

tromyography performed on the patient's unaffected limbs 3 months later. How, then, can this event be explained? First, the occurrence of burning pain—neuropathic character—despite a dense motor block 5–6 h after a successful block performed with 30 ml ropivacaine, 0.5%, is unusual because the duration of the sensory block is approximately 12–15 h. This suggests an “acute trauma” of the brachial plexus. Second, the long duration of surgery (3 h 45 min) let us think that the procedure was complicated, meaning that the placement of the prosthesis had probably required a large amount of traction—physically induced stress—on the brachial plexus. Studies have shown that abduction challenges the brachial plexus.⁹ Arm extension, wrist extension, and head rotation to the contralateral side add further stress on the nerves.^{9,10} Ikeda *et al.*¹¹ have demonstrated in experimental studies that an elongated nerve is much more vulnerable to compression injury (surgical retractors). This constellation favors an acute “physically induced trauma” of the brachial plexus to explain the development of this complication. This is supported by the electromyography recordings on day 11, consistent with axonal loss. On the other hand, the toxic effect of local anesthetic placed outside the epineurium, as shown by ultrasound in the current case, would have more likely shown signs of demyelination. Last, testing the anterior part of the shoulder with cold ice gives information regarding blockade of the medial branch of the supraclavicular nerve, not the axillary nerve. Positioning and surgically induced stress are certainly greatly underestimated by anesthesiologists as causes of brachial plexus damage after shoulder surgery.

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Nerve Blocks, Ultrasounds, and Multiple Sclerosis

To the Editor:—I read with great interest the case report by Koff *et al.*¹ The authors rightly highlighted two important points of general interest. First, patients with multiple sclerosis may have a compromise of the peripheral nerves. Second, anesthesiologists must be aware that patients with a preexisting neurologic deficit (even if subclinical) may be more susceptible to perioperative injuries (double-crush phenomenon).

However, I would like to express some consideration about this case. The authors stated that “despite testing modalities, it may be difficult to differentiate between multiple etiologies of brachial plexus injuries.” I perfectly agree with this statement but, sometimes, useful clues about the etiologies of brachial plexus damage may be achieved by the research of the site of the initial injury. I would like to examine two possible local causes of “second crush”: the peripheral nerve block and the surgical procedure.

An injury caused by the needle or by a toxic effect of the local anesthetic mixture injected at the interscalene level should probably affect, at least at the beginning, the highest part of the plexus, with a sparing of the lowest roots (C8–T1), usually not reached by the needle or by the local anesthetic. *Vice versa*, a local surgical factor (*e.g.*, a compression by a retractor protracted for several hours)² may cause an injury at the cord level (deltopectoral approach), with a possible block of the arm from the shoulder to the fingers (including the median and the ulnar nerves) and a sparing of the nerves emerging from the roots or the trunks, like the long thoracic, the dorsal scapular, and the suprascapular nerves.

Unfortunately, the authors did not provide us with data on the function of the long thoracic, the dorsal scapular, and the suprascapular nerves. Therefore, we can only analyze the clinical and instrumental data available.

On postoperative day 1, these are the data recorded: loss of light touch sensation in C6–T1, shoulder pain exacerbated by arm movements (a normal postoperative pain?), and flaccid motor block of the entire extremity (obviously including the hand). The magnetic resonance imaging

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performed on postoperative day 3 demonstrated swelling and increased signal of the brachial plexus at the thoracic level (no data on the cervical part of the plexus). The electromyogram performed on postoperative day 4 showed loss of the median and ulnar F waves. On postoperative day 11, the same procedure demonstrated active denervation of all the muscles examined and absence of median, ulnar, and radial sensory nerve action potentials. All of these clinical and instrumental data seem to indicate, in my opinion, a distal (cord) site of secondary injury.

The only fact that could indicate a proximal site of injury is the recording of visible atrophy of the proximal musculature at 8 months postoperatively. However, I do not know whether this finding might be attributable to a specific nerve lesion or to the prolonged inactivity of the whole arm.

On the basis of these data (albeit incomplete), I think that, in this patient, the most probable responsible of the “second crush” should be searched at the surgical field and that the anesthesiologic factors did not play a main role in the development of the postoperative neurologic deficit. Therefore, in my opinion, other evidences are necessary before establishing a correlation between peripheral nerve blocks and nerve damage in multiple sclerosis patients.

Moreover, this case report does not give us any further information about the usefulness of ultrasound-guided techniques in the prevention of neurologic injuries.³

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In Ultrasound-guided Interscalene Block, Do We Know Where the Epineurium Is?

To the Editor:—The case report by Koff *et al.*¹ illustrates that ultrasound guidance of peripheral nerve blockade will not eliminate the potential for nerve injury. The role of underlying nerve pathology, even if asymptomatic, is highlighted, and the accompanying editorial provides an excellent summary of the many factors that may impact nerve integrity in the perioperative period.²

One issue that bears additional discussion is intraneural (intraepineurial) injection. Many regionalists avoid this to the extent possible, for fear of injuring fascicles during needle insertion or injection, which may or may not produce symptoms³ and which may or may not be visible on ultrasound.⁴ Limited data provide evidence that intraepineurial injection may be safe,⁵ but these data are far from conclusive.

At the level of interscalene block, distinguishing the epineurium of individual nerves with ultrasonography, or even the separation or grouping of nerve elements, is difficult. The article by Moayeri *et al.*⁶ in the same issue of *ANESTHESIOLOGY* shows why this is so. The epineurium in the gross anatomy cross sections appears to be immediately adjacent to the fascial lining the interscalene groove, and barely distinguishable from it. On ultrasound, the largest nerve fascicles at interscalene levels appear as round or oval hypoechoic nodules, usually tightly embraced by the scalene muscles, with a small amount of nonneural tissue apparent between the muscle and nerve. Whether this tissue consists of the fascial lining of the muscle, frequently characterized as the “sheath” of the brachial plexus, or the epineurium of the roots or trunks, or a combination of both is unclear on ultrasound images. It is likely that, as we scan the interscalene region, we visualize fascicles grouped in ways that we cannot discern, and that moving the needle between what we perceive as roots may well result in piercing the inapparent epineurium. Because injectate frequently issues forth from a perforated nerve during injection,⁷ this would not necessarily be apparent on ultrasound imaging. Likewise, the characteristic swelling of the nerve, expected during intraneural injection,^{5,7} would be difficult to appreciate because the actual boundaries of the nerve are not apparent to us. What we perceive as expansion of the groove may, indeed, represent swelling of the nerve due to intraepineurial injection.

A study of the images in the article by Moayeri *et al.* makes another point clear. Although nerve trunks and roots of the plexus become oligofascicular as we proceed proximally,⁸ they do not appear to be monofascicular at the level of interscalene block. We probably can see only the largest fascicles. The ultrasound image from the case report by Koff *et al.* shows only three, large fascicles, considered to be the C5, C6, and C7 nerve roots. However, the cross-sectional images provided by Moayeri *et al.* show no less than 14 fascicles at the interscalene level, many of which appear to be too small to appreciate with standard bedside ultrasound imaging units. Comparisons of ultrasound imaging and histologic sections reveal that only a portion of fascicles in peripheral nerves may be seen on ultrasound imaging.⁴ In my experience, the image provided by Koff *et al.* is quite characteristic of ultrasound imaging in the interscalene region. My concern is that we may not be able to appreciate the boundary of the nerve elements (epineurium) and some of the contents (small fascicles).

The interscalene region differs from many other sites of peripheral nerve blockade. Because the fascial lining of the scalene muscles

tightly invests the neural elements, as illustrated and exploited by Winnie when he described the interscalene block,⁹ local anesthetic solution injected within the “groove” appears to be rather constrained. Although solution injected here may move both proximally and distally, and frequently escapes from the “sheath,”¹⁰ it nevertheless appears to stay very much approximated to the nerves on both ultrasound and radiographic contrast studies.^{9,10} The situation differs from a peripheral nerve coursing its way distally through an extremity, surrounded by adipose tissue or various muscle layers, but without a well-defined and constraining fascial envelope. The sciatic nerve in the popliteal fossa, or subgluteal space, for example, has little to “hold” the injected local anesthetic near it, and injection at one spot frequently fails to surround the nerve, leading to the possibility of partial or inadequate nerve blockade. In this setting, efforts to create a “halo” of local anesthetic surrounding the nerve seem appropriate. However, this is probably not necessary at interscalene levels. Before the use of ultrasound for guidance of interscalene block, peripheral nerve stimulation was used without direct visualization, and most authors recommended a single injection of local anesthetic when the motor stimulation was refined to a 0.2- to 0.5-mA range. Reported success rates with this technique were high.^{9,11} If one single injection, without visualization, led to such efficacy, it is unclear why multiple injections would be necessary when ultrasound is used. An injection “in the groove,” *i.e.*, limited by the scalene muscles and their investing fascia, has a high likelihood of success.

Koff *et al.* note that they were careful to avoid penetrating the epineurium during the interscalene block. However, they also relate that the needle was moved to three separate sites to completely surround the three nerve roots with local anesthetic solution. Given the anatomical particulars described above, inserting the needle repeatedly around large fascicles within trunks or roots to ascertain that each is completely surrounded by local anesthetic may require repeated intraepineurial injections. I do not wish to criticize this practice by the authors, because I have done the same out of concern that I had not adequately “covered” the roots or trunks with local anesthetic. Further, any relation of the block technique to nerve injury in this case report is unclear. However, to avert injury to small, inapparent fascicles and to avoid repeated intraneural injections, it is probably safest to minimize needle manipulations and injections in the interscalene region.

As noted in the editorial by Hebl,² we cannot control all of the elements of nerve injury in the perioperative period and will never eliminate them. But the number of needle “sticks,” or insertions, in the vicinity of nerves is best held to the minimum that will be efficacious. One injection of local anesthetic solution into the interscalene groove, guided by ultrasound, should be highly successful in providing adequate blockade of the superior and middle trunks. Confirmation of local anesthetic solution surrounding the nerves need not occur at the level of local anesthetic injection: Examination of the supraclavicular area after a single site of interscalene injection usually shows highlighting of the superior elements of the plexus, evidence that solution freely moves distally, and amply bathes this portion of the plexus, as necessary for a successful interscalene block.⁹

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