

# INTRANEURAL INJECTION DURING PERFORMANCE OF US BLOCKS

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## **Introduction**

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Nowadays, pharmacological intraneural injection is one of the great worries of anesthesiologists specialized in regional anesthesia. This is due to the belief that intraneural injection causes, invariably, irreversible neurological damage due to direct nervous lesion. Nevertheless, no study has corroborated this dogma.

At the start of regional anesthesia, the nerve block technique was closely related to the injection of cocaine in the nerve, this behavior being known as 'intraneural injection'. Thus, Victor Pauchet (1), in his book "L'anesthésie Regionale", defines what happens after an intraneural injection: "A fusiform enlargement of the nerve ensues that disappears quickly. The injectate diffuses along both sides, that is why an intraneural injection can exit through the branches that leave the nerve close to the injection site". This signs have recently been reconsidered as signs of intraneural injection (2-7).

## **Internal nerve structure (figure 1)**

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The nerves are clearly defined anatomical structures. The noble part of the nerve is formed by the nervous fibers (axons). These axons are protected by a thin supporting layer, the endoneurium. The group formed by the sheath of axons and their endoneurium forms the fascicles. Nervous fascicles form a unique anatomo-functional structure. These fascicles are protected by a thick cellular layer, the perineurium. This perineurium is the authentic layer of axonal protection. Furthermore, this noble structure, formed by the nervous fascicles, is widely protected by a fibroadipose tissue: the epineurium. Fascicles can be isolated or clustered in fascicular groups, with connective tissue between them. The different fascicular groups are contained in a more lax epineurial tissue, with a greater amount of fat. This epineurium can be divided into the interfascicular epineurium (between fascicles or fascicular groups), or the epineurium that surrounds the nerve (supepineurial epineurium), which will form the epineurial membrane.

In the peripheral nerve, we can thus consider to clearly differentiated parts: the epineurium and the nervous fascicle. There is a different epineurial-fascicle relationship (ranging from 30 to 70%) between peripheral nerves and plexus, and between the peripheral nerve along its length (8).

## **Theoretical injection points, expected clinical answer and risk of postoperative disfunction (figure 2, table 1)**

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Once the neural structure is known, it is easy to theorize concerning the different possible injection sites, considering its different compartments. Hence, we can classify intraneurial injections as:

### ***Extraneurial injection***

Injection outside the epineurial cover. Of maximal security, probably there is an absence of neurostimulation answer at classical intensity (<0.5 mA), and a late-onset, occasionally incomplete, blockade (depending on the nerve being stimulated). The distribution of anesthetic along the nerve will be erratic, making it necessary to perform frequent redirection of the needle.

### ***Epineurial injection***

Injection inside the epineurial layer, but outside the perineurium (outside the fascicle). Its efficacy and security will be very dependant on the site of injection, and of the nerve's characteristics. It can be sub-classified into:

#### *Inter-branch or inter-nerve injection (figure 2; b)*

Injection between complex nerves / trunks grouped in the same epineurial tissue. When an injection is performed in the sciatic nerve or in a trunk, division or chord of the brachial plexus; we usually find ourselves in this space, and we will see a good distribution of the anesthetic drug along the nerve groups that conform the nervous unit, without need of moving or redirecting the needle. This injection is safe, with an elevated blocking efficacy, variable responses to neurostimulation (usually with answers to intensities greater than 1 mA), and low resistance to the drug injection, allowing for a clear definition of the nerves' limits afterwards.

#### *Subepineurial injection (single nerve) (figure 2; c')*

This injection is performed under the epineurial sheath. Injection in this site doesn't present a high resistance, and answer to neurostimulation is variable, but usually happens at standard intensity (0,5 mA). Drug distribution happens along the nerve (thin subepineurial distribution), with a displacement of the nerve (due to the injection's pressure), followed by an extraneurial disposition of the drug. Administration at this site associates with a low risk of post-blockade neurological dysfunction.

#### *Intraepineurial injection (single nerve) (figure 2c).*

This injection happens in the centre of the neural area (between fascicles or fascicular groups). When the needle is placed in this space, we will usually observe clinical signs (paresthesias) and a response to low-intensity neurostimulation (<0.5 mA, frequently <0.3 mA). Injection of drug at this level will show displacement of fascicular groups or isolated fascicles (swelling), and clear echogenicity changes in the nerve. This injection must be avoided, since there is a greater (although infrequent) risk of post-block dysfunction. When we visualize this in the screen of our ultrasonograph, injection must be stopped and the needle must be slightly withdrawn before we proceed.

#### *Intraneurial injection (Inside a group of fascicles) (Figure 2, d).*

This happens when injection is performed inside a group of densely united fascicles (with a high content of collagenous, and a low content of adipose, tissue). This will present with paresthesia, response to a low intensity neurostimulation (<0,3 mA), and high resistance to drug injection. It has a high risk of post-blockade dysfunction, with an ultrasound image identical to the one described in the previous section (Swelling).

### ***Intrafascicular injection***

This happens inside the fascicle. It is probably impossible to perform in awake patients (the risk will hence be when performing it in anesthetized patients). The neural damage, in this case, is guaranteed. There is a high resistance to injection, with response to minimal neurostimulation intensity, etc. Again, the ultrasound image will be undistinguishable from the previously described swelling.

## **Ultrasonographic signs of neural puncture and intraneurial injection**

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In specialized anesthesiology literature, the definition of intraneurial injection is not clear; despite the peripheral nerve is a clearly characterized structure, as we have explained in the previous section. Intraneurial injection must be defined as drug injection inside the peripheral nerve. We can then divide intraneurial injection into intrafascicular injection, as the one performed inside the nerve fascicle (with disruption of the perineurium); or intraepineurial-extrafascicular injection, which happens inside the epineurial tissue (Table I).

We can nowadays identify signs that will suggest the administration of anesthetic drug in the intraneurial tissue. Nevertheless, these signs are still too loosely defined, or are of difficult identification or interpretation, to be helpful in forming the criteria that assures us we have performed an intraneurial injection. The main inconveniences of imaging techniques are that, in many occasions, they are incapable of delineating the nerves' limits, much less to identify fascicles. That's why ultrasound has a low predictive capacity in defining the site of injection, and thus of predicting the possible risk of post-block dysfunction.

Ultrasound signs of puncture and/or intraneurial injection are varied and observer-dependant. The established criteria should be capable of answering to two different situations. Firstly, to evaluate the incidence of intraneurial injection in non-ultrasound guided anesthetic techniques (i.e: neurostimulation-guided techniques); and, secondly, to evaluate the incidence in ultrasound-guided techniques, were puncture control is performed in real-time. In both situations, there will be signs of higher or lower specificity:

### ***Dynamic signs of neural puncture and injection:***

Viewing the needle inside the nerve (not demonstrable clinically nowadays, due to ethical considerations)(Figure 3). Neural puncture is an occasional, undesired observation; what can usually be observed is neural injection. Control and viewing of the needle tip is good when we perform an 'in plane' technique, and when the puncture angle is less or equal to 30° (9).

Dynamic view of the area's increase. Direct vision of the nerve's distension, with fascicle separation (increase of the neural diameter) when we start drug injection (3,5,6,9) (Figure 4,B).

Elastic reduction of the area when ceasing drug injection (Figure 4,C). This suggests elastic distention of the epineurium, which will disappear when there is rupture of the epineurial cover or anesthetic diffusion along the neural structure, as suggested by Pauchet in 1914 (1).

### ***Static signs of neural injection:***

Increase in the nerve's area and diameter due to the anesthetic's expansive effect at the site of injection (4,7,10) (Figure 5, B).

Diffusion of the anesthetic, creating a fine halo, in proximal and distal senses (4,10) (Figure 5, C).

Nerve swelling. Change in echogenicity due to edema effect or to increase in the aqueous proportion in the tissues (4,9,10) (Figure 5,C).

## **Risk of nerve damage associated to nerve puncture and intraneurial injection**

Puncture and intraneurial injection implies the possibility of neurological damage. This hypothetical damage will depend on various factors. Firstly, on the nerve's own capacity to protect itself against an external noxa. Thus, internal anatomical characteristics of a nerve, and its possible previous pathology, will be factors to consider in post-block lesions. Secondly, the noxa's own aggression capacity must be considered. Classically two mechanisms are described: the needle's own mechanical effect inside the nerve, and the drug's effect (which can cause toxic and/or ischemic repercussions).

There are various nerve characteristics that may condition a higher or lesser degree of risk in case of intraneurial puncture or drug injection (8,10,11). These are:

***The relationship between the epineurial and neural tissues*** (between epineurial areas and fascicles).

The epineurium acts as a sustaining tissue, protecting the fascicles. Hence, nerves with a greater quantity of epineurial tissue (i.e. the sciatic nerve) will be harder to damage by puncture.

***The size of the fascicles and fascicular groups.***

Inside the nerves, fascicles can be of a different size; either thickly clustered forming fascicular groups, or more or less isolated in the epineurium. Thickly clustered fascicles will be easier to damage by direct needle puncture, whereas isolated fascicles will be more susceptible to damage by drug injection, due to the breaking of communicating bridges between fascicles (interfascicular plexus).

***Elongation capacity of the fascicles and lassitude of epineurial tissue.***

Nerves that are under stretch forces and those that present attachments or loss of elasticity present a higher risk of damage both by needle puncture and by drug injection.

***Neural vascularisation.***

Vessels, as fascicles, can be damaged by needle puncture or drug infusion. They present the same anatomical qualities that those described for the fascicles, and they can thus be equally damaged. Intraneurial hematoma, or of the nerve's *arteria nutriens* is a pathogenic mechanism to be remembered.

## **Conclusion**

Nowadays, regional anesthesia can not be conceived without the use of ultrasonography (12). Despite the helpfulness of this tool, it doesn't assure us of a total lack of complications associated to the regional technique. The main risk of complications associated to regional anesthesia doesn't depend so much on the way to approach the nerve as to the nerve's characteristics, its intrinsic pathology and the skill of the anesthesiologist performing the technique.

The present ultrasound technology doesn't have enough definition to allow us to establish the relationship between the nerve fascicle and the needle tip. The important thing to know is that the signs of intraneurial injection don't differentiate between subepineurial, interfascicular or intrafascicular; so we need other signs or techniques to improve safety. The clinic,

neurostimulation response, injection pressure control, etc, are still necessary to minimize the risk of post-block nerve complications (13-16).

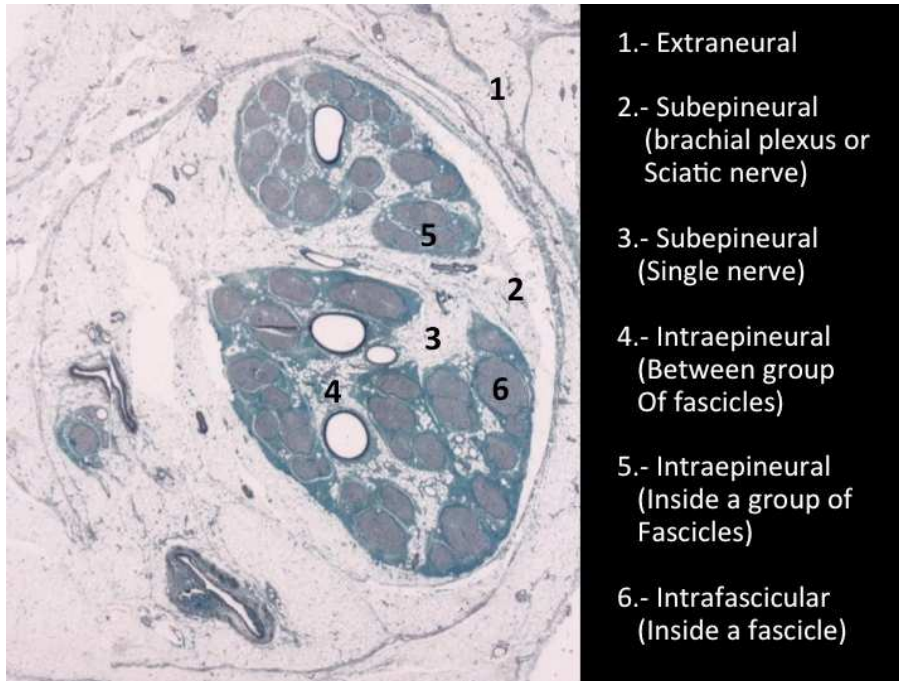
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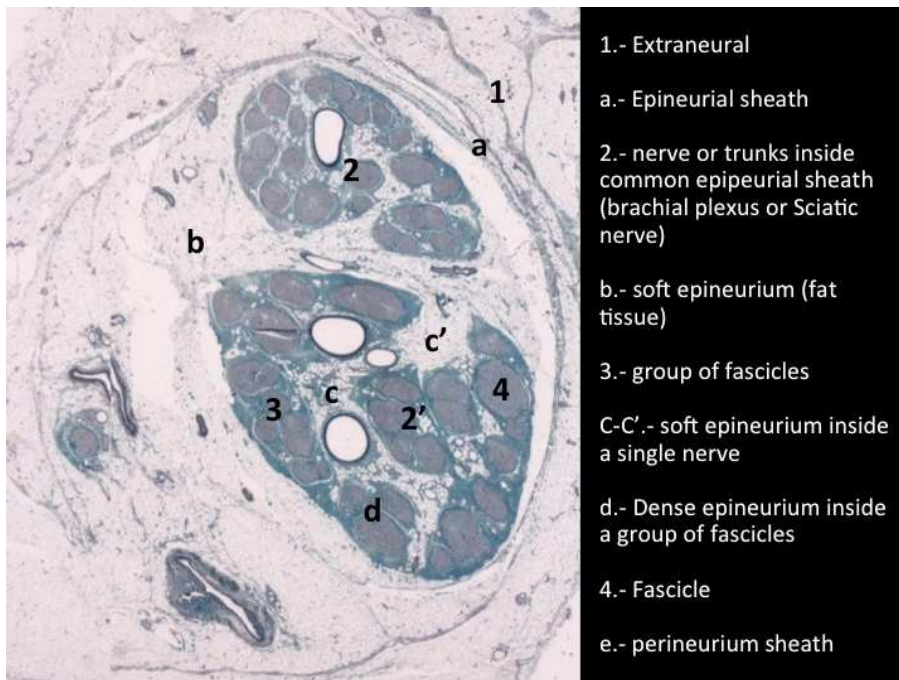
## Figure legends

**Figure 1 :** Microscopically anatomical section of sciatic nerve above the division showing the structure of a complex nerve like sciatic.



- 1.- Extraneural
- 2.- Subepineural (brachial plexus or Sciatic nerve)
- 3.- Subepineural (Single nerve)
- 4.- Intraepineural (Between group Of fascicles)
- 5.- Intraepineural (Inside a group of Fascicles)
- 6.- Intrafascicular (Inside a fascicle)

**Figure 2 :** Microscopically anatomical section (same than figure 1) showing the possible injection sites inside the nerve.



- 1.- Extraneural
- a.- Epineurial sheath
- 2.- nerve or trunks inside common epineurial sheath (brachial plexus or Sciatic nerve)
- b.- soft epineurium (fat tissue)
- 3.- group of fascicles
- C-C'.- soft epineurium inside a single nerve
- d.- Dense epineurium inside a group of fascicles
- 4.- Fascicle
- e.- perineurium sheath

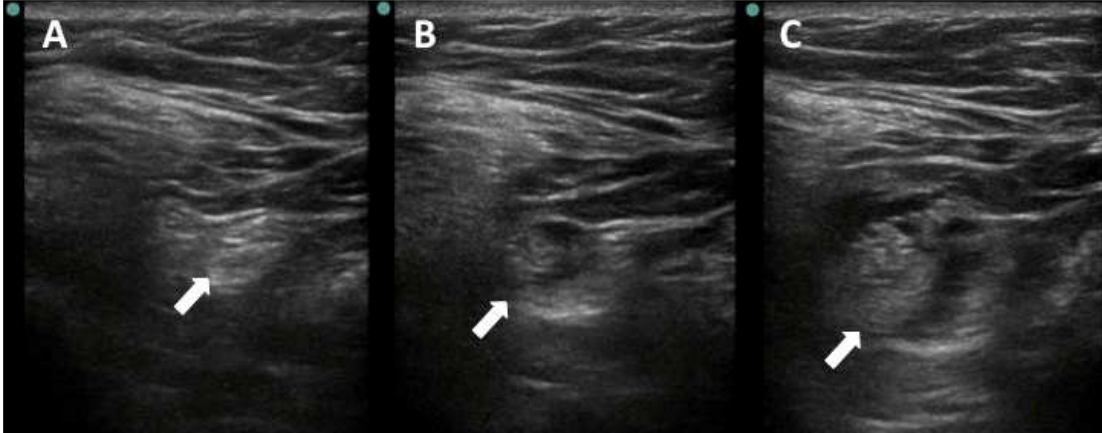
**Figure 3 :** Ultrasound imaging demonstrates the intraneural needle disposition in the ulnar nerve at the elbow in a cadaver model.



**Figure 4 :** Dynamic view of intraneural signs in femoral nerve block. Preinjection (A), during injection (B-area increase, and fascicular separation) and after stop the injection (C – elastic reduction of area).



**Figure 5 :** Static signs of intraneural injection of sciatic nerve block showing the nerve's area and diameters increase (B) and the swelling and halo around the nerve (C).





**Table 1 :** Characteristics of intraneurl injection

		Paresthesia	NRS (motor response)	Pressure	Volumen Distribution (US)	Risk postoperative disfuncion
Extraneural administration		No	No response or high intensity (>1 mA)	Low (< 5 PSI)	Erratic	Very low
Epineurial injection	Interbranch es	Uncommon	No response or high intensity (>1 mA)	Low (< 5 PSI)	Good distribution in a single injection. Distribution along the nerve	Very low
	subepineurial	Possible, uncommon	< 1 mA (frecuently < 0,5 mA)	Low (< 5 PSI)	Thin halo arround the nerve. Epineurium sheath visible, encrease area of nerve and distribution along the nerve	Very low
	intraepineurial	Frecuently	< 0,5 mA (frecuently <0,3 mA)	Low (5-10 psi)	Swelling and encrease area and distribution along the nerve	low
	Intra-group of fascicles	Very common	<0.3 mA	High (10-15 psi)	Swelling and encrease area and distribution along the nerve	High
Intrafascicular injection		Yes (respuesta retirada)	Mínima (<0.1 mA)	High (> 15 psi)		Very high