That Which We Call a Rose by Any Other Name Would Smell as Sweet—and Its Thorns Would Hurt as Much

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In this issue of *Regional Anesthesia and Pain Medicine*, Mariano et al[1] and Antonakakis et al[2] both conclude that more work is needed to place their ultrasound-guided posterior approaches to the interscalene block in true perspective. We are eagerly awaiting these further reports, but I suspect they will discover that there is much more to this block than a straightforward garden-variety interscalene block.

When involved in a busy shoulder surgery institute some 11 years ago, like Borgeat et al,[3] we encountered a number of patients who experienced transient neuropathic-type burning pain in their arms after shoulder surgery and continuous interscalene block. We therefore sought an alternative and used the existing "Pippa" technique from posterior[4] with a Tuohy needle and stimulating catheter.[5–7] When visiting the first patient postoperatively, the patient reported no pain and, to the disgust of the surgeon, lifted his arm above his head to demonstrate his lack of pain—potentially ruining his repaired rotator cuff. We realized that we were onto something—a good sensory block with almost no motor component. This could potentially be an ideal block for most situations—except of course for a freshly repaired large rotator cuff tear! We postulated that the predominantly sensory block was the result of placing the catheter near the posterior sensory parts of the brachial plexus roots.[6,7]

We started to use what was later known as the *continuous paravertebral block* (CCPVB) for other shoulder surgery, especially for frozen shoulder, and found that the problem of the transient "burning arm" did not occur in the first 48 patients nor in the large number of patients over the next 11 years of using this block on selected roots for all upper limb surgery. All 48 and subsequent patients reported good surgical anesthesia,[6,7] but most of the initial patients reported unacceptable pain where the catheters penetrated the extensor muscles of their necks. We performed cadaver dissections and found a window between the levator scapulae and trapezius muscles through which one could reach the plexus without having to pass through the often tense and tender extensor muscles of the neck. We thus actively avoided penetrating the extensor muscles, and to a large extent, the problem of posterior neck pain disappeared.[6,7] Mariano et al[1] also avoid penetrating the neck muscles for their approach, whereas Antonakakis et al[2] do not. It will be interesting to follow this aspect in the follow-up work of these authors. Placing a catheter through the middle scalene muscle, however, may have different consequences than placing a catheter through the extensor muscles of the neck.

Over the years that followed, not only have we replaced our standard continuous interscalene block (CISB) (nothing but an anterior root block) for shoulder surgery with the continuous cervical paravertebral block, but it also has become our first-choice continuous block for all other major upper limb surgery. We could easily approach different roots for different surgical requirements, for example, the C5/6 root for shoulder surgery with a biceps or deltoid motor response, or the C7/8 roots with a triceps motor response for surgery to the elbow or wrist, therefore avoiding the often disappointing continuous infraclavicular block for distal surgery. This valuable differentiation unfortunately will not be available to the Antonakakis group,[2] because they do not use nerve stimulation, although Mariano et al,[1] who do use nerve stimulation, will likely soon introduce this concept to their practice.

The block was originally named the *cervical paravertebral block* because the technique was essentially the same as that of the lumbar and thoracic paravertebral blocks. Because the needle and catheter end up between (the origins of) the anterior and middle scalene muscles, Mariano et al[1] and Antonakakis et al[2] both named their blocks the "*posterior approach to the interscalene space*" and claim a distinct difference from our ultrasound description[8] because they avoid bony contact, whereas we use the bony pars intervertebralis (or articular process of C6 or the short transverse process) contact as a reference point to judge the depth and correct position of the needle tip in the paravertebral space when ultrasound guidance is not available. Bony contact is perhaps not needed if ultrasound is consistently available and well understood. Yet whatever the name, the needle and catheter finally

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ISSN: 1098-7339
DOI: 10.1097/AAP.0b013e318194cf23

settle on the *roots* of the brachial plexus, the CCPVB on the posterior aspect of the root and the CISB perhaps on the anterior aspect of the root in the paravertebral space, and I believe we should teach bony contact, nerve stimulation, and ultrasound techniques, plus loss of resistance to air or 5% dextrose in water as the needle passes though the tendinous part of the posterior or middle scalene muscles, because neither ultrasound nor nerve stimulation is always available or feasible to use.

Like Shakespeare, we have to ask the question, "What's in a name?" I suggest that naming this block by any other name makes no difference to the block, because it remains a root-level block, regardless of the direction or technique we use. However, the block's name is critically important to the respect we afford it, because its characteristics and dangers remain the same. All the disastrous complications that both articles refer to can be attributed to not fully understanding the implications of confusing the microanatomy of the plexus roots with that of peripheral nerve branches rather than, as the authors insinuate, because ultrasound was not used. Inappropriate naming and thus not affording this block its necessary respect result in using inappropriate indications and equipment. It remains to be discovered if ultrasound guidance will reduce the prevalence of these complications. Both studies[1,2] appropriately used this continuous nerve block for major surgery only. One can only hope that others will follow them and not use it for single-injection block with thin, sharp needles (as is the practice in Europe) or for minor surgery, which could result in more disastrous complications and perhaps even lead to the abandonment of this otherwise useful and safe block. Both *paravertebral block* and *posterior approach to the interscalene block* are probably inappropriate names. The serious implications of disregarding the microanatomic differences between the different parts of the plexus can only be avoided once we realize that a *root block* is a root block is a root block, no matter how and from where it is approached. It appears that the characteristics of the two blocks, when approached from anterior (more motor) or posterior (more sensory), are distinctly different when small volumes and low concentrations of local anesthetics are infused for analgesia on subsequent days following the large initial bolus.

Our understanding of the microanatomy of the peripheral nervous system is not new. Key and Retzius[9] in 1876 used Richardson's stain, whereas Horster and Whitman[10] in 1931 used trypan blue to study the spread of intraneurally injected solutions. In more "recent" times, French et al[11] in 1948 studied intrafascicular injection with radiopaque contrast medium in dogs. This was followed by the work of Moore et al[12] in 1954, who used methylene blue–stained exocaine. In a 1978 study, radioactive local anesthetic agent mixed with fluorescent dye was used by Selander and Sjöstrand[13] to study the microanatomy of different parts of the sciatic nerve of rabbits. Since this early work, even after the introduction of electron microscopy,[14] no new insights have been introduced to refute these concepts or add significant new knowledge.

Although the embryological formation of the branches or peripheral nerves occurs later than roots and trunks, for ease of understanding, the peripheral nerves will be considered first. Peripheral nerves are composed of numerous fasciculi; each surrounded by a dense perineurium and held together by a looser epineurium[9–15] (Fig. 1).

The *epineurium* consists of a condensation of areolar connective tissue that surrounds the perineurial ensheathment of the fascicles of unifascicular and multifascicular nerves.[15] (This condensation of areolar connective tissue is similar to the plexus sheaths, and although not yet shown, one wonders if the epineurium is not merely a continuation of the plexus sheaths.) The attachment of the epineurium to surrounding connective tissue is loose, so that the nerve is relatively mobile except where tethered by entering blood vessels or by branches.[15] Greater amounts of connective tissue are normally present where nerves cross joints. In general, the more fascicles that are present, the greater the quantity of epineurium. Variable quantities of fat in the epineurium have a protective function in cushioning the

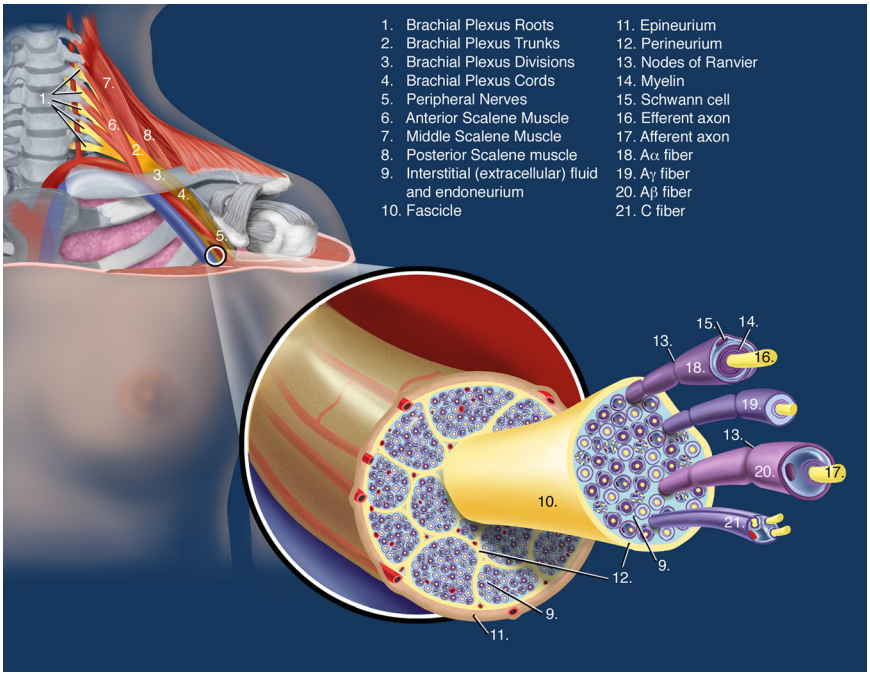

FIGURE 1. Transection through peripheral nerve depicting the nerve fascicles surrounded by perineurium. (Drawing and copyright M. K. Bryson, Brysonbiomedical Illustrations—used with permission.)

fascicles.[16] The vasa nervorum enter the epineurium, where they communicate with a longitudinal anastomotic network of arterioles and venules.[15] The epineurium also contains lymphatic vessels, which are not present within the fascicles. These lymphatic channels accompany the arteries of the peripheral nerves and pass into the regional lymph nodes.[15]

The essential structure of the *perineurium* is a lamellated arrangement of flattened cells separated by layers of collagenous connective tissue.[9] It provides an ensheathment for both the somatic and peripheral autonomic nerves and their ganglia. The cellular lamellae are composed of concentric sleeves of flattened polygonal cells, and these cells are equipped to function as a metabolically active diffusion barrier, although they do not have the morphological features of a true epithelium.

The term *endoneurium* is sometimes erroneously used to denote the intrafascicular compartment of the nerve; it should only be used to refer to intrafascicular connective tissue.[15] Approximately 40% to 50% of the intrafascicular space is occupied by nonneural elements, and about 20% to 30% of this is the endoneural fluid (cerebrospinal fluid [CSF]) and connective matrix (endoneurium).[15]

Longitudinal flow within the fascicle is inhibited minimally, whereas lateral extension is restricted by the relatively noncompliant perineurium.[15] As the nerve approaches the dural penetration from distal to proximal, 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.

Injection into a peripheral nerve fascicle is difficult. Depending on the volume and pressure, the intrafascicular injectate has direct access to the CSF and interstitium (medulla) of the spinal cord.[13] The channels by which this progression occurs have been called *perineurial spaces*, and these have been previously demonstrated.[13] Injection into a dural cuff or sleeve of a spinal root or into the root itself, on the other hand, is easy, and this injectate similarly has direct access to the CSF or spinal cord interstitium—the clinical consequences of which depend on the volume, rate, and pressure of the injectate and the path taken via the perineurial spaces of the axons.[13]

Experimental work of Selander and Sjöstrand[13] on intraneural injections into rabbit sacral nerves demonstrated that, during injection deep to the epineurium but outside the perineurium, an irregular bleb formed around the injection site. The tracer that they injected spread for a short distance within an easily expanding epineurium, which often ruptured. When 50 to 100 μL was injected at 100 μL/min, the injection pressure rose within a few seconds to 30 to 60 mm Hg and thereafter quickly decreased to a steady 10 to 30 mm Hg. As soon as the injection stopped, the pressure returned to zero. During intrafascicular injection deep to the perineurium, however, the tracer was seen to spread rapidly proximally and distally inside the fascicle. The longitudinal spread varied, but in all cases, it reached the sacral plexus. Distally, the tracer colored the tibial nerve, sometimes even reaching the foreleg. In another study,[11] the tracer reached the lumbar plexus via the injected fascicle and sometimes tracked distally via an entirely different nerve originating from the plexus. This study also showed that high-pressure intrathecal injection of contrast medium spread down the fascicles of peripheral nerves.

Selander and Sjöstrand[13] demonstrated that, if the injection was made into a small fascicle, the injectate did not extend beyond the sacral plexus, but if the injection was made into a large fascicle, the injectate easily passed the sacral plexus and reached the spinal cord. During slow injection, the spread in the medulla was just under the pia mater. In some of the experimental animals, the spread was into the CSF, and the dura and arachnoid were also colored. In 1 animal, the blue stain extended to the cerebellum. In cross sections of the spinal cord, the fluorescent tracer used was mainly seen in the thin subpial space.[13] Accumulation of the tracer was noted in the dorsal root–medulla junction area, extending into the substantia gelatinosa of the anterior horns, and into the anterior median fissure. They recorded pressures of between 435 and 675 mm Hg when injecting 50 to 100 μL with a rate of 100 μL/min into a fascicle. After cessation of the injection, the pressure remained above the estimated capillary perfusion pressure (50 mm Hg) for at least 10 minutes (Fig. 2).

The trunks of the plexuses are transitional areas.[11] The perineurium surrounding the fascicles splits away, and forms perineurial sheath interdigitations or septae. There seems to be interindividual variation on the level at which the septae form, but functionally and practically from a regional anesthesia perspective, the trunks should be regarded as transitional areas between clearly defined fasciculi with rigid perineuria at the branches to the root area where perineuria are not present and all the perineuria have joined to form the dura[11] (Fig. 3).

After splitting away from the fascicles, at the level of the nerve roots, the perineurium thickens and fuses with the dura.[11,15] (Embryologically more correct, the peripheral nerve perineuria are continuations of the dura mater.) The axons inside the roots are consequently not protected by the perineurium anymore, and the extracellular or tissue fluid is the CSF. The connective tissue framework of the peripheral nervous system therefore arises entirely from the dura mater to a continuation of the perineurium around the fascicles of the branches. As the nerve progresses peripherally, it is more and more subdivided by perineurial interdigitations until each fascicle of nerve axons eventually has its own perineurial sheath.

The mesothelial cells of the arachnoid membrane in the spinal canal become hyperplastic where they exit the nerves and form a cuff around the roots just after they penetrate the dura mater.[15] Beyond this cuff, no tissue can be seen that is recognized as arachnoid.

With the recent introduction of ultrasound to regional anesthesia, it became clear that nerves can either be hyperechoic or hypoechoic.[16] When studying ultrasonographic appearance, it can be seen that the more proximal the nerve, the more hypoechoic (black appearance); and the more distal, the more hyperechoic the nerve ("honeycomb" appearance) (Fig. 4). With the insight of the nerve microanatomic morphology, this should be easy to understand in practical terms—even if perhaps not entirely correct in pure physics terms (Fig. 4).

Although intraneural but extrafascicular injection at the terminal branch level is probably without consequences,[17] injections at the root level (and perhaps trunk level of some individuals because of interindividual variation on anatomy) should be regarded as epidural injections, because the injection is made directly outside the dura-epidural.[18] All the time-tested safety practices for spinal epidural injections should therefore similarly apply for root-level or paraneuraxial epidural injections. These, in my opinion, should include the use of large-bore, relatively blunt Tuohy needles; the avoidance of sharp, thin needles (for continuous and single-injection blocks–yes, including interscalene blocks[19]); the use of test doses for intravascular or intrathecal injection; fractionation of the main dose; and perhaps even similar guidelines for anticoagulation,[8] although this is open to debate and can be expected to be further contested.[20] All the catastrophic, potentially catastrophic, and tragic

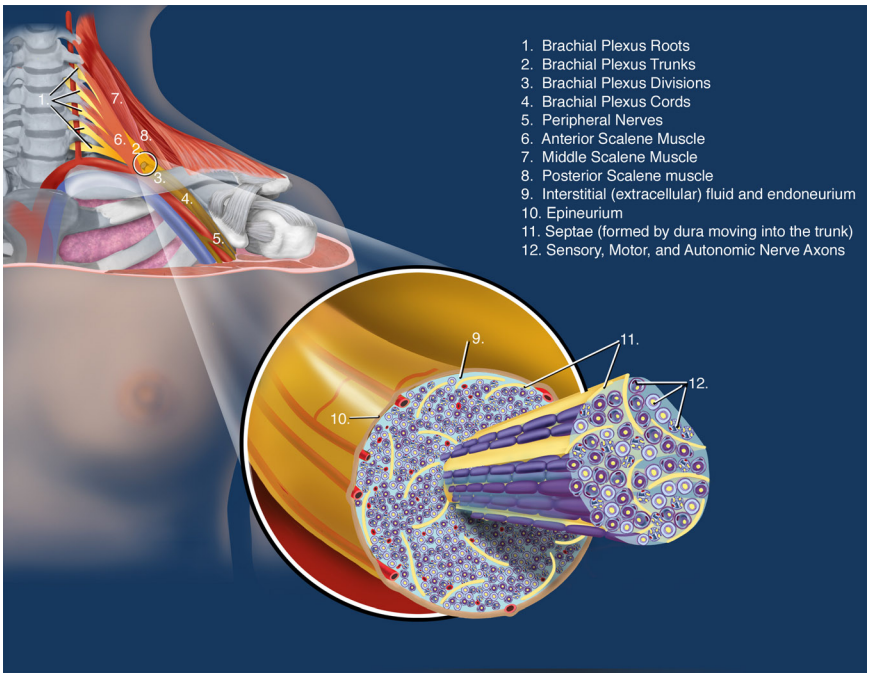

FIGURE 2. Transection through brachial plexus trunk depicting septae as a continuation from the perineurium to the dura. (Drawing and copyright M. K. Bryson, Brysonbiomedical Illustrations—used with permission).

cases, ranging from total spinal block to quadriplegia, and referred to in the articles by Mariano et al[1] and Antonakakis et al[2] (and the cases of Benumof[19]), can comfortably be explained by intraroot (subdural) injections with relatively thin and sharp needles that were not designed for use around the dura. All the presented cases were spinal root or trunk-level blocks performed with needles that one would not use for a spinal epidural block. All root-level blocks (cervical, thoracic, lumbar, and sacral), and perhaps even trunk-level blocks, such as interscalene blocks in certain individuals,[19] should probably be regarded and respected as paraneuraxial epidural blocks similar to neuraxial epidural blocks to afford them the appropriate level of respect that will avoid disastrous complications. I am convinced that ultrasound alone without this respect will not do that, although it may help.

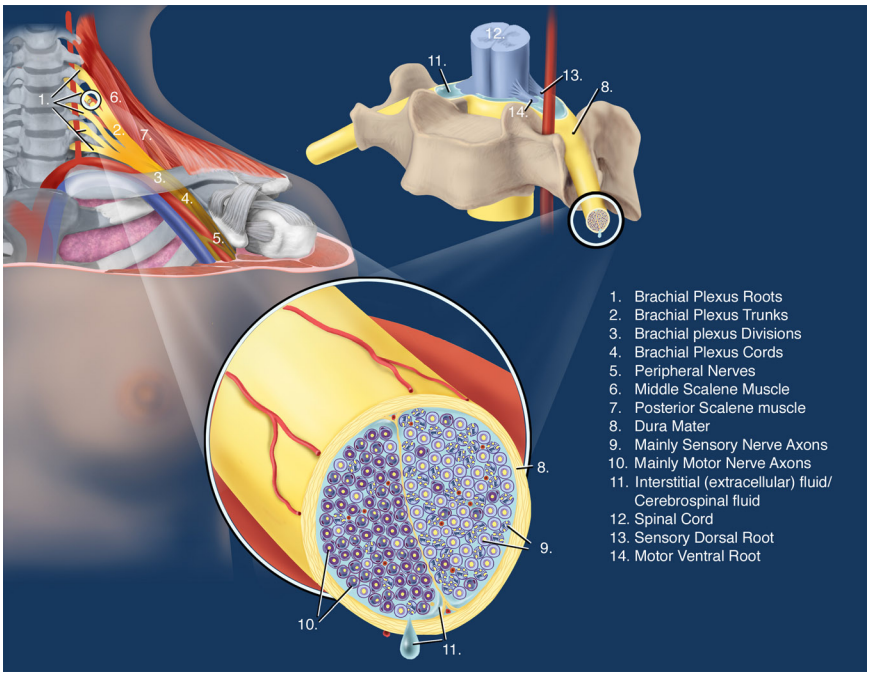

FIGURE 3. Transection through brachial plexus root depicting the dura as a continuation from the perineurium in the peripheral nerve and the septae in the trunk. (Drawing and copyright M. K. Bryson, Brysonbiomedical Illustrations—used with permission).

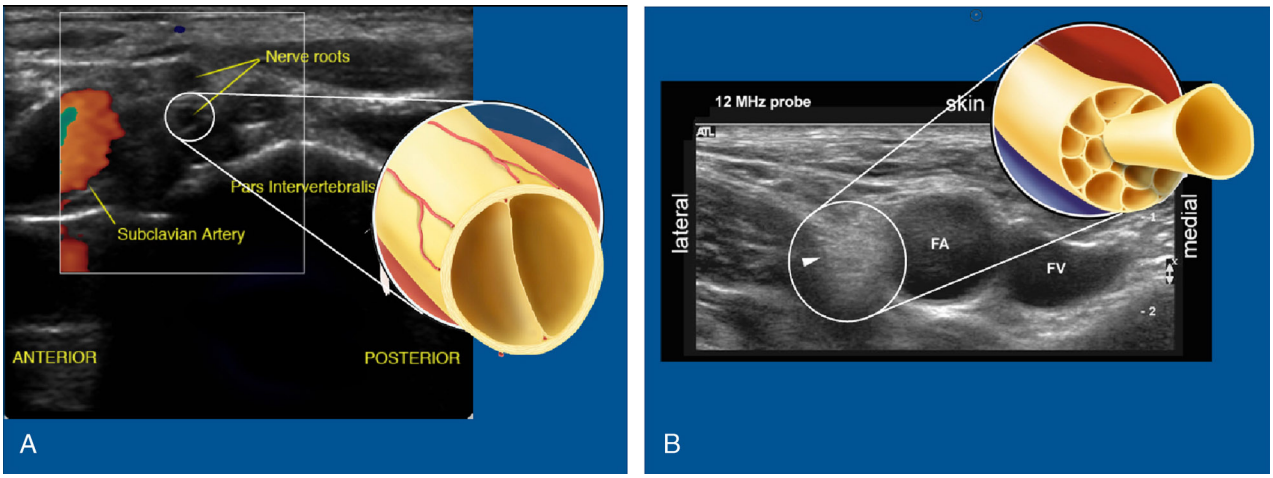

FIGURE 4. (A) Ultrasound appearance of the nerve roots at the cervical paravertebral area showing the hypoechogenic appearance of the roots. Inlay drawing is of the nerve root at this level without the axons and endoneurium. (B) Ultrasound appearance of the femoral nerve in the groin area showing the hyperechogenic or "honeycomb" appearance of the nerves at the peripheral level. Inlay drawing is of the peripheral nerve at this level without the axons and endoneurium.

In summary, as the roots of the brachial plexus exit the spinal column, they consistently have sleeves of dura surrounding them, and they do not have fascicles. The same lamellated arrangement of flattened cells separated by layers of collagenous connective tissue that surround the fascicles at the terminal branch level (perineurium) forms septae at the trunk level and the dura mater sleeves that surround the nerve roots and spinal cord. These sleeves can extend variable distances down the plexus, sometimes even reaching the trunks or even further in certain individuals. An injection deep to this dura at the paraspinal or paravertebral position represents a subdural injection with similar consequences to any other subdural injection at the central spinal position. These consequences depend on the position, volume, pressure, and chemical consistence of the injectate. Whether the block that Mariano et al[1] and Antonakakis et al[2] describe and claim to be their own is named a *posterior approach to the interscalene block*, a *continuous Pippa block*, or a *continuous cervical paravertebral block*, and whether it is performed with or without ultrasound, with or without bony contact, and from whatever direction, the block is a root-level block and should be afforded the same respect as any other epidural block. Anterior and posterior root level blocks have strikingly different clinical characteristics, as will no doubt become more clear later as we develop our knowledge and experience with this block. This is perhaps due to the fact that the dorsal root contain mainly sensory fibers and the ventral root fibers are mainly motor fibers.

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