

more nerve roots, thus increasing the extent of neurological injury.

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SP21

NEEDLE ARCHITECTURE: VULNERABILITY OF DIFFERENT NERVES TO INTRAFASCICULAR INJECTION WITH DIFFERENT NEEDLE BEVELS

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Deliberate or inadvertent intraneural injection may be associated with a variety of neurologic complications. Intraneural injection has traditionally been subdivided into *intrafascicular* or *extrafascicular* injection. In the latter instance, the injected solution spreads between the fat cells without breaking or disturbing them, causing the nerve to swell, which can be seen during ultrasound-guided injection.

We have recently demonstrated that after deliberate intraneural injection in fresh cadavers, the possibility of *intrafascicular* spread is low.^{1,2} In this study, spread occurred mainly in the *extrafascicular* adipose tissue and between the cells of the perineuriums of some fascicles. At low magnification, *intrafascicular* spread could be demonstrated as an ‘island’ inside the fascicle, but this spread on high magnification clearly proved to be between the perineurium cellular layers that formed the perineuriums of the fascicles and the cells that form the perineurial septae inside the fascicles. This gave rise to the concept of ‘pseudo-intrafascicular’ spread, which appeared *intrafascicular* at low magnification but in fact was not within the endoneurial tissue when the tissues were examined under high magnification light microscopy.^{1,2} Our original assumption was that because of the pressure gradient between the *intra-* and *extrafascicular* spaces, the entire orifice of the needle had to be inside a fascicle to result in pure *intrafascicular* spread. When the distal needle orifice was partially outside the fascicle and partially inside the fascicle, the spread would preferentially follow the route of least resistance toward *extrafascicular* tissue, which contains low-resistance adipose tissue. A mathematical model allowed us to calculate the portion of a needle orifice inside fascicular tissue to evaluate the

influence of the type of needle, the angular approaches used for nerve blocks, and the kind of nerve being blocked.

We used cross-sectional images from subgluteal- and popliteal-level sciatic nerves approximately at their bifurcation, a median nerve at the wrist level, and nerve roots of the 5th, 6th, and 7th brachial plexus.³ On these sections, we superimposed images of the distal orifices of a 22-gauge, 15° ‘Stimuplex® D’ needle and a 22-gauge, 30° ‘Stimuplex® Ultra 360®’ needle at exactly the same magnification. These samples served only to evaluate the proposed method and were not intended to be clinically relevant.

Three virtual angular approaches of the needles to the nerves were studied: 1) perpendicular (90°) to the cross-section of the nerve (90CS), 2) at a 45° angle to the cross-section of the nerve (45CS), and 3) at a 45° angle to the longitudinal axis of the nerve (45LA).³

Pre-processing of needle and nerve images: Digital image processing techniques were used to measure the portion of the distal needle orifice section that was inside the fascicles.^{3,4} First, we performed a pre-processing of the nerve and needle images to reduce the complexity and the computation burden of the proposed method. The three-dimensional (3D) colored cross-section images (RGB images) were converted to two-dimensional (2D) images, assigning the white color (value equal to 1) to the fascicles and the background of the image, and the black color (value equal to 0) to the *extrafascicular* tissue. The same procedure was followed for the needle images; the white color was assigned to the distal needle orifice, with the background in black. This procedure was done manually using Adobe Photoshop. Although both nerve and needle images were captured with the same magnification.

Because the background of the image and the fascicles was white to simplify the manual pre-processing of converting 3D images to 2D images, the fascicle tissue was automatically identified by searching white pixels (fascicular tissue) on a black background (*extrafascicular* tissue). A new gray-scaled image was created by assigning the value 1 to the *extrafascicular* tissue, the value 2 to the fascicular tissue, and the value 0 to the background of the image.

The needle image was superimposed onto the cross-section image, simulating the insertion of the needle into the nerve. To evaluate all the possible scenarios where the needle could be inside the nerve fascicle, the needle orifice image was progressively positioned from the bottom to the top of the nerve image in steps of $\delta 1$ pixels (or equivalent millimeters) and from left to right in steps of $\delta 2$ pixels (or equivalent millimeters).³ A new gray-scaled image was obtained for each move. This image represented the sum of the nerve image and the distal needle orifice image, where *extrafascicular* pixels had the value of 2, the fascicular pixels had the value of 3, and the background pixels had the value of 1 in the regions where the needle orifice was positioned.³ From this gray-scaled image, the percentage of the orifice needle inside of fascicular tissue was computed as the number of pixels with value 3 divided by the number of pixels with value lower than 3 inside the orifice needle. As a result, a new image of these percentages, $P_{R \times T}$, was obtained, where R is the number of displacements in the vertical axis and T is the number of displacements in the horizontal axis. This procedure was performed using Matlab R2017b (Math Works, Inc., Natick, MA).³

Bidimensional and tridimensional graphical representations of the percentage of the needle orifice inside the fascicle were obtained with different views.³ A 0% to 100% scale with its

corresponding gradient of colors from red to dark blue was included in each figure. Within each cross-section nerve image, the corresponding color has been assigned according to the percentage measured, with blue to dark blue indicating areas in which the highest percentage (80%–99%) of orifice area is inside the fascicle.³

In reference 3 was showed in images, the percentage, from 70% to 99% of the needle orifice, inside the fascicle when the needle was inserted (virtually) perpendicular to the cross-section nerve (90CS), at a 45° angle to the cross-section nerve (45CS), and at a 45° angle to the longitudinal axis of the nerve (45LA), respectively. Although the graphs showed a percentage from 70% to 99% with the intention of focusing our attention on the events of greatest interest, however we studied all the percentages included, from 0% to 100%.³

For this calculation, the needle orifice was positioned inside the nerve and moved in steps of Δ_1 and Δ_2 equal to 0.1 mm in the horizontal and vertical axes. These percentages were calculated for both types of needles, while Δ_1 and Δ_2 values were selected to have a detailed model considering the computational burden. For the three types of insertion approaches, the ECO 30° needle was found within the fascicles more frequently than the NE 15° needle.

Slight differences in needle distal orifice occupancy were found between the three types of insertion angles for the needle orifice inside the fascicles of peripheral nerves at 90CS, 45CS, and 45LA, with higher percentages of occupancy in the case of 45LA in the brachial plexus roots. Although there was a difference between the average fascicle surface area of the sciatic nerve at the subgluteal and popliteal levels (0.20 vs 0.25 mm²), the fascicles were more concentrated at the popliteal level, and thus the percentage of a distal needle orifices partially inside the fascicular tissue was higher at the popliteal level. For both needle types, significant differences for needle distal orifice occupancy inside the fascicles were found for 90CS versus 45LA and 45CS versus 45LA in all nerves except the brachial plexus nerve roots of C5 for the ECO 30° needle ($P = 0.08$) and the brachial plexus nerve roots of C5, of C6, and of C7 for the NE 15° needle ($P = 0.06, 0.66, \text{ and } 0.17$, respectively). In addition, significant differences were found for 90CS versus 45CS for the NE 15° needle in all nerves except the median nerve at the wrist ($P = 0.15$).

With this study, we have introduced and evaluated a new mathematical method to calculate the theoretical vulnerability of nerve fascicles and the risk of possible intrafascicular injection in nerves. The nerves and needles selected and the values obtained were examples to evaluate the potential of this tool for future studies that will be applied to large numbers and different types of nerves. The tool identified critical areas inside the nerve most at risk for intrafascicular injection depending on the needle type chosen for each type of nerve block: root level (brachial plexus), singular (median nerve), and grouped nerves (subgluteal and popliteal sciatic nerves).

The central core of the fascicles in dark blue sowed in reference 3, should be at higher risk because only at these areas could we demonstrate that the orifice of the needle was entirely or almost entirely inside of the fascicles. Conversely, the more peripheral areas within the fascicle were assigned another color because the occupancies of the needle orifice inside the fascicles here were incomplete.³ The risk, however, increased when we used the 30° beveled needles. This was because their orifice areas were smaller than that of the 15° beveled needles, thereby increasing the chances of obtaining

large numbers of measurements with 80% to 99% occupancy of the orifice.

The sizes, shapes, and number of fascicles, and their relation to the amount of fat that surrounds them were different in each nerve. This is important because it may offer varying possibilities regarding partial to full occupation of a needle orifice within fascicular tissue. Our team was able to conclusively demonstrate that it was almost impossible to obtain intrafascicular spread inside the endoneurium – even with high injected volumes and pressures – if the needle orifice was only partially occupied by fascicles. In fact, the injected solution completely leaked to fat in the extrafascicular compartments, and no marker was observed inside the fascicles. For this reason, the size and shape of fascicles, needle orifice used, and thickness of fat surrounding the fascicles are critical for intrafascicular spread to take place.

From this current study, we can confirm that the prevailing ideas around intra- and extrafascicular injection as a consequence of deliberate or accidental intraneural injection are most probably incorrect.

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SP22 FOR EMERGENCY CS, A LABOUR EPIDURAL SHOULD BE REMOVED AND A SPINAL ANAESTHETIC USED INSTEAD

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Planning, Preparation and Pre-emption are three key concepts in the practice of anaesthesia. In obstetric anaesthesia specifically, these three ‘P’s are particularly relevant as parturients are commonly present the Delivery Suite for a period of time prior to requesting or requiring anaesthetic intervention. One frequently encountered example of implementing Planning, Preparation and Pre-emption by the obstetric anaesthesiologist is the recommendation of starting epidural analgesia during labour. Unless contraindicated, this is suggested or advisable in parturients with modified WHO 3 and modified WHO 4 heart disease¹, in women with maternal obesity², in active COVID-19 infection³, in the presence of certain ophthalmic pathologies⁴, and in laboring women with pre-eclampsia⁵, among others. This is to ensure labour analgesia and patient comfort; to prevent deterioration of medical conditions due to the added physiological and psychological stresses of labour; to reduce the need for further anaesthetic intervention should anaesthesia be required for a surgical procedure; and to avoid general anaesthesia wherever possible, reducing the incidence of associated complications and protecting healthcare staff from aerosol-generating procedures.

The main benefits of having an established Labour Epidural providing good epidural analgesia are: 1) the possibility of its