Introduction: An in vivo animal model for Carpal Tunnel Syndrome has been developed using angioplasty balloon catheters to cause electrophysiological changes in median nerve function. The present study is an investigation into the morphological changes that occur in the median nerve with increasing pressure in the carpal tunnel.

We wished to evaluate whether increasing pressure would cause changes in quantifiable measures of nerve degeneration at the light microscopic level, as previously reported with electrophysiological testing.

Methods: Angioplasty catheters were placed in the carpal tunnel in the forepaws of New Zealand white rabbits. Pressures of 50 and 80 mm Hg were applied to 2 groups of 10 rabbits each until a 15% decrease in distal motor latency was observed for 2 consecutive weeks by EMG measurement. All of the animals in the 50 mm Hg and 80 mm Hg groups showed a 15% delay in latency; the 50 mm Hg group in an average of 3.8 weeks and the 80mmHg group in an average of 1.3 weeks. The animals were euthanized and the median nerve within the carpal tunnel taken for histological examination.

Nerve samples were fixed in 10% neutral buffered formalin, post-fixed in 0.1% osmic acid, and embedded in glycol methacrylate (Technovit 7100). Compressed median nerve samples were compared to median nerve samples from the carpal tunnel of normal unoperated rabbits. Three samples of median nerves at the level of the carpal tunnel were measured in all groups.

Density and diameter of myelinated axons within each fascicle were assessed on three micron sections stained with osmic acid. Three specimens from each pressure group and three normal nerves were measured. Images were captured in Simple PCI imaging software (C-Imaging systems, Pittsburgh, Pa.) using a Spot RT digital camera (Diagnostic Instrument Co.). A sample field from every fascicle in each nerve was assessed. Sections stained with hematoxylin, eosin, and phloxine were used for analysis of cellular changes.

Results:

Axon Density:
The 50 mm Hg and 80 mm Hg both showed a similar decrease in the average density of myelinated nerve fibers compared to the normal nerves. The normal nerves had an average density of 16.4 ± 4.2 and the 50 mm Hg and 80 mmHg groups had an average densities of 10.1 ± 2.5 and 11.0 ± 4.8, respectively.

Histology:

Both the 50 and 80 mm Hg groups exhibited a range of degenerating fascicles, from those exhibiting severe degradation of fascicles to those with normal morphology. Myelin changes included Wallerian degeneration, myelin thinning, myelin swelling, and axon dropout. Although the 80mm Hg group contained more severely degenerating fascicles, the type of cellular changes in both compressed groups was similar, and was not quantified. Fascicles containing degenerating fibers showed an increase in overall cellularity compared to the normal nerves. Most degenerating fascicles contained large phagocytic cells throughout the endoneurium that were not seen in any of the normal nerves. In addition, these fascicles showed a greatly increased population of endoneurial fibroblasts and Schwann cells. An increase in cellularity was evident in the epineurium surrounding degenerating fascicles.

Discussion and Conclusion:

Compression of the median nerve by a balloon catheter resulted in a graded histologic and electrophysiological response to two different pressures. The 80 mm Hg group reached a 15% delay in latency sooner than did the 50 mm Hg group. Cellular changes in both groups were similar, exhibiting increased cellularity and phagocytic activity associated with fiber degeneration. Both compressed groups showed a similar decrease in myelinated fiber density. Changes in diameter size distribution were similar in the two groups, with the number of small fibers increasing and the number of large fibers decreasing. These changes were more pronounced in the 80 mm Hg group, indicating a graded response to increasing pressure.

This study further validates the balloon catheter system as an ideal method to model carpal tunnel syndrome. The graded compression was able to create differential amounts of perturbation in motor conduction and in myelinated axon morphology.

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Fig densities of myelinated axons

Statistical analysis is based on counts of more than 9000 myelinated axons in 106 fascicles of 9 median nerves; expressed as number/100 μm².