Chapter

Tracking of Fascicles of Cutaneous Nerves of Thigh: A Histological Study

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Abstract

Present study uncovers the secrets of internal morphology of femoral nerve branches namely, cutaneous trunk, subcutaneous trunks, saphenous, medial cutaneous and intermedius cutaneous nerves innervating the skin of anteromedial thigh at fascicular level. Therefore, the aim of the study is to track, correlate, interpret and identify the pathways of fascicles through histological slides. The femoral nerve and its branching points were calibrated in distances from inguinal ligament. These trunks and nerves of a cadaver were processed for histological slides staining with haematoxylin and eosin. The fascicles in the histological slides were identified, tracked, correlated and interpreted from cranial most slide to the last terminal slides of these nerves and trunks. The correlation of the pathways of fascicles revealed that these fascicles are continuous, consistent and traceable interrupted by split, fusion and multiplexing. Femoral nerve branches/fascicles/nerve fibres if damaged, impair the sensation of corresponding area of skin of anteromedial thigh creating helm of neurological complications. Hence the injured fascicles can be repaired with the help of identification and correlation of fascicular pathways carried out in this study with least invasion. The findings of present study will be of paramount importance for intraoperative stimulation to diagnose and identify the fascicle for microneurosurgical repair/graft/regenerate/neurotisation in the cutaneous branches of femoral nerve at fascicular level.

Keywords: cutaneous nerves, microanatomy, transformational process, pathways of fascicles

1. Introduction

There are many variations of femoral nerve and these have been classified by Singh et al. [1]. A femoral nerve cropped from a cadaver was type II of classification of Singh et al. [1]. This femoral nerve bifurcated into muscular and cutaneous trunks at one centimetre below the inguinal ligament. The cutaneous trunk further splits into sub-cutaneous trunk of thigh and the saphenous (S) nerve. The subcutaneous trunk, then, bifurcates into intermedius cutaneous (IC) and medial cutaneous (MC) nerves of the thigh. The group of afferent fascicles of S, IC and MC supply skin of anteromedial thigh.

Though the injuries to the IC and MC nerves have hardly been reported yet few cases of pain and paraesthesia over the anterior and medial aspects of thigh, as a

result of engagement of IC and MC nerves of the thigh, are described. However, sensory loss on the medial side of the thigh, leg and foot up to the ball of the great toe because of engagement of the saphenous nerve through iatrogenic lapses or otherwise are well reported. The outcome of injuries may not be fatal or produce unbearably serious signs and symptoms so the patients may not be opting for costly neurosurgical diagnosis (MRI) for detection of location and degree of injury and procedures.

The neuro-therapy of neuropathological morbidity requires accurate diagnosis and treatment. There is very limited scope of investigating location and identification of injured fascicle or nerve fibres under current knowledge of internal morphology of nerve. Though Chhabra et al. claims that location and degree of injury can be identified through MR advanced neurography [2] yet it has its own limitations regarding resolution and image defects. Therefore, a micro-anatomic study has been planned to track fascicles in histological slides of subcutaneous trunk, S, IC and MC for improving identification of injured fascicle, its location and degree of injury for diagnosis and imagery interpretation together with non-invasive neurosurgical repair, grafting and regeneration of injured nerve fibres.

2. Tracking and correlation of fascicles

A24 slide was prepared from the femoral nerve just above the inguinal ligament. This femoral nerve just below the inguinal ligament bifurcated into muscular and cutaneous trunks. Cutaneous trunk then bifurcated into saphenous nerve and subcutaneous trunk which further divided into intermedius and medial cutaneous nerves. Saphenous, intermedius and medial cutaneous nerves innervate skin of anteromedial thigh. Histological slides of cutaneous, saphenous nerve, subcutaneous trunk, medial and intermediate cutaneous nerves were prepared and stained with haematoxylin and eosin. The fascicles in these nerves/trunks were identified, tracked, correlated and interpreted.

3. Naming scheme of fascicles

For deciphering the fascicles of individual nerves and to avoid confusing duplicate numbers, the name of the fascicles at the point of transformational processes was changed in sequential order with prefix from CF of composite fascicles in femoral nerve to CCF in cutaneous trunk and SCCFs in subcutaneous trunk extending it to SCF in S nerve, MCCFs and ICCFs in MC and IC respectively.

The composite fascicles (CFs) in slide A24 1 have been identified as CFs {(303, 304); (280, 257, 270, 312, 313): (316, 317, 318)}* of both cutaneous and muscular trunks. CFs 316, 317, 318 corresponds muscular trunk and CFs {(303, 304); (280, 257, 270, 312, 313)} to cutaneous trunk (**Figure 1**).

4. Tracking and correlation of fascicles in cutaneous trunk

The cutaneous trunk was cut into 6 pieces and six blocks C1, C2, C3, C4, C5 and C6 were prepared. From C1, 13 slides were processed. C1 13 was the cranial most slide of C1. Similarly variable number of slides were prepared from C2, C3, C4, C5 and C6.

In C24 1, composite fascicles, {(303, 304); (280, 257, 270, 312, 313)} correspond to cutaneous trunk, but CF313 of A24 1 splits and formed CCF 318 and 319

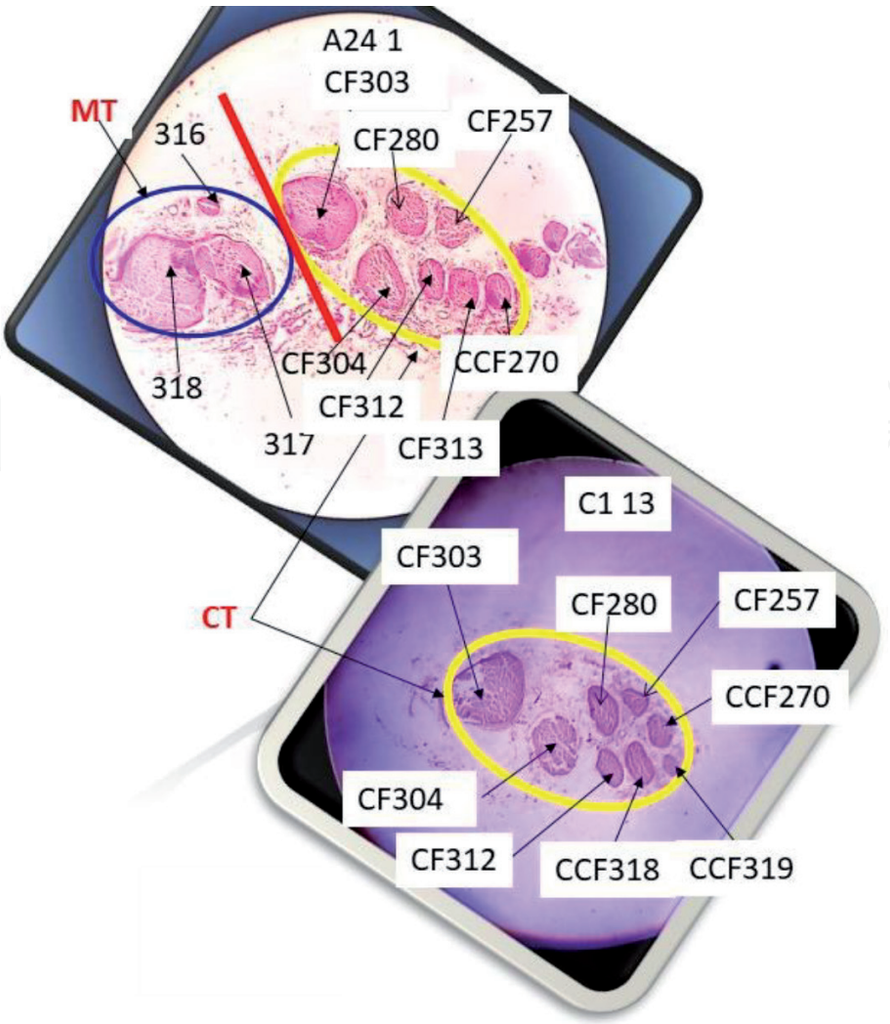

Figure 1.
Correlation between A24 1-C1 13. MT- muscular trunk, CT- cutaneous trunk.

in C1 13. So C1 13 consists of {(303, 304); (280, 257, 270, 312, 318, 319)} (**Figure 1**). These fascicles continuously consistent up to slide C2 16, the cranial most slide of C2 block.

The fascicles in C2 16 were continuous, consistent and correctable up to slide C2 12. In slide C2 12, CF312 and CCF318 fused forming CCF320 and CF280 in slide C2 12 split into CCF321, 322 and 323 in C2 11 (**Figure 2**). C2 11 is traceable to C2 1 meaning that the fascicles which were present in slide C2 11 were continuing up to slide C2 1.

In C2 1 slide CCF321, 322 and 257 fused forming CCF324 in C3 3 (**Figure 3**). So the slide C3 3 consists of CFs 303, 304, CCFs 319, 320, 323, 324 and 270 fascicles. CCF223 changed the shape forming CCF 323. Fascicles of C3 3 were traceable, continuous, and consistent up to slide C3 1.

CCF270 and CCF324 in C3 1 fused forming CCF325 in C4 4 (**Figure 4**). So slide C4 4 consists of CFs 303, 304, CCFs 320, 323, 325 and 319 fascicles. Fascicles of C4 4 were traceable, continuous, and consistent up to slide C4 1.

CCF325 in C4 1 split into CCF326 and 327 in C5 5 (**Figure 5**). So slide C5 5 consists of CFs 303, 304, CCFs 319, 320, 323, 326 and 327 fascicles. C5 5 is traceable, continuous, and consistent up to C6 1.

In C6 1 fascicles CFs 304 and 303 and CCFs 319, 320, 323, 326 and 327 were found to be surrounded by internal epineurium (**Figure 6**) indicating subcutaneous trunk and saphenous nerve are formed and ready to emerge.

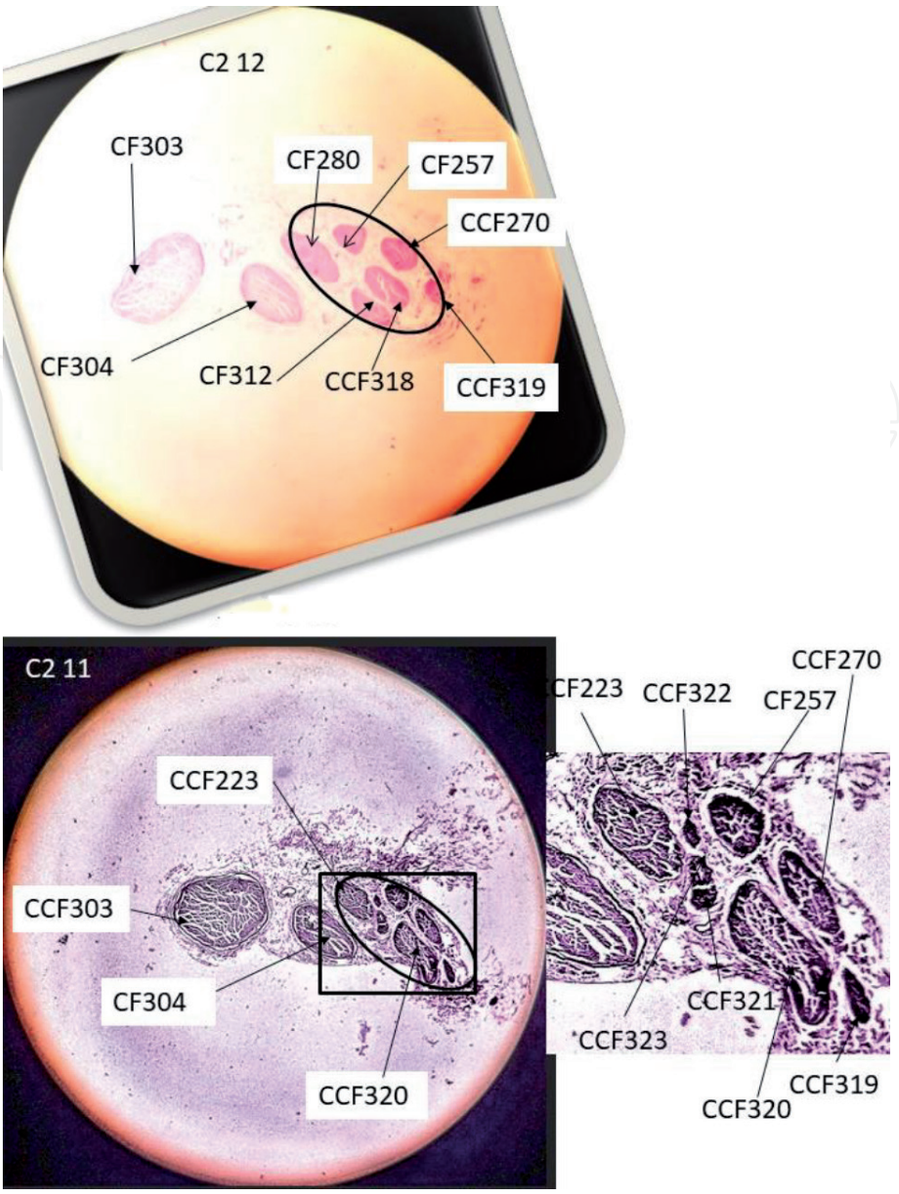

Figure 2.
Correlation between C2 12-C2 11.

After C6 1, cutaneous trunk bifurcated into a) S nerve containing CCFs 319, 320, 323, 326 and 327 as observed in S1 1 of S1 block and b) sub-cutaneous trunk consisting of CFs 304, 305 and 306 in SCT1 1, slide of SCT1 block (**Figure 7**).

5. Tracking and correlation of fascicles in saphenous nerve

S nerve was cut into 6 pieces and six blocks S1, S2, S3, S4, S5 and S6 were prepared. Slides prepared from these six blocks were stained with haematoxylin and eosin and fascicles of S nerve were correlated starting from S1 block to S6 block.

The S nerve having CCFs 319, 320, 323, 326 and 327 in S1 1 emerged out after C6 1 (**Figure 7**). These CCFs were traceable from the slides of block S1 through S2 1 the caudal most slide of S2 block.

The CCFs 319 and 320 in S2 1 fused together forming SCF 328 in S3 13 the cranial most slide of S3 block (**Figure 8**). So, S3 13 slide consists of 323, 326, 327 and 328 fascicles. These fascicles were continuous, consistent and traceable up to slide S3 1.

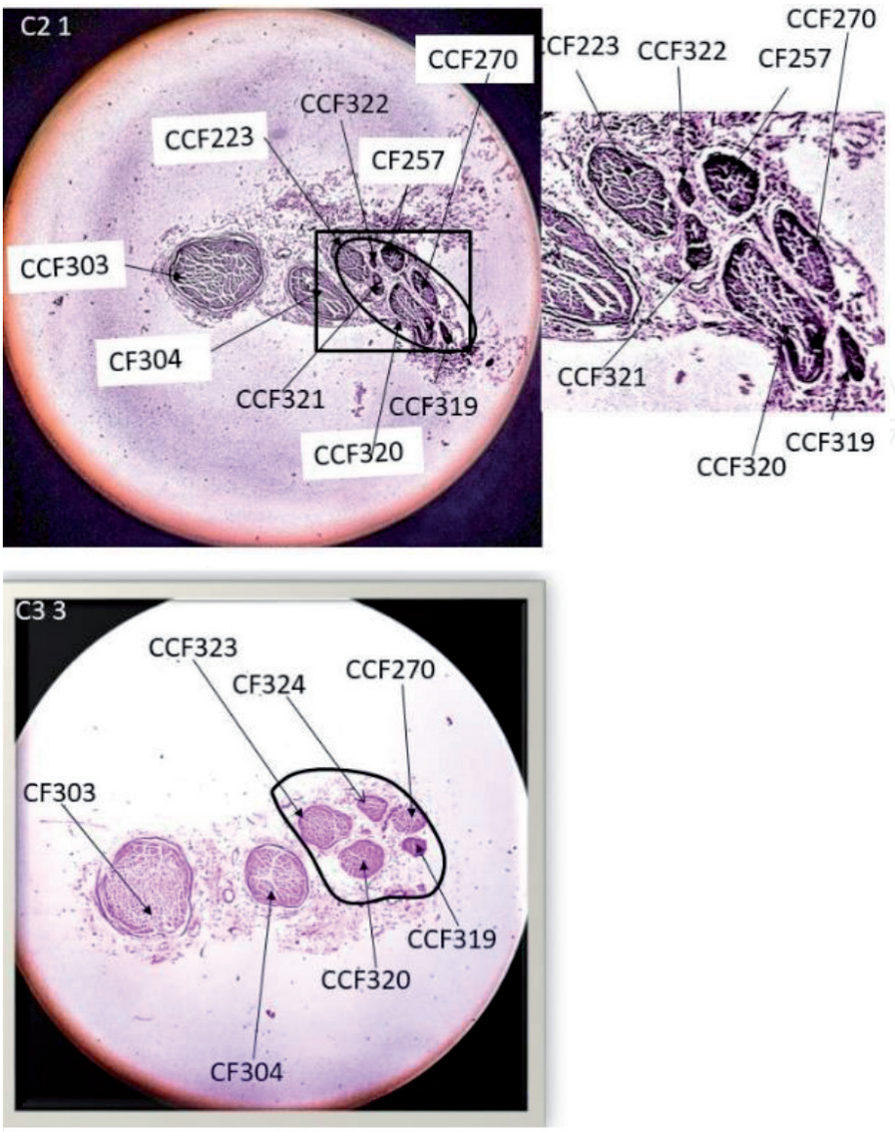

Figure 3.
Correlation of C2 1 with C3 3.

CCF328 in S3 1 slide split into SCFs 329 and 330 in S4 12, the cranial most slide of S4 block (**Figure 9**). So, the slide S4 12 consists of 323, 326, 327, 329 and 330 fascicles. The fascicles of S4 12 slide were continuous, consistent and traceable up to slide S4 1.

CCF330 emerged out as branch of S nerve after S4 1 as this fascicle was not found in next slide. CCFs323 in S4 1 split into SCFs331 and 332 S5 12, CCFs326 in S4 1 into SCF333 and 334 in S5 12, CCF329 in S4 1 into SCF335 and 336 in S5 12. So slide S5 12 consists of 331, 332, 333, 334, 335, 336 and 327 (**Figure 10**). These fascicles in S5 12 were continuous, consistent and traceable up to slide S5 1.

The fascicles from S5 1 reorganise their position through migration and rearrange in S6 11. The fascicles got separated laterally into infrapatellar branch having SCFs (331, 332, 335, 336) and main S nerve having SCFs (327,333, 334) in S6 11 (**Figure 11**) continued caudally.

The fascicles are traceable between S6 11 and S6 7. Again reorganisation of fascicles is taking place from S6 7 to S6 6 (**Figure 12**). These fascicles in S6 6 were continuous, consistent and traceable up to slide S6 1. Infrapatellar branch emanated laterally from S nerve after S6 1.

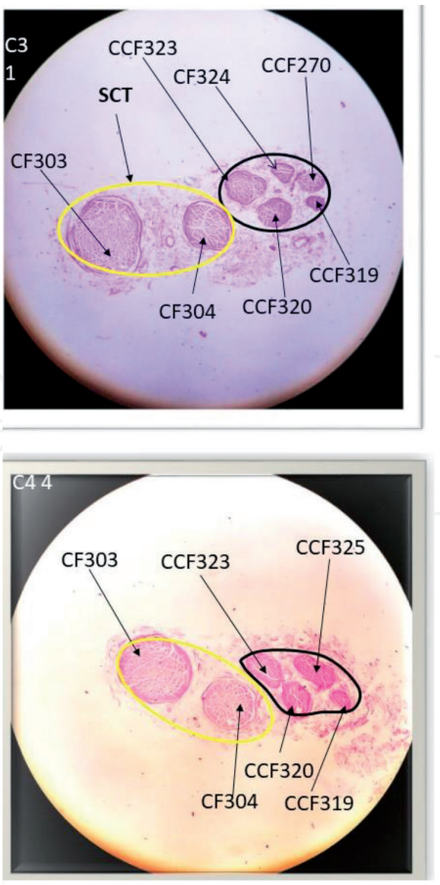

Figure 4.
Correlation of C3 1 and C4 4.

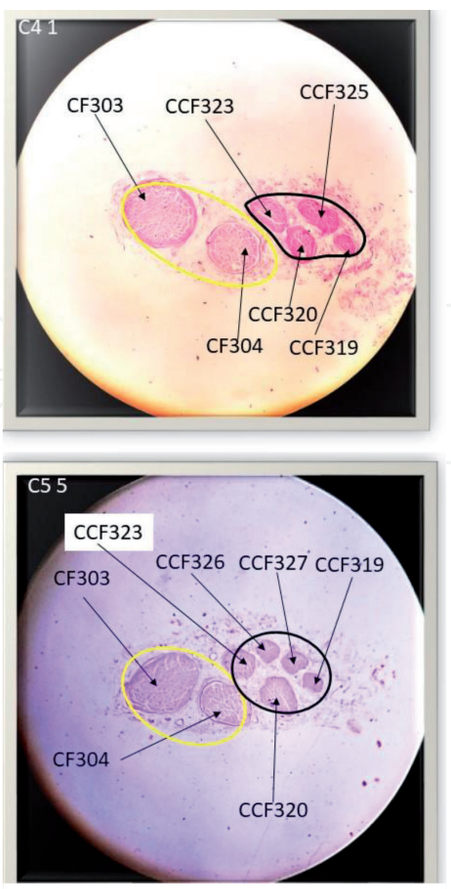

Figure 5.
Correlation of C4 1 and C5 5.

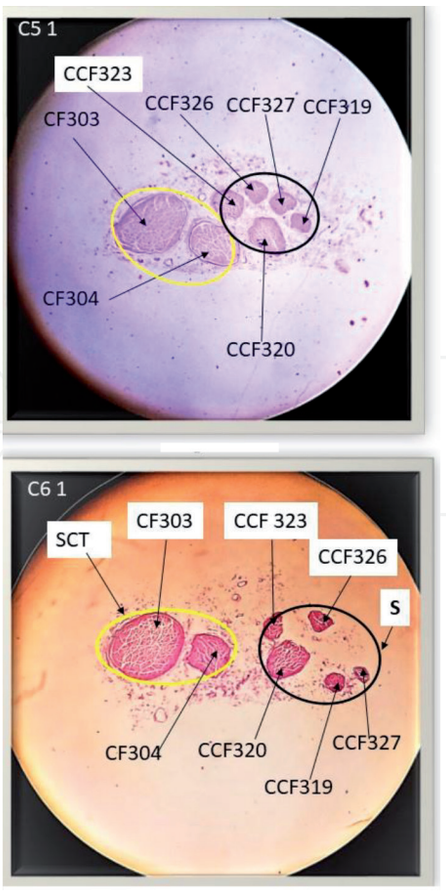

Figure 6.
Correlation of C5 1 and C6 1. SCT- fascicles of subcutaneous trunk, S- fascicles of saphenous nerve.

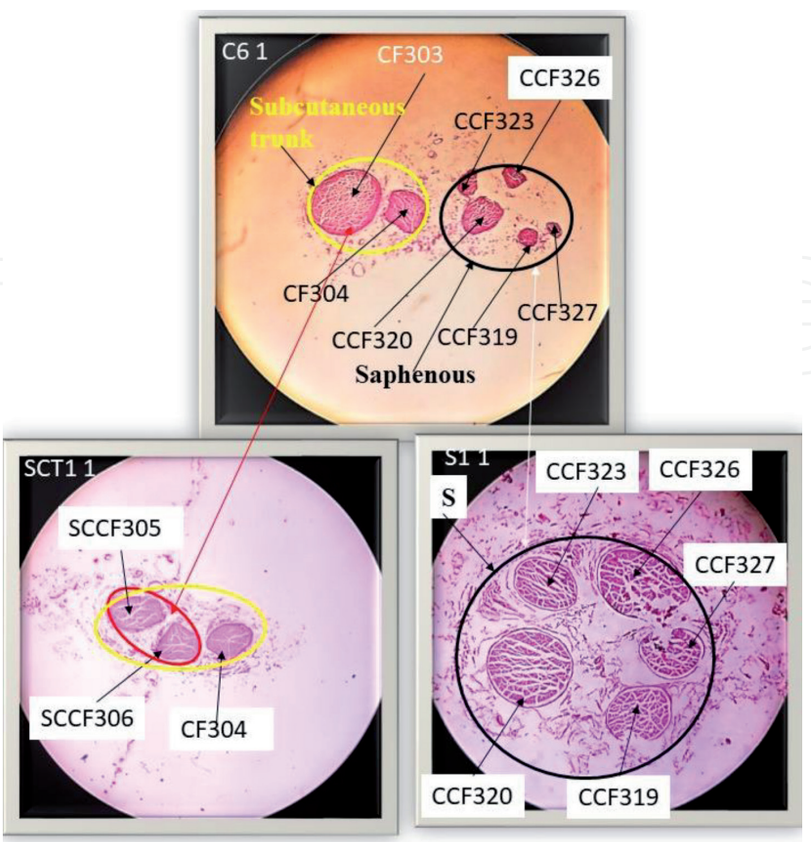

Figure 7.
Correlation of C6 1 and S1 1 and SCT1 1.

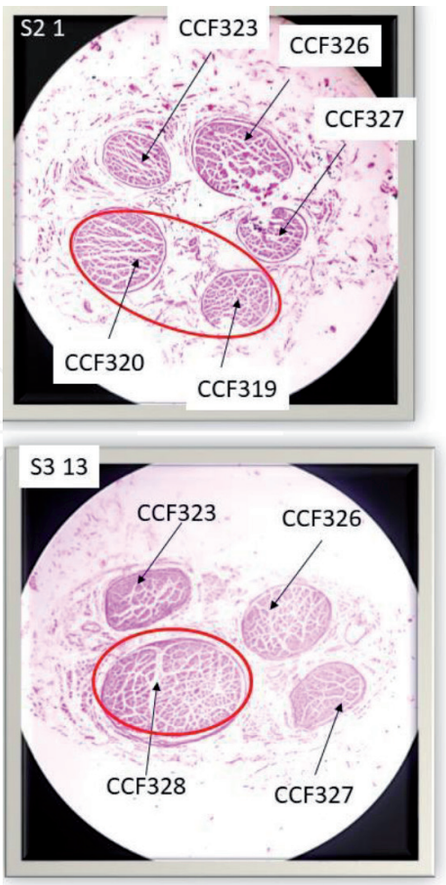

Figure 8.
Correlation of S2 1 and S3 13.

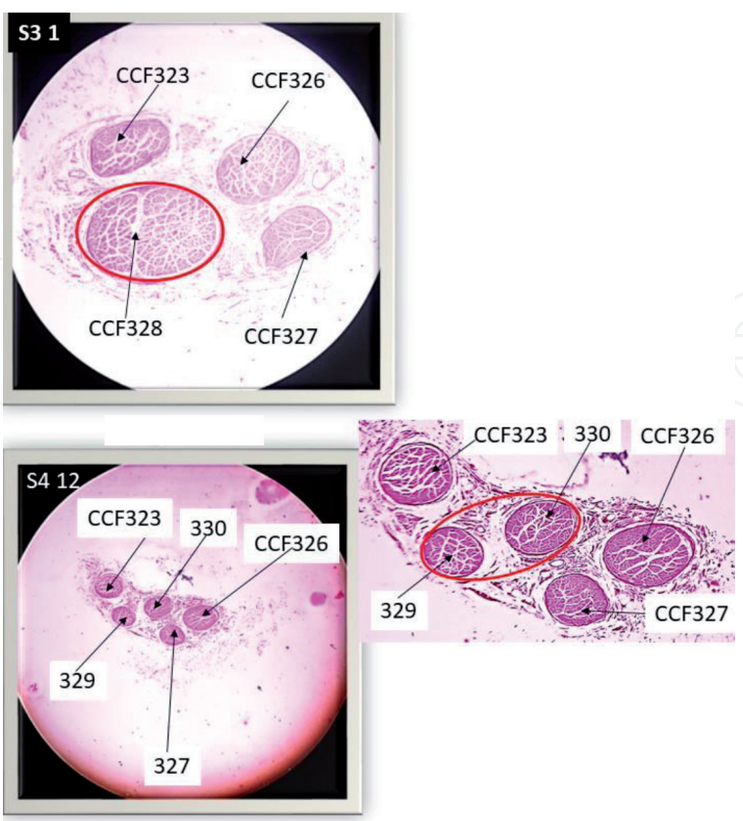

Figure 9.
Correlation of S3 1 and S4 12.

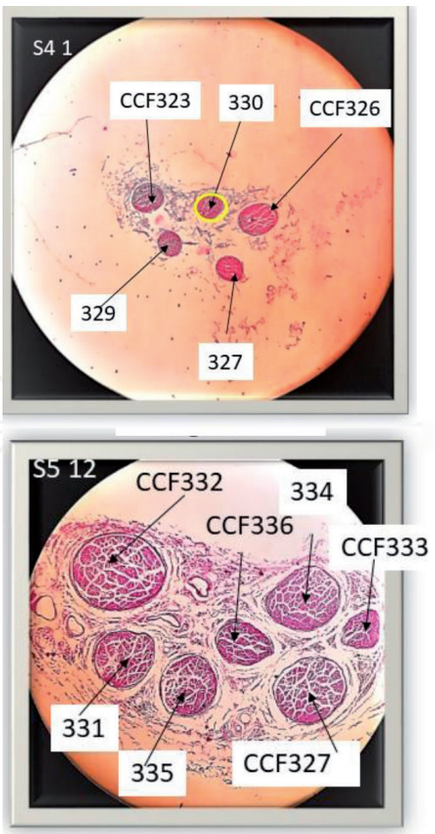

Figure 10.
Correlation of S4 1 and S5 12.

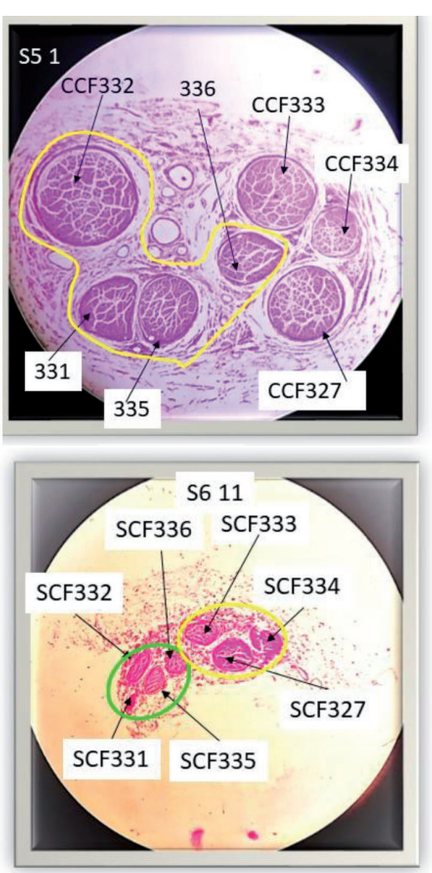

Figure 11.
Correlation of S5 1 and S6 11.

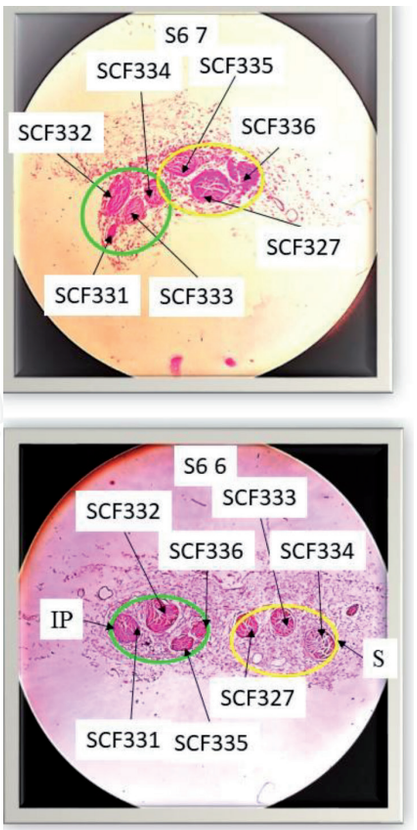

Figure 12.
Correlation of S6 7 and S6 6. IP- infrapatellar branch, S- main saphenous nerve.

6. Tracking and correlation of fascicles in subcutaneous trunk

Subcutaneous trunk was cut into 3 pieces and 3 blocks SCT1, SCT2 and SCT3 were prepared. Subcutaneous trunk bifurcated into MC and IC. One block of

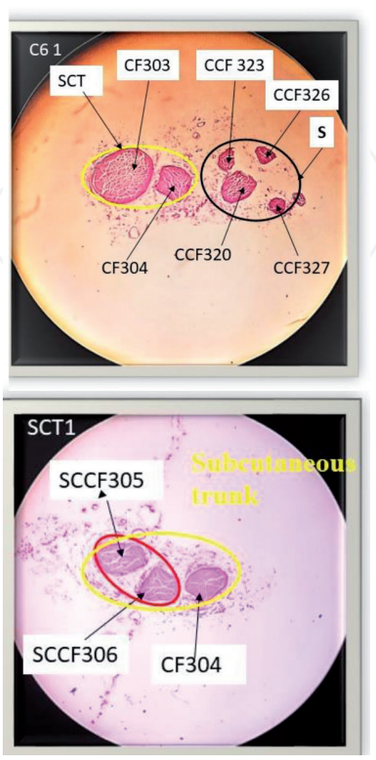

Figure 13.
Correlation of C6 1 with SCT1. SCT- subcutaneous trunk, S- saphenous nerve.

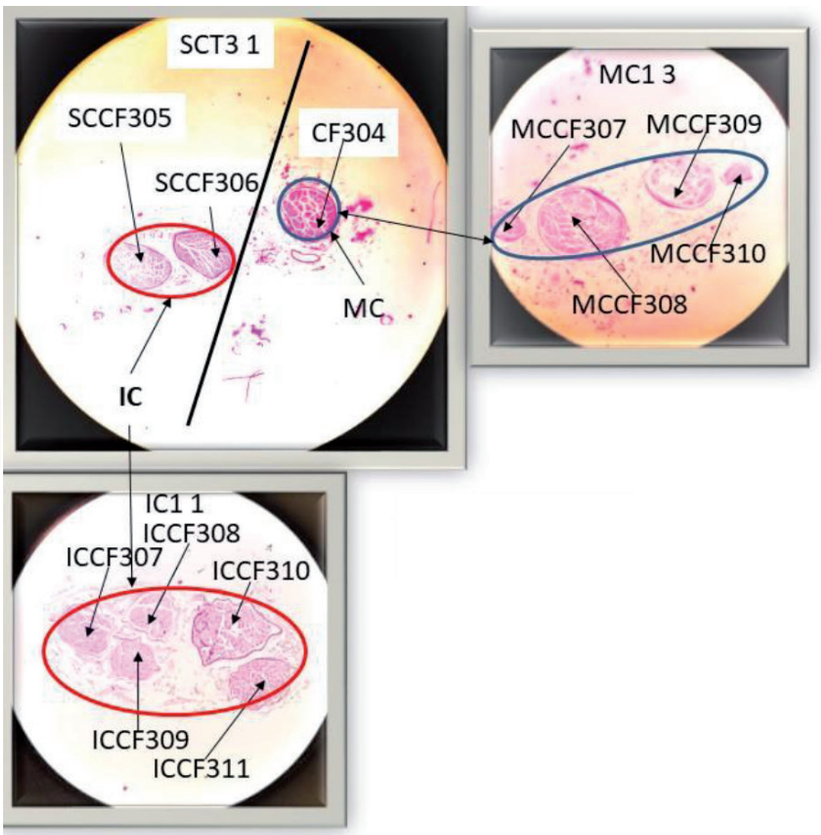

Figure 14.
Correlation of SCT3 1 with IC1 1and MC1 3.

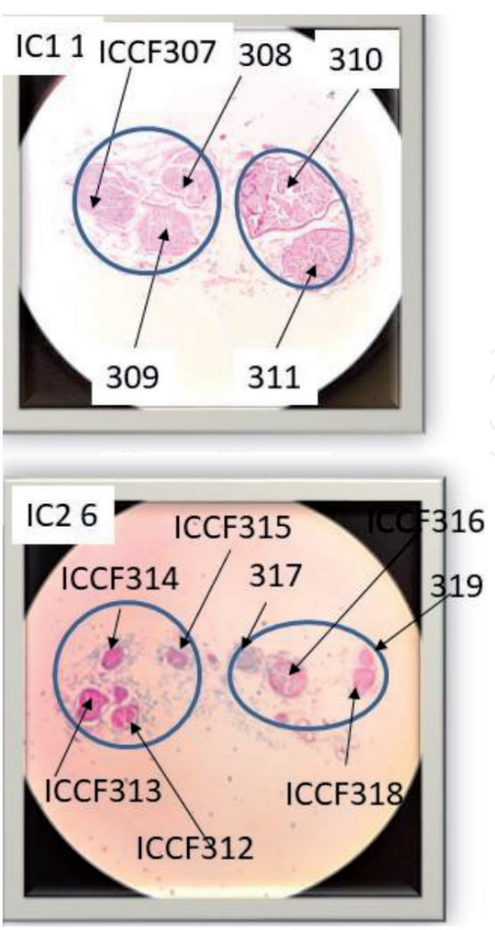

Figure 15.
Correlation between IC1 1 and IC2 6.

MC,MC1 and two blocks of IC, IC1 and IC2 were prepared and slides from aforementioned blocks were stained with haematoxylin and eosin and fascicles were correlated as elaborated below:

The CFs 303 and 304 constituted subcutaneous trunk which was separated laterally from cutaneous trunk after C6 1 (**Figure 6**). Then CF303 split into SCCF 305 and 306 in SCT1 1 slide (**Figure 13**). So the subcutaneous trunk now consists of fascicle CFs 304, SCCFs 305 and 306. After the slide SCT1 1, the CFs 304, SCCFs 305 and 306 were traceable from SCT1 1 up to SCT3 1.

The subcutaneous trunk bifurcated into IC and MC nerves after SCT3 1 slide. The CF304 constitute MC and 305 and 306 IC (**Figure 14**). Then CF304 split into MCCF307, 308, 309, 310 in MC1 3 slide. The SCCF305 split into ICCF307, 308, 309 and SCCF306 into ICCF310, 311 in IC1 1 respectively (**Figure 14**).

ICCF308 IC1 1 split into ICCF314 and 315, ICCF309 IC1 1 split into ICCF312 and 313. ICCF310 split into ICCF316 and 317, ICCF311 split into ICCF318 and 319 (**Figure 15**). These fascicles form fine nervelets innervating skin of thigh.

7. Clinical significance of this study

No such study has been carried out involving sensory nerves of femoral nerve. If the fascicles of S, MC and IC are damaged, the communication of sensory information from the innervated area will be interrupted leading to aggravation of clinical problems. So it is not merely nerve where injury should be investigated rather injured fascicles should be targeted for diagnosis for complications which may occur anywhere in entire fascicular path from origin to point of innervation. The diagnosis of neural insults requires not only the location and degree of injury but also identification, isolation, orientation, directivity, and matching of shape and size of injured nerve CFs for planning surgical repair, grafting and regeneration [3].

The location and degree of injury is investigated by the high resolution MRI advanced neurography [2, 4]. But this has its own limitations of recording and interpretation. This generates uncertainty in diagnosis and thereby in treatment. Thus the radiologists and neurosurgeons face the impediments of pinpointing the probable position of injury and identification of fascicles. Therefore, the imagery coupled with our internal morphological study together can refine the interpretation for identification of injured CF and location of injury. Methodically, it can be done by one to one correlation between images of transverse histological and high resolution MRI advanced neurographic sections at the same position from inguinal ligament. The distance of location of injured fascicle from inguinal ligament may be computed in MRI neurography and then the calibrated histological sections of cutaneous, subcutaneous trunks, S, MC and IC nerves at the same level may be compared and examined for confirmation of identified injured fascicle. After identification of injured fascicle, the idea of shape, size, location and orientation can also be derived from histological slides for matching, alignment and directivity of nerve fibres for repair and grafting.

7.1 Personal communication

The neurosurgery at fascicular level is currently uncommon however, with upcoming science and technology in future, present study will be highly useful for neurosurgeons. The study will help in carrying out less invasive surgery as stimulation of identified injured fascicles will not involve other fascicles which in case of nerve stimulation may be stimulated causing discomfort to the patient.

8. Conclusion

The histological slides of cutaneous, subcutaneous trunks, S, MC and IC nerves brought out correlation of fascicles and grouped fascicles together with their configuration data present the straight, continuous and identified pathways of CFs interrupted by transformational processes calibrated in distance from inguinal ligament. This data will be of utmost importance to imagery guided microneuro-surgical interventions more precisely at fascicular level together with the imagery interpretation to radiologists and neurosurgeons to assess injury and its location in an identified fascicular pathway to plan for its repair and surgical access. Fascicular electrode may be designed and developed like nerve cuff electrode [5] to improve neural microsurgery tremendously at fascicular level.

9. Limitation

This study involves variations in the branching pattern of sensory nerves in one individual. Further studies are recommended to encampass variations in other individuals.

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