to SNRB with mild to moderate foramen narrowness is unpredictable.
e) The medical compounds used with SNRB vary among surgeons. In general, local anesthetics are required for diagnostic purposes, and non-steroidal hormones are required for therapeutic procedures. In clinical reports, various drug mixtures have been used for cervical SNRB. The common compound is a steroid and lidocaine mixture 1.0–1.5 ml (mixing ratio 1:1–1:1.5) [24, 61]. Based on a study spanning 13 years and involving 4612 patients, it has been recommended to use a 1.0–1.6 ml mixture (steroid and lidocaine of 1: 2–1: 3) for the initial diagnostic block and a 1.3–1.6 ml mixture (steroid and lidocaine of 1: 1 or 1: 2) for repeated blocks (therapeutic protocols) [13].
f) Does drug volume affect the spread of the solution? According to a prospective study

[64], there was no intraforaminal epidural spread in patients given a 1 ml injection, but it did occur in 13 cases (24.5%) treated with a 4-ml injection. While the spreading pattern did not seem to influence pain relief, it still needs to be investigated in studies with larger sample sizes.

CONCLUSIONS

SNRB has been an effective non-surgical treatment for the neurological symptoms caused by CSR. Currently, the widespread, minimally invasive surgery emphasizes SNRB due to the requirement for accurate preoperative localization of the affected nerve roots. This requires the surgeons performing cervical SNRB to be familiar with the various possible approaches and the risk factors for complications to be able to perform cervical SNRB more safely. In summary, based on the studies discussed in this review, a good understanding of the relative location of the carotid and vertebral arteries during preoperative MR are essential.

a) When the carotid sheath is positioned anteriorly, the anterolateral approach is recommended. In this instance, the risk of vertebral artery damage is the lowest.
b) When the carotid sheath is positioned posteriorly during the lateral or posterolateral approach, the needle trajectory is likely to intersect the vertebral artery, especially in cases with Luschka joints or facet joint osteophytes. In this instance, it is suggested to estimate the relative location of the vertebral artery to avoid accidental injury.
c) When the carotid sheath is positioned posteriorly and accompanied by a deviation of the vertebral artery or the posterior wall of the intervertebral foramen, which increases the risk associated with the lateral and posterolateral approaches, the dorsal approach may be a better choice. Thus, it is beneficial for surgeons to be proficient in multiple techniques to manage various conditions that could be encountered.

FUTURE PERSPECTIVES

As a beneficial method for CSR therapy and responsible segment localization, SNRB has been adopted increasingly in recent years. Based on this narrative review, there are still some controversial questions in the SNRB procedure. For instance, (1) if the steroid types, anesthetic types, and their mixture ratio will affect the outcome? (2) if it exists a preferable approach for more or even every condition? (3) if there is a better option in US, X-ray and CT guidance? This review was hoping to encourage more research with high quality and a larger sample size focusing on the issue in the future. Many technical details within the procedure need further investigation in order to establish eventually a safe and effective standard operating procedure.

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