# The anatomical relationship of the superficial radial nerve and the lateral antebrachial cutaneous nerve: *A possible factor in persistent neuropathic pain.*

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## ABSTRACT

The Superficial branch of the Radial Nerve (SBRN) is known for developing neuropathic pain syndromes after trauma. These pain syndromes can be hard to treat due to involvement of other nerves in the forearm. When a nerve is cut, the Schwann cells and also other cells in the distal segment of the transected nerve, produce NGF in the entire distal segment. If two nerves overlap anatomically, similar to the Lateral Antebrachial Cutaneous Nerve (LABCN) and SBRN, the increase of secretion of NGF, that is mediated by the injured nerve, results in binding to the high affinity NGF receptor, tyrosine kinase A (TrkA). This in turn leads to possible sprouting and morphological changes of uninjured fibers, that ultimately causes neuropathic pain. The aim of this study was to map the level of overlap between the SBRN and LABCN.

20 arms (5 left, 15 right) where thoroughly dissected. Using a new analysis tool called CASAM (Computer Assisted Surgical Anatomy Mapping) the course of the SBRN and LABCN could be compared visually. The distance between both nerves was measured at 5 mm increments and the times they intersected were documented.

In 81% of measurements the distance between the nerves was less than 10 mm and in 49% the distance was even less than 5 mm. In 95% of the dissected arms the SBRN and LABCN intersected. On average they intersected 2.25 times.

The close (anatomical) relationship between the LABCN and the SBRN can be seen as a factor in the explanation of persistent neuropathic pain in patients with traumatic or iatrogenic lesion of the SBRN or the LABCN.

## INTRODUCTION.

In 1984, Dellon and Mackinnon[1] stated that surgery on the radial side of the wrist is notorious for the development of neuropathic pain. Their explanation was that in 80 % of cases the cause of this complication was stretch or compression of the superficial branch of the radial nerve (SBRN).

Mackinnon and Dellon[2] also presumed, that the reason for the persisting symptoms in some patients might be caused by the fact, that the course of the Lateral Antebrachial Cutaneus Nerve (LABCN) for a large part overlaps with the course of the SBRN. Thus, when the SBRN is lacerated, the LABCN almost certainly also is cut. Therefore, they postulated that in these patients the pain was caused by the LABCN and not the SBRN.

By performing a diagnostic nerve block to the LABCN using a local anesthetic, (1% lignocaine), pain can be temporarily reduced in some patients[3]. This shows that there is at least a relation between pain caused by lesion of the Radial Superficial Nerve (SBRN) and the LABCN. However, it remains unclear at which level the actual problem is localized: distal segment, Dorsal Root Ganglion or even central parts of the nervous system[4].

It has been postulated that NGF plays a role in neuropathic pain[5-8], although the exact mechanisms remain elusive[9,10]. When a nerve is transected, Schwann cells, but also other cells, in the entire distal segment of this transected nerve produce NGF[11,12]. This production is being initiated by the axonal degeneration and the Schwann cell upregulation, also known as Wallerian degeneration. If branches of two nerves overlap anatomically (e.g. in case of the LABCN and SBRN) the produced NGF in the distal part of one nerve stimulates the other nerve, causing pain. Therefore, our interest is to demonstrate the areas of overlap between the LABCN and SRBN, more precisely. This is hard to describe by standard anatomical techniques and therefore a system called Computer Assisted Surgical Anatomy Mapping (CASAM) was used. CASAM is a system created in the Erasmus MC Anatomy lab[13,14] able to create an average of all used dissections (i.e. a virtual 'average arm', and subsequently creating a visual representation of the 'average' course of the SBRN and the LABCN. (see the CASAM paragraph below)

The goals of the study were twofold: to describe the variation in the anatomy if the LABCN and the SBRN, to quantify the amount of overlap between the LABCN and the SBRN creating a visual model using CASAM.

## MATERIALS AND METHODS.

Twenty arms (9 male, 11 female; mean age 79,35 (range 61-90); 15 Right, 5 Left) were embalmed with a solution containing 4% formalin preceded by flushing the specimen with Anubifix™. All dissections were performed using a 2,5 times magnifying loupe.

To ensure comparable exposures, the dissection and imaging method was standardized(20). Incisions were made from 5 cm below the caput humeri up to 5 cm above the elbow exposing the biceps. At the ends of the incision lines, two perpendicular incisions were placed, creating two skin flaps that could be removed laterally and medially. Once the biceps brachi muscle was exposed, the fascia surrounding the muscle was incised and via blunt preparation and the biceps was released from the underlying muscle tissue. Right behind the biceps the musculocutaneous nerve, being the origin of the LABCN, could be identified and the biceps was cut at the insertion and removed proximally. The LABCN was dissected along its course distally down to the metacarpal region. Along the way, the nerve was marked using colored pins. Once the distal 1/3 of the arm was reached, the brachioradialis muscle was identified and bluntly dissected from the underlying tissue, whilst keeping the LABCN intact.

In step 2, the SBRN was identified deep to the brachioradialis muscle (BR). Once identified, the nerve was followed to the insertion of the BR where it continued to run a more superficial course. This spot was also marked with a colored pin. The SBRN was also dissected distally down to the Metacarpal joint level.

To quantify our findings, necessary to operate CASAM, the following measurements were taken.

1) The distance between both the epicondyles and the point where the SBRN emerges.
2) The distance to both epicondyles and the first branch of the SBRN, the same procedure was performed with regard to the LABCN.
3) The distance between both epicondyles and the location of crossings between the SBRN and LABCN

Furthermore, along the course of both nerves, every 5 mm the smallest distance between the SBRN and the LABCN was measured using digital calipers (IP67 waterproof digital caliper, Hogetex, Varsseveld the Netherlands).

Every arm was photographed with a digital camera (Nikon D 60 with Sigma 50 mm 1:2,8 DG MACRO lens). The camera was placed perpendicular to the specimen with a distance of 100 cm on a tripod. The pictures were loaded into Photoshop CS4 and the measurements performed on each arm were stored digitally.

## Statistics.

Statistical Package for Social Sciences (SPSS) 17 was used to perform basic statistical analysis of the data and to produce graphs. Because of the difference in length of each arm the x-axis was standardized for length of the forearm. (lateral epicondyle to Lister's tubercle). Then the x- and y-axes were divided into a grid of small squares. To squares inside the region where a data point is located, the number 1 is added for each specimen. The result is a grid of counts, each showing how many of the individual data points cover the corresponding squares.

Finally, a "smoothing" procedure was applied to the histogram to reduce the influence of sampling variation.[13,15]

## CASAM

Since human arms vary in size, anatomical comparison can be difficult. Therefore, a program called CASAM was used. In CASAM it is possible to morph the digital image of each individual arm to the average size off all arms.

CASAM is based on the fact that the bony landmarks, such as Lister's tubercle, lay in the same place relative to every arm. These are called 'bony landmarks' (BL). Besides bony landmarks so called 'shape defining landmarks' (SDL) were created, to mark the outline of the arm, by dividing the space between two BL's into equal parts. We take these BL's and SDL's and mark them in the program. The picture can now be warped around these boney landmarks using Active Shape Modeling (ASM) creating an average arm. All arms are then warped to the dimensions of the average arm making is possible to compare all the arms directly. The 'scaled' course of the SBRN and the LABCN of all individual arms can now be compared directly.

The 'bony' landmarks were used at: the lateral and medial epicondyle, the caput ulnae, the Lister's tubercle, the lateral and the medial side of the MCP and IP joints of the thumb, the caput phalanx I of the index finger and the caput phalanx I of the 3rd finger (fig. 1; green marks). These BL's were used, because their relative position in each arm is the same.

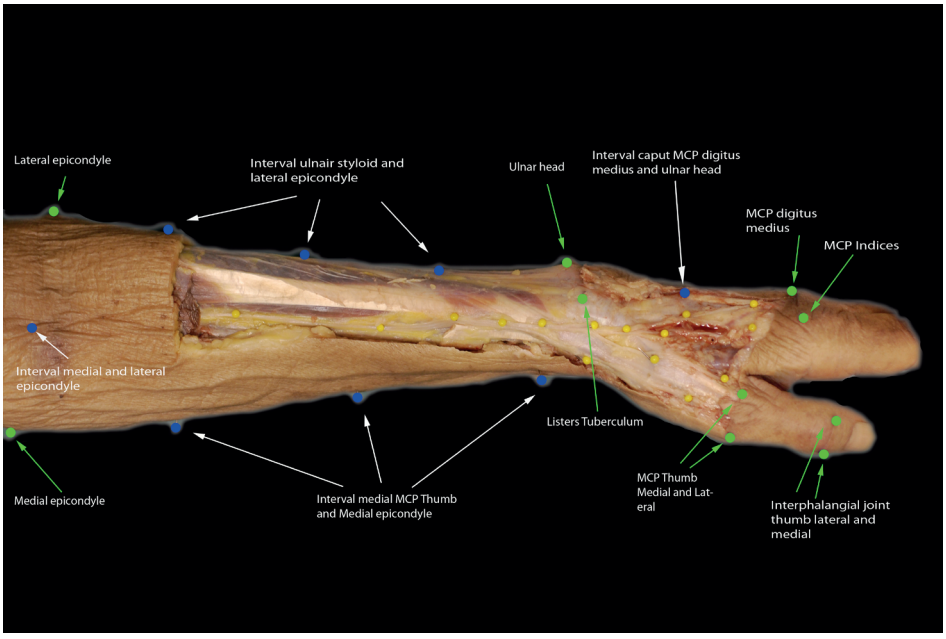


**Figure 1.** Landmarks used to outline the arm.

The distance between the epicondyles and caput ulnae was divided into four equal parts thus forming the three SDL's at the dorsal site of the arm. At the ventral side of the arm the distance between medial epicondyle and MCP I was divided into four equal parts, forming the ventral SDL's. The last two SDL's were defined as: halfway between medial and lateral epicondyle and halfway between caput ulnae and caput phalanx I (fig.1 blue marks.)

The image created by CASAM, shows a template of the individual course of the SBRN and the LABCN, scaled to the average dimension of all twenty arms. The mean distance between a line through the lateral and medial epicondyle and Lister's tubercle, was 239.15 mm (range 209-281mm), This distance was used as the reference length of the arm.

### Photoshop.

Photoshop CS4 was used to trace the SBRN and the LABCN in all pictures of the specimen. Then all morphed pictures could be compiled into one picture for further reference.

## RESULTS

The LABCN runs a course from a point under the biceps on the lateral side of the tendon in the elbow. It can be found in the subcutaneous fatty tissue on the radial side of the arm over the complete length of the forearm. It was noted that in 25% (n=5) the LABCN branched early into two main branches continuing on both sides of the Cephalic vein. In 70% (n=14) of cases the main branch of the LABCN was localized volar to the Cephalic vein. In 5% (n=1) the LABCN lay dorsal to the Cephalic vein.

The radial nerve divides into the posterior interosseous nerve and the SBRN emerging from a point deep to the brachioradialis muscle at an average distance of 159.6 mm (14.07) from the lateral epicondyle representing 2/3 of the length of the arm. On average, the SBRN showed 5.75 (5-7) branches. Two branches reached the thumb, two the index finger and one is localized in the direction of the middle finger. The SBRN was present in the subcutaneous fat tissue in the distal 1/3 of the arm.

In 5 arms the SBRN and the LABCN showed a total overlap and in 14 arms partial overlap was observed. 1 arm showed no overlap (table 1)

In all cases the main branch of the LABCN runs volar to the point where the SBRN emerges. In the distal third of the arm where the 2 nerves overlap, the LABCN crossed the SBRN with a mean of 2.25 times these crossings (n=45) occurred between 148.12 to 256.04mm (Corrected for length of the arm) distal to the lateral epicondyle. In 95% of the arms (n=19) the LABCN intersected with the SBRN at the point where the SBRN emerged from under the BR (figure 2) a Pearson correlation of 0.820 with a significance of 0.00 (2-tailled) was found. Corrected for the length of the arm the correlation coefficient dropped to 0.034, suggesting that there is an absolute distance between the two measurements. The distance between the first intersection

**Tabel 1**

| Arm nr. | Left/Right | Male/Female | Length of arm | No of SBRN branches | No of LABCN branches | No of crossings | Overlap | LABCN combines with SBRN |
|---|---|---|---|---|---|---|---|---|
| 1 | R | F | 306 | 5 | 4 | 2 | Yes | No |
| 2 | R | M | 378 | 7 | 2 | 2 | Yes | No |
| 3 | R | F | 294 | 5 | 2 | 5 | Yes | No |
| 4 | R | F | 327 | 6 | 3 | 2 | Yes | No |
| 5 | R | M | 362 | 5 | 2 | 2 | Yes | No |
| 6 | L | M | 361 | 6 | 3 | 3 | Yes | No |
| 7 | L | F | 327 | 6 | 3 | 2 | Yes | No |
| 8 | L | M | 307 | 5 | 2 | 2 | Yes | No |
| 9 | L | F | 311 | 5 | 3 | 3 | Yes | No |
| 10 | L | F | 328 | 6 | 2 | 3 | Yes | Yes |
| 11 | R | M | 330 | 7 | 1 | 2 | Yes | Yes |
| 12 | R | F | 340 | 6 | 3 | 3 | Yes | No |
| 13 | R | M | 395 | 6 | 4 | 3 | Yes | No |
| 14 | R | F | 320 | 5 | 2 | 2 | Yes | No |
| 15 | R | F | 337 | 5 | 2 | 0 | No | No |
| 16 | R | M | 374 | 6 | 4 | 2 | Yes | No |
| 17 | R | F | 300 | 5 | 2 | 2 | Yes | Yes |
| 18 | R | M | 369 | 5 | 3 | 3 | Yes | No |
| 19 | R | M | 352 | 5 | 2 | 1 | Yes | No |
| 20 | R | M | 307 | 6 | 3 | 1 | Yes | No |

Tab 1. Results of 20 arms

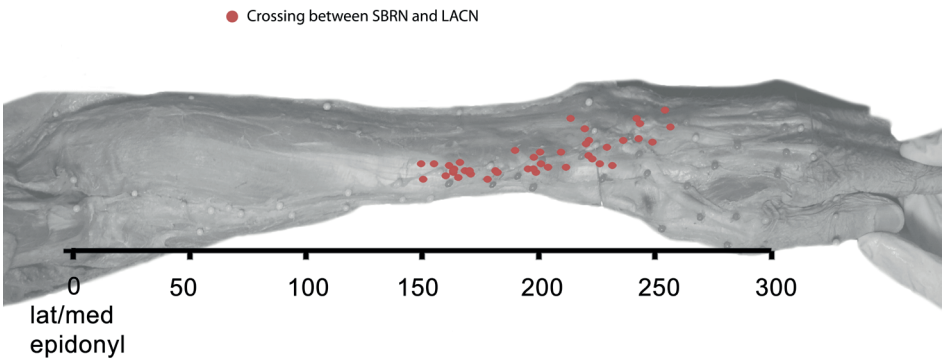


**Figure 2.** Spread of the intersection of the SBRN and LABCN (corrected for length of the forearm)

and the site where the SBRN emerged from under the BR is 8,8mm (SD 12 mm). The distance between the nerves was measured in 5 mm intervals resulting in an average of 30 data points per arm. In 81% of the measurements the distance between the two nerves was less than 10 mm and in 49% even less than 5 mm. Also, the data shows that the closest proximity can be found just after the SBRN emerges from under the deep fascia. (Figure 3)

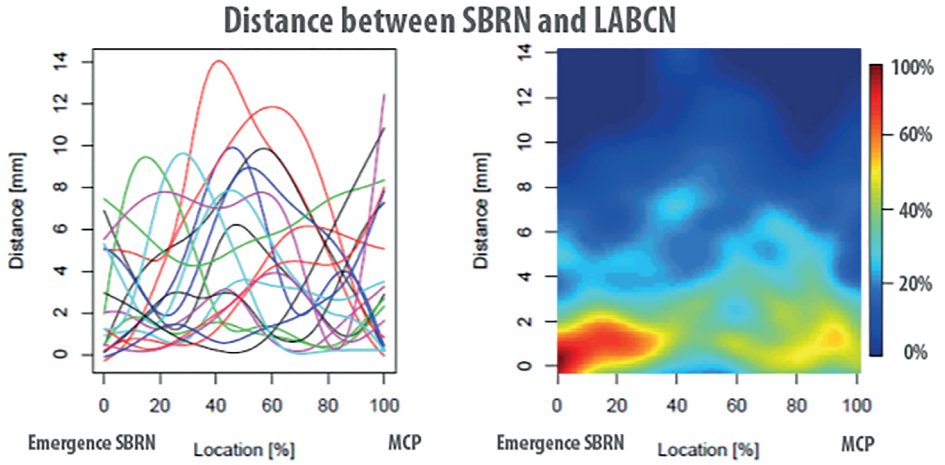


**Figure 3.** left: distance of SBRN to LABCN in each individual arm. Right: Rendering in which the color indicates the percentage of arms with the distance between the SBRN and LABCN is the same. Dark red 100%, dark blue 0%

In two cases the most volar branch of the SBRN merged with the LABCN continuing along the radial side of the thumb.

In 3 cases the LABCN merged with the SBRN to innervate the radial aspect of the thumb.

In the images created in CASAM, the close distance between the courses of the two nerves is clearly visible. The image shows that there actually is no real safe zone concerning surgical trauma to LABCN and SBRN in the radial part of the wrist. (figure 4)

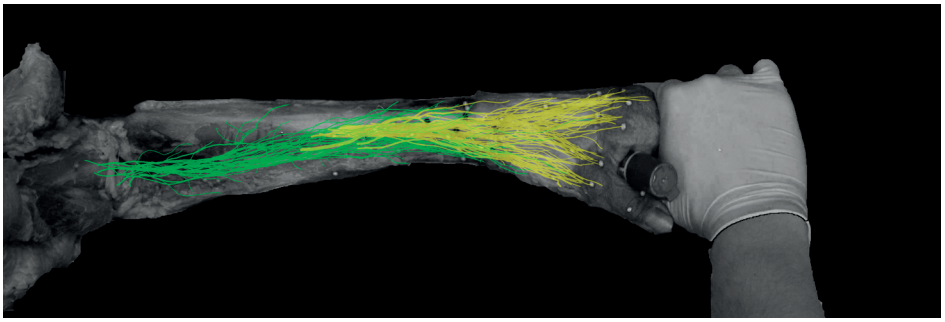

**Figure 4.** Course of 20 SBRN (Yellow) and 20 LABCN (Green)

## DISCUSSION

Surgery to the radial aspect of the wrist is known for its pain related complications[16-18]. There are many hypotheses, to explain the susceptibility of the wrist to neuropathic pain. One of the explanations is based on the intimate anatomical relationship between the end branches of the two nerves. The purpose of this study was to map the course of the LABCN and the SBRN and especially the close relation between both nerves at some point resulting in actual, topographical intersections of these two nerves.

In this study a close relation between the SBRN and the LABCN was demonstrated. In all but one arm the nerves overlapped and intersected on average 2.25 times. The point where the SBRN emerges from a deep point to the BR is also closely related to the first intersection with the LABCN. The correlation between the two measurements was high and not dependent on the length of the arm. In 50% of cases the first crossing was within 18 mm from the point where the SBRN pierces the fascia.

Mackinnon and Dellon [2] showed, that in 75% of cases there is an overlap of the terminal branches of the LABCN and SBRN. They concluded, that if the SBRN is damaged; the LABCN also has a high probability of being damaged. This lesion of the LABCN explains why excision of a neuroma in the SBRN sometimes does not relieve the sensation of pain in patients with neuropathic pain.

Beldner[19] showed, that in several cases, the LABCN flanks the Cephalic vein on both sides. This study also found a close relation between the cephalic vein and the LABCN. This flanking pattern was found in 15% of cases. The fact that the LABCN and the Cephalic vein are closely related, makes it much easier to identify the nerve.

The conclusion that the two nerves lie closely together, does not in itself explain why neuropathic pain is so common in this area. A possible explanation has already been given by Dellon and Mackinnon. Their suggestion was that if the SBRN was injured, the LABCN was likely to also be injured.

Another possible explanation could be that uninjured peripheral nerve fibers are responsible for transmission of pain. It has been demonstrated that the neurosomes of an injured nerve are populated by collateral sprouting fibers from adjacent uninjured nerves[20]. These uninjured nerve fibers may change functionally as a consequence of a peripheral nerve lesion. Due to Wallerian degeneration of the distal segment of the injured nerve, intact nerve fibers are in close proximity of activated Schwann cells, macrophages, and other inflammatory cells, which secrete high levels of neurotrophic factors like NGF. These neurotrophic factors are known to influence excitability, enhance sensory transmission, and/or induce ongoing activity in uninjured peripheral nerve fibers. Also, more proximal, in the Dorsal Root Ganglion (DRG), signaling from injured DRG cells could infer uninjured Dorsal Root Ganglions either directly or via non-neuronal cells. Consequences could be changes of excitability and/or ectopic activity in the cell bodies.

Another postulated mechanism for neuropathic pain at the site of the injured nerves is the expression of novel sodium channels that have ongoing and evoked ectopic excitability.

So, it is possible, that if the LABCN is sectioned iatrogenically, the SBRN might be responsible for the pain and vice versa. This also explains why, if pain remains after treatment an SBRN neuroma, the pain is often diminished on denervation of the LABCN, without finding a treatable neuroma in the LABCN, as described by LLuch. However, this does not explain the role of the Posterior Interosseous Nerve (PIN) in persistent neuropathic pain on the radial side of the wrist, since this nerve does not have a neurosome in the skin, and yet, denervation of the PIN in radial sided pain of the wrist does sometimes reduce pain.

Clinically, when patients present with pain in the area of the SBRN or LABCN, diagnostic blockades are performed with 1% lidocaine of SBRN, LABCN, PIN and Palmar cutaneous branch of the Median nerve (PCBMN). To determine the efficiencies of such blocks, they are performed in sequential order, with minimally half an hour in between blocks. The next step consists of denervation of the nerve causing pain.

In conclusion, the close (anatomical) relationship between the LABCN and the SBRN can be seen as a factor in the explanation of persistent neuropathic pain in patients with traumatic or iatrogenic lesion of the SBRN or the LABCN.

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