FINITE ELEMENT MODELING OF INTRANEURAL GANGLION CYSTS OF THE COMMON PERONEAL NERVE

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INTRODUCTION

Intraneural Ganglion Cysts (IGC) are mucinous cysts which form within the epineurium of peripheral nerves, most commonly the Common Peroneal Nerve (CPN). They produce neurologic deficit (i.e., a foot drop). It pathogenesis and treatment are subjects of intense debate for clinicians. Previous studies (Spinner, Atkinson et al., 2003) support the theory that synovial fluid from the superior tibiofibular joint enters the articular branch of the CPN subsequent to joint capsule disruption through injury. The increased pressure caused by continuous influx of fluid compresses nerve fascicles, expands the nerve radially (Fig. 1 - stage I) and causes further propagation proximally into the CPN (Fig. 1 - stages II, III and IV). To effectively treat IGC and eliminate the common situation of postoperative recurrence, surgeons would benefit from an understanding of the underlying mechanics that influence cyst growth. The objective of this study is to introduce computational modeling as a tool for analysis of cyst development. In particular, this study will explore the phenomenon of proximal cyst propagation.

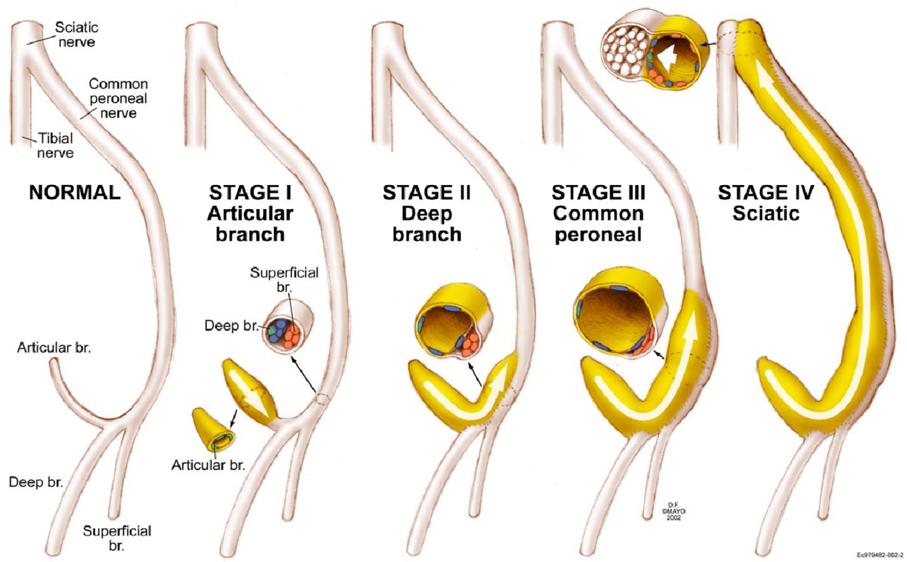

Figure 1. Growth stages of a peroneal intraneural ganglion cyst

METHODS AND PROCEDURES

A two-dimensional planar finite element model of the junction between the articular and the deep branches of the CPN has been constructed (Fig. 2). The articular branch, labelled AB in the figure, meets the deep branch (DB) at an acute angle of 45˚. The positive X-axis represents the proximal direction and the negative X-axis represents the distal. The model contains two regions: a blue region, representing the fascicular region, modeled as a Mooney-Rivlin hyperelastic isotropic material with properties of collagen (α_1 = 168700 Pa, α_2 = 10600 Pa) (Hirokawa and Tsuruno, 1997), surrounded by a red region, representing the softer epineurium, modeled as a Mooney-Rivlin material with properties that are an order of magnitude less than that of the fascicle. Dimensions are taken from intra-operative images and MRI images. The model is meshed with plane-183 elements of ANSYS. The boundary conditions include translational restraints at the two ends along the X-axis and the application of a pressure load of 7932.31 Pa (corresponding to a 15 N load) in the U-shaped cyst face region in the articular branch.

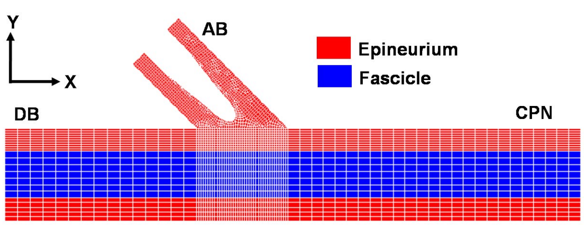

Figure 2. Finite element mesh showing different regions of the nerve

RESULTS

Figure 3 is a vector plot of the first principal stresses around the cyst face where the direction of the arrows represents the principal direction and the length represents the magnitude. It shows that the greatest tensile stresses occur below and to the right of the cyst face and their directions support the clinical observation of the tendency of the cyst to propagate proximally.

DISCUSSION

The location of the peak tensile stresses' occurring on the right side of the cyst face is believed to be a primary reason for the chosen direction of cyst propagation in the proximal direction. It is also believed that the fascicular portion of the articular branch acts as a "road block" that impedes cyst from propagating distally. A three-dimensional finite element model needs to be constructed and analyzed to further investigate the latter point.

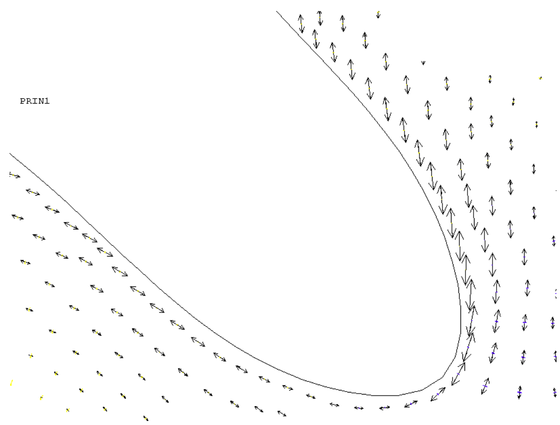

Figure 3. Principal stress directions below the cyst face

REFERENCES

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