Neurostimulation guided Interscalene block – How close are we to the Neuraxis?

Sandeep Diwan[1]

Abstract

The interscalene brachial plexus block is the gold standard for proximal humerus and shoulder surgeries. Since its inception into clinical practice there have been incidences of neuraxial spread and its consequences. Several modifications in approach target to decrease the incidence of respiratory paralysis and neuraxial injuries. The point of administration of an interscalene block is at the level of roots-trunks, likened to paravertebral and close to neuraxis. This article focuses on the cadaveric dissection and reveal the path towards the neuraxis. A couple of clinical contrast studies also depict the unwanted spread.

Keywords: interscalene brachial plexus, neurostimulation

Paraesthesia

Winnies [1] described the interscalene approach to brachial plexus. He assumed and demonstrated that the brachial plexus lies in a tubular sheath extending from the cervical area to the axillary area. Of importance is the direction of the needle during the interscalene approach. Winnie [1] mentions the needle should be directed perpendicular to the skin planes. The needle tip is oriented medially, caudally and dorsally.

A paraesthesia at the shoulder or the arm was considered to be the end point. Winnie [1] emphatically states that if paraesthesia is not elicited, the U-shaped end of the transverse process is "walked," millimeter by millimeter, until a paresthesia is evoked. This was before the advent of the use of the nerve stimulator. Winnie1performed the contrast studies post interscalene block and observed a tubular dilatation of the sheath. At no point the contrast spread medially towards the neuraxis – the epidural and spinal canal.

Immediately after its introduction in clinical practise, Kumar et al [2] described a high epidural block following an interscalene approach. They used a 22g 1.5-inch needle, encountered the transverse process without a paraesthesia hence on both the occasions they walked caudally off the transverse process to obtain paraesthesia distal to mid arm. After careful aspiration 32ml and 40ml were injected, in both the cases respiratory distress developed and were adequately treated. Postoperative both demonstrated extensive anaesthesia from cervical to thoracic dermatomes C2 –T8 and C1 – T4 respectively. The authors commit that the needle must have been inserted to a greater depth than necessary.

This author suggests that walking off caudally off the "U" shaped transverse process brings the needle tip more close to the cervical intervertebral foramina. This was also observed in couple of cadaveric dissections mentioned later in the same article.

This was followed by another case report mentioning a spinal anaesthesia complicating an interscalene block. Ross and Charles [3] report a total spinal anaesthesia during an interscalene block. After obtaining paraesthesia in right arm with a 22g, 2-inch needle,30ml local anaesthetic was injected after a negative aspiration. The patient developed a rapid onset presentation typical of a total spinal anaesthesia. Several isolated case reports appeared fearing the neurological complications following either with spread of the drug in the neuraxis or the needle tip close to the neuraxis.

Gregoretti [4] reported that after what appeared an ideal location of interscalene plexus with paraesthesia injection of 10ml of local anaesthetic lead to apnea. The patient eventually recovered one hour later. A possible subarachnoid spread of the local anaesthetic via the perineural space following intraneural injection is projected. Gregoretti [4] advocates needles no longer than 1 inch for the interscalene approach to the brachial plexus.

Dutton et al [5] and McGlade [6] have independently reported total spinal anaesthesia and extensive central neural blockade following an interscalene block. Norris [7] experienced a delayed neuraxial blockade after administrating an interscalene brachial plexus block. One hour after the block the patient developed signs of bilateral neuraxial block, progressing over the following hour to involve the cervical to lumbar dermatomes, with sparing of the phrenic nerves. The patient was awake, alert and haemodynamically stability. Seventy-two hours later, the patient experienced severe frontal and occipital pain, typical of a post dural puncture headache, which responded to fluids and recumbency.

This example of delayed central neural blockade complicating interscalene block is presented in contrast to other reports, which have usually occurred promptly after injection, accompanied by complete sensory and motor block requiring cardio-respiratory support. The authors reveal that the

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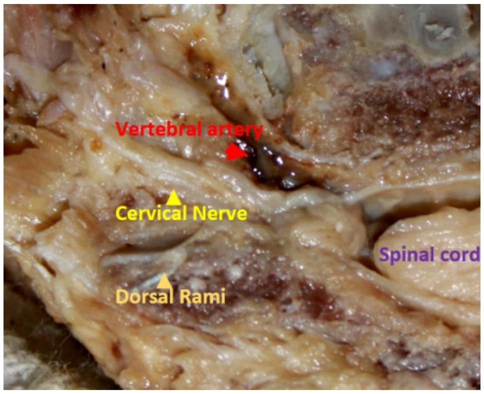

Figure 1: Transverse section of cadaveric cervical spine demonstrating the spinal cord, cervical nerve root and vertebral artery. Cadaveric dissection by Sandeep diwan

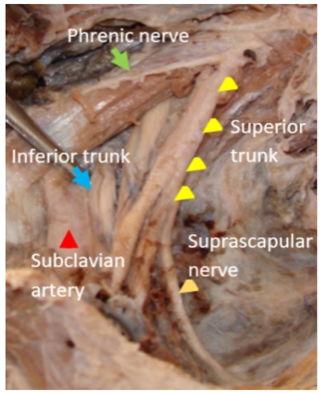

Figure 2: Brachial Plexus Elements. Cadaveric dissection by Sandeep Diwan

Figure 3: Notice the needle tip placement is perpendicular to the scalene muscles hence to the superior trunk. Cadaveric dissection by Sandeep Diwan

presumed mechanism of the delayed onset of bilateral neuraxial spread was a dural cuff puncture with slow CSF spread from a plexus sheath "depot" of local anaesthetic. Paraesthesia has been used as late as 2013. A similar report of total spinal anesthesia have been reported recently by Loha et al [8] and Deepa Kattishettar et al [9]. Both interscalene blocks were performed by 22g hypodermic needle and paraesthesia were elicited in the arm and forearm.

It is disheartening to understand the use of paraesthesia technique in an era of neurostimulation and now ultrasound!

It is postulated and presumed that the drug can enter the spinal space through at least three different routes. First, the drug may be injected direct intrathecally. Second, a dural cuff sometimes may accompany a nerve root distal to the intervertebral foramen, which may be accidentally punctured, making a direct intrathecal injection. Finally, local anaesthetics injected intraneurally could spread in a central direction to the spinal space.

Cadaveric Cervical Spine and the Neuraxial Spread.

The transverse cadaveric cervical spine (Fig 1) demonstrates the spinal cord with the cervical nerve root emerging between the anterior and posterior tubercle. The anterior tubercle hosts the vertebral artery. The dural sleeve is closely approximated to the nerve root and macroscopically the extraforaminal length cannot be identified. It thus seems prudent that the needle tip lies in the interscalene groove and the tip should not walk off the U of the transverse process.

Appropriate Neurostimulation and Neuraxial Spread

In the posterior triangle of the neck the suprascapular leaves the brachial plexus sheath (Fig 2) proximal to the omohyoid, neurostimulation of the suprascapular nerve (dark blue) reflects a false notion that the needle tip is inside the brachial sheath. Silverstein et al [10] maintain that the deltoid motor response is the end point during a neurostimulation guided interscalene block. They made a very important statement: "Acceptance of a deltoid twitch during ISB eliminates the need for further probing and may translate into better patient acceptance and in a smaller risk of needle-induced nerve damage".

In spite of a proper placement of the needle tip after obtaining an appropriate evoked motor response i.e deltoid and biceps at 0.4Ma, there are reports of neuraxial spread and resultant complications.

One of the case reports [11] mention a permanent neurological damage after an interscalene block. The interscalene block was performed under general anaesthesia. Neurostimulation at 0.2Ma identified the brachial plexus at C6 with 3 inches stimulating needle. A total spinal developed five minutes later. EMG study five months later revealed a severe medial and minimal posterior cord. The authors discuss that the nerve stimulator makes it possible to perform nerve blocks on patients under general anaesthesia.

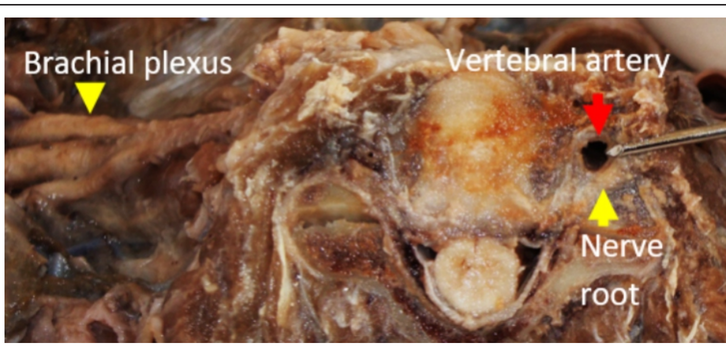

Figure 4: Notice the angle of the needle tip if horizontal it is possible to enter the vertebral artery (right side of cadaver). Also note the brachial plexus formation as it leaves the cervical paravertebral area (left side of the cadaver). Cadaveric dissection by Sandeep Diwan

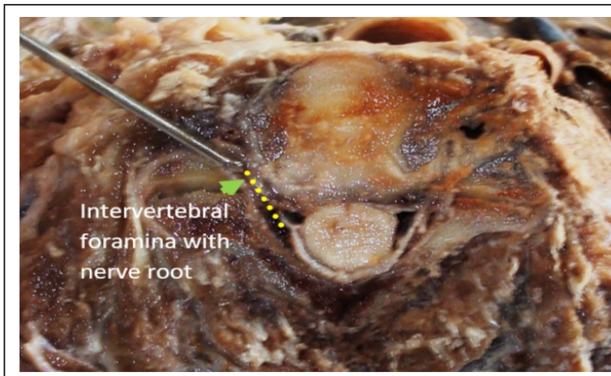

Figure 5: Needle in the intervertebral foramina. Notice the closeness of the needle tip and the neuraxial space(yellow dotted line). Cadaveric dissection by Sandeep diwan

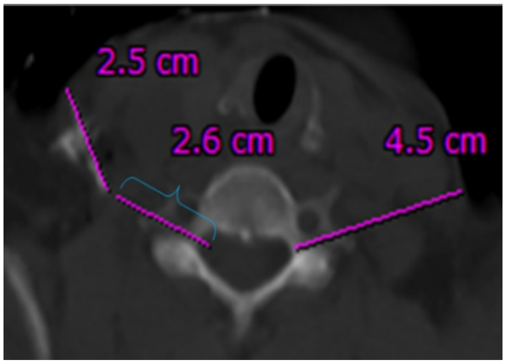

Figure 6: The ideal interscalene catheter length in the interscalene groove is not more than 3cm.

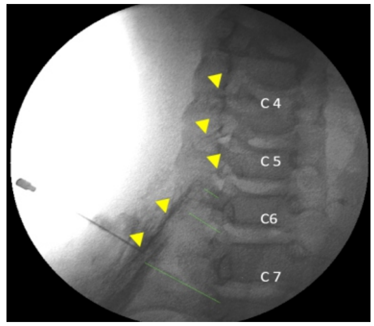

Figure 7: The contrast extends interscalene brachial truncal sheath to the foraminain the epidural space and exits through the foramina above.

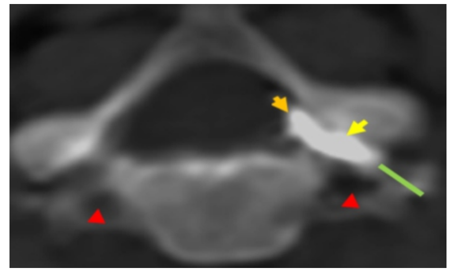

Figure 8: In an interscalene block the needle was placed at the level of C6 and deltoid – biceps contractions were evoked at 0.4Ma. CT contrast delineated the cervical nerve root and the lateral cervical epidural space in the axial section

The authors [11] conclude:
The needle, despite caudal and posterior direction, could have passed directly through an intervertebral foramen into the subarachnoid space.
a. The needle tip could have been inside an extrathecal nerve root for part of the local injection, and then been moved, resulting in puncture of a dural sleeve,
b. The tip of the needle was located in an extrathecal nerve root for the entire injection of local anaesthetic.
c. The local anaesthesia could have been tracked distally, causing neurologic damage, and proximally, dissecting through the nerve trunk and penetrating into the subarachnoid space.
Haci Ahmet Aliciet et al [12] report the development of an unusual rapid subdural block during a neurostimulation guided interscalene (elbow flexion at 0.5Ma). A postoperative neurological examination revealed sensory anesthesia from C3 to T6 on her right side and from C5 to T4 on her left side. Severe hypotension characteristic of total spinal was not present and the epidural space does not extend intracranial hence the authors maintain this to be a sudural spread. They further hypothetize the possible needle tip placement in the posterolateral area of dorsal root ganglion Dural cuffs [5] can extend as far as 8 cm laterally and the most plausible explanation would be a needle tip entrance in one of the dural root sleeve. Thus, it is observed that in spite of using a nerve stimulator and with currents ranging from 0.2-0.5Ma, utilization of 3cm stimulating needle, neuraxial complications have been observed.

Direction of and length of the needle.

As against the popular concept of needle perpendicular to the skin in all planes this author (Sandeep Diwan) feels the needle tip (Fig. 3) should be directed perpendicular to the scalene muscles. Since the scalene muscles host the brachial trunks and are enclosed in a sheath the needle tip if directed perpendicular towards the scalene muscles will also be directed perpendicular towards the brachial trunks. A cadaveric study demonstrates the placement of the needle (Fig. 3).
It is crucial that the direction of needle insertion be slightly caudad as well as dorsal and medial, for if the roots of the plexus are not contacted, the caudally directed needle will be stopped by the transverse process of the next cervical vertebra. This author feels at no point during the needle passage, the bone be encountered.
If the direction of insertion is horizontal, the needle which happens to bypass the plexus will not be stopped and is free to penetrate deeper and to strike the vertebral artery or even to enter the peridural or subarachnoid spaces (Fig. 4).
Sardesai et al [15] consider that the C6 root is the accepted target of an ISBPB. In the classic interscalene approach the distance between skin - intervertebral foramen was 3.7 (2.5-5.9) cm. This implies that if a 5-cm needle is used, the intervertebral foramina of the majority of patients could be reached using the classic interscalene approach. A 2.5-cm needle has been recommended in the literature.
But with indentation at interscalene groove it is possible to lessen the distance from skin to intervertebral foramina. In this case a 2.5-cm needle would find its way in the intervertebral foramen.
Sardesai A et al [15] confirmed in their study that a needle angulation of greater than 30° would seem to ensure that the needle will pass below the C6 foramen and a caudal angle greater than 50° would ensure that the needle passes below the C7 foramen. The greatest degree of alignment was with the classical Winnies approach to interscalene. Sardesai et al [15] assure that a competently performed classic interscalene ISBPB with a short (2.5 cm) needle should not pose a threat to a patient's neuraxis.
Russon et al [16] studied the angle needed to enter the spinal canal. A 8-cm 22G needles were inserted into the spinal canals of four preserved cadavers using the skin entry point most commonly associated with the lateral interscalene brachial plexus block or Winnie approach (that is, at the level of the cricoid cartilage). Eleven successful attempts were confirmed by computed tomography.
These authors offer cautious conclusions:
a. Possible to pass needle from traditional interscalene into the spinal canal.
b. Needle angles that were cephalad, transverse or slightly caudad were associated with entry into the spinal canal at depths of 5.0 cm or less from the skin.

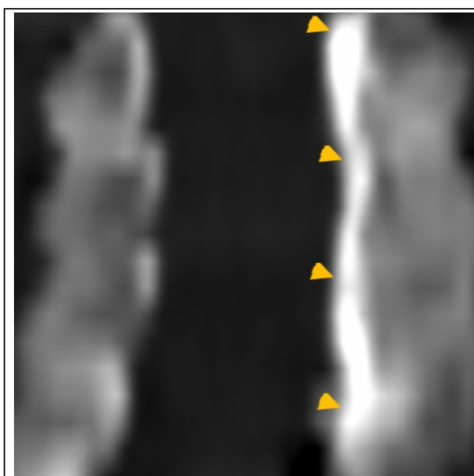

Figure 9: Lateral cervical epidural space marked with yellow arrow heads

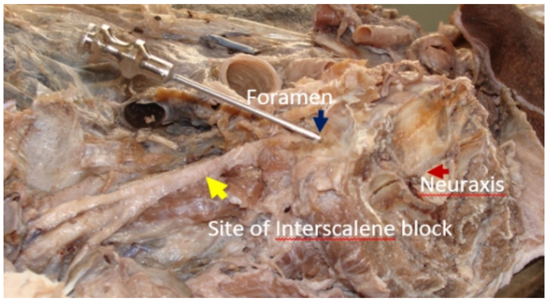

Figure 10: The path of the foraminal and spinoepidural spread from brachial plexus.

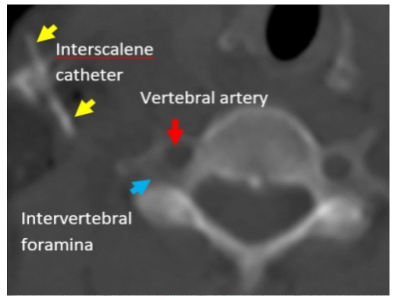

Figure 11: Continuous Interscalene catheter in the interscalene groove.

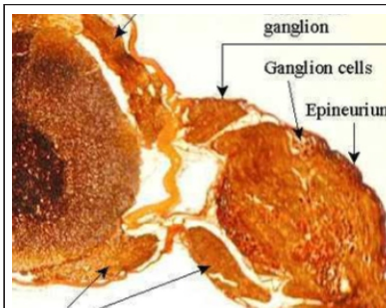

Figure 12: The dural sleeve fuses into the epineurium unrecognised.

c. Caudal needle angulation more than 50^0 to the transverse plane offers some protection from entry into the spinal canal. A cadaveric study demonstrates the needle placement beyond the interscalene groove and close to the intervertebral foramina (Fig 5). Injections at this point will probably open the perineural-dural junction and sweep the drug in the neuraxial space.

Continuous Interscalene block

Frasca D et al [13] report a case of spinal anaesthesia due to the accidental catheterization of the spinal canal at the time of an interscalene block. They examined images of myelography with a non-ionic contrast media agent in the catheter at the time of X-ray control. They advocate cautious use of a major sedation, short needles, an improvement of puncture techniques. Interestingly they also advocate the use of ultrasound location (2007) or use of stimulating catheters (2007) that can decrease the risk of neurological spread. Yanosvski B and Coll [14] report a case where in the patient received a bolus of local anesthetic through the existing interscalene catheter (neurostimulation guided)close to 2300pm. The patient was found dead in the bed in the morning. A post death CT Scan revealed the intraspinal catheter and hence the cause of the death. There are several shortcomings that can be discussed regarding this case. The block was performed under general anesthesia. The local anesthetic was not injected through the catheter (40 ml local anesthetic was injected prior to catheter insertion). To identify the complications earlier it is best to inject through the catheter. Insertion of catheter not more than 3 cm in the space (catheter was inserted 7 cm).

In the average Indian population the skin – intervertebral foramina is around 4.5cm (Fig 6). The needle tip placement is perpendicular to the scalene muscles (Fig 6). Note if the angle is changed the tip is directed towards the neuraxis (blue brace). The catheter tip placement in the interscalene groove should not be more than 2-3 cm. The distance between the catheter tip, when placed in the interscalene groove close to superior trunk, and, the intervertebral foramina will be anywhere from 2-3cm (Fig. 6).

Contrast studies and Analysis of Interscalene Block

This author performed several contrast studies during an interscalene block. The end point was either a deltoid or a biceps motor response at 0.4Ma. After injecting the local anesthetic contrast was injected to assess the needle spread in the interscalene area and the possible spread to the neuraxis. In more than 50% of the times the contrast spread cephalad to the level of the cervical roots and spilled into the lateral cervical epidural space. In the perineurogram (Fig 7) notice the elegant spread of the contrast along the perineural sheath and extending towards the level of cervical roots (C5). The contrast spreads laterally across the cervical epidural space and spills from the C3 and C4 roots (Fig 7). The cervical nerve roots C3 and C4 are well delineated (Fig 7).

In an interscalene block (Fig 8) the needle was placed at the level of C6 and deltoid – biceps contractions were evoked at 0.4Ma. CT contrast (Fig 8) delineated the cervical nerve root and the lateral cervical epidural space in the axial section. Thus the regional anesthesiologist has to be careful in selection of the depth of the needle at the time of injection. Both superior trunk and C6 root stimulation will evoke the deltoid motor response. The depth of the needle will be unusually more in the C6 neurostimulation.

In the longitudinal section (Fig 9) the

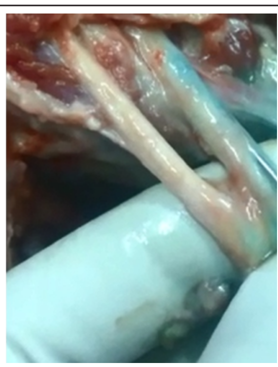

Figure 13: Fresh cadaveric needle tip placed subepineural. Methylene blue dye spread towards the central neuraxis.

Figure 14: The longitudinal approach.

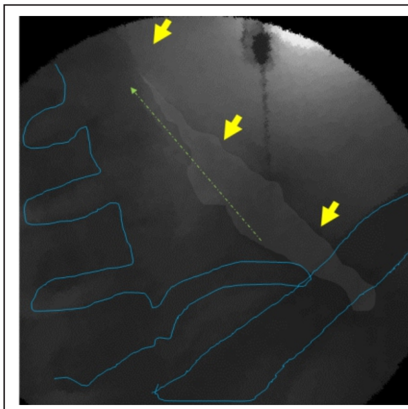

Figure 15: Needle almost vertical in the interscalene groove.

vertical contrast spread was observed. The lateralization of the contrast spread was visible over several vertebral levels. Norris [7] proposed two anatomical explanations to understand the cause of delayed epidural or intraduralanesthesia during an interscalene brachial plexus block

a. Injection into a dural cuff

b. Injection into a subepineural space.

The cadaveric dissection (Fig 10) explains the route from the interscalene brachial sheath. The dissection revealed the tubular sheath extending retrograde from the interscalene through foraminal to the spinoepidural space. The needle entrance was from the upper part of the trunks of the brachial plexus (cervical root), the tip was found close to the neuraxis (Fig 11).

Position of perineural catheter in the Interscalene groove

As far as the catheter tip placement in the interscalene groove is concerned the tip should be placed not more than 3cm in the groove. (Fig 11).

Literature

It is very important to understand that the interscalene area is close to the cervical paraveretebral space. In the image (Fig 7) as the needles are inserted more cephalad the needle tip is more closer to the intervertebral foramina (green dotted line). This author suggests that an approach at C7 would be more appropriate as the distance of IVF from the needle tip is more than at level of C6 and C5. The authors choice is: wherever the interscalene groove is maximally palpable the interscalene block is administered. Further any interscalene block would be potential epidural injection as understood from many of the contrast images this author has come across (Fig 7, 8, 9).

This cervical root level approach provides an excellent analgesic block [17].But it is not readily appreciated that at this level the roots are surrounded by dura and penetration of the dura leads to a subdural injection [17] . A subdural can be intramedullary, because the nerve tissue here is nothing but the axons originating in the spinal cord, which are accompanied by perineural spaces in which the local anaesthetic agent spreads centrally [17].

The trunks of the plexuses are transitional. Histologically the perineurium surrounding the fascicles split away and axons are separated by perineurial sheath interdigitations or septae [18]. This is a delicate and fragile zone at a point where the dura ends and perineurium begins. This can be referred as the dural –perineurial zone. After splitting away from the fascicles, at the level of the nerve roots, the perineurium thickens and fuses with the dura [18]. (Embryologically more correct, the peripheral nerve perineurium is a continuation of the dura mater).

Thus, the trunks should be regarded as transitional areas between fasciculi with perineuria. From the branches to the root area all the perineuria have joined to form the dura [18]. Hence the neurostimulation guided interscalene blocks have to be cautiously performed with aspiration and injections in small aliquots. Needle tip placement at the dural-perineural zone (Fig 12) and forceful injection can possibly open up the perineural space and can lead to cephalad and central spread of the local anesthetic leading to disastrous complications.

Subepineural injection and central spread.

A fluid deliberately or accidentally injected into a fascicle of a peripheral nerve has direct access to the cerebrospinal fluid (CSF) and interstituim (medulla) of the spinal cord, and such spread depends directly on the volume and pressure applied [19].

A cadaveric study demonstrates the central spread of subepineural injection of methylene blue dye. The more the needle tip closer to the nerve the more likelihood of central neuraxial spread of the drug. Longitudinal flow within the fascicle is inhibited minimally, whereas lateral extension is restricted by the relatively non-compliant perineurium [19]. As the nerve approaches the dural penetration, resistance to extension increases and a peripherally injected medium comes to lie in clefts in the perineurium. Final emergence into the subarachnoid space occurs first by way of the subdural space and subsequently by breakthrough across the arachnoid barrier into the subarachnoid space.

The channels by which this progression occurs have been called perineurial spaces, and these have been previously demonstrated [19]. Injection into a spinal root, on the other hand, is easy, and this injectate, similarly has direct access to the CSF and spinal cord interstitium – the clinical consequences of which depends on the volume, rate, and pressure of the injectate and the path taken via the perineurial spaces of the axons. The injectate will generally follow the route of least resistance via these perineural spaces [19].

Experimental work of Selander and Sjöstrand [19] on intraneural injections into rabbit sacral nerves demonstrated that, during intrafascicular injection deep to the perineurium, the tracer was seen to spread rapidly, proximally, and distally inside the fascicle. Selander et al [19] demonstrated that if the injection was made into a large fascicle, the injectate easily passed the sacral plexus and reached the spinal cord. In another study [18], the tracer reached the lumbar plexus via the injected fascicle. In one animal, the blue stain extended to the cerebellum. In cross sections of the spinal cord, the fluorescent tracer used was mainly seen is the thin sub-pial space [20] . Accumulation of the tracer was noted in the dorsal root-medulla junction area, extending into the substantiagelatinosa of the anterior horns, and into the anterior median fissure [20].

Intra Axonal.

The axons inside the roots are not protected by the perineurium and the extracellular or tissue fluid is the CSF. There is no arachnoid as it becomes hyperplastic beyond the dura-perineural zone [21]. As the nerve progresses peripherally, it is more and more subdivided by perineural interdigitations until each fascicle of nerve axons eventually has its own perineurial sheath [21].

Thus, it is probably safe to inject the local anesthetic beyond the cervical root level and not at the cervical root where the dural cuff engulfs the root.

Thus, all injections at the root level (and perhaps trunk level of some individuals) should be regarded as epidural injections, because the injection is made directly outside the dura-extra-dural, peri-dural, or epidural [17,22].

Boezaart AP [17,22] confirms that all the time-tested safety practices for spinal epidural injections should apply for root level or paraneuraxial or paraspinal extra- or epidural injections.

a. The use of large bore relatively blunt Tuohy needles.

b. The avoidance of sharp thin needles (for continuous and single-injection blocks).
c. The use of test doses to test for intravascular or intrathecal injection.
d. The fractionation of the main dose.
e. Frequent aspirations before injections.
The Interscalene anesthesia should probably be regarded and respected as para-spinal or para-neuraxial epidural blocks similar to spinal epidural or neuraxial blocks to afford it the appropriate level of respect that will avoid disastrous complications.

Does the change in the approach to decrease the neuraxial spread?.

When performing the interscalene blocks, one has to be careful to follow the original description of mesiad, posterior and caudal direction when inserting the needle.
To avoid entering the intervertebral foramen, most of the authors practitioners [23,24] have converted to the longitudinal approach to interscalene area. Recently this author approaches the brachial trunks with more longitudinal approach in the interscalene groove thus aligning the needle parallel to the interscalene trunks.
The superior trunk was identified, and deltoid and biceps contractions were evoked at 0.4Ma. The contrast injection demonstrates spread across the groove right up to the level of the cervical roots. The distance of the spread of the contrast from the needle tip is more than 5cm. Most of the contrast spread occurs cephalad to the level of the cervical roots as evident from several images of contrast.
This author cautions against an aggressive approach towards interscalene brachial block.
a. Correct palpation of the interscalene groove.
b. Needle insertion wherever the groove is maximally palpable and not necessarily at C6.
c. Appreciation of the loss of resistance of the fascia over the interscalene groove.
d. Neurostimulation evoking the deltoid and biceps motor responses at 0.4mA.
e. Avoid needle manipulations beyond this point.
f. Avoid hitting any bony structure.
g. Adequate volume and concentration of local anaesthesia to be loaded (0.5 % bupivacaine and 2% xylocaine – adrenaline 20ml).
h. Careful aspiration and injection of LA in small boluses.
I. Avoid high pressures during injections.
j. Appropriate monitoring and communication with the patient.

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