A Comparative Study of Carpal Tunnel Compliance

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INTRODUCTION:
Clinical studies of carpal tunnel syndrome (CTS), a pressure-induced neuropathy of the median nerve, are limited by the difficulty of evaluating the early stages of pathology. Thus, a validated animal model of CTS is an important need. A proper animal model would have comparable anatomy to the human carpal tunnel. In addition, because carpal tunnel syndrome is characterized by increased carpal tunnel pressure, the carpal tunnel of the animal model should have mechanical characteristics similar to the human carpal tunnel. Compliance of the carpal tunnel directly affects the pressure alteration. Thus, it is important to know if the compliance of animal carpal tunnels is comparable to that of the human carpal tunnel. The objective of this study was to measure the compliance of the carpal tunnel in candidate animal models of CTS. The null hypothesis was that the compliance of the carpal tunnels of the various species was not different.

METHODS:
Forepaws from ten dogs, ten rabbits and ten rats with intact carpal tunnels and six fresh frozen human wrist cadavers were used for this study. The animal cadavers were obtained immediately after sacrifice for other Institutional Animal Care and Use Committee (IACUC) approved studies, in which the paws were not involved.

The skin, subcutaneous tissue, and all the tissues in the carpal tunnel were removed from the specimens with the carpal tunnel intact. The length and thickness of the transverse carpal ligaments were measured with an electronic digital caliper. The prepared specimen was mounted on a custom-made testing device. The measurement system consisted of one mechanical actuator with a linear potentiometer, a 25lb load cell and a tapered metal rod. Due to the variable size of the carpal tunnel from different species, different sizes of rods were used for each species. An 80 mm long metal rod tapering from 10 to 26 mm diameter, a 53.6 mm long metal rod tapering from 7.6 to 18.6 mm diameter, a 40 mm long metal rod tapering from 4.5 to 12.5 mm diameter, and a 22.6 mm long metal rod tapering from 1.2 to 3.2 mm diameter were used for humans, dogs, rabbits and rats, respectively. The tip of the metal rod was connected to the actuator through a flexible metal cable which passed through the carpal tunnel. The actuator pulled the metal rod through the carpal tunnel from proximal to distal. The start position of the metal rod was set to contact as much as possible of the carpal tunnel entrance without any measurable load. The motor rate of the actuator was set at 1mm/sec and the samling rate at 20 Hz. The displacement varied according to species to 35mm, 20mm, 15mm, and 12mm for humans, dogs, rabbits and rats, respectively. Throughout testing, the specimens were kept moist by spraying with phosphate-buffered saline. Each specimen was tested five times, and the means of the five tests were used for data analysis. The normal force on the wall of the carpal tunnel was deduced from the original force recorded from the load cell adjusted by the tangential angle of the tapered rod.

The increasing radius ratio (InRR) was calculated from the absolute increasing radius of the tapered rod during the test divided by the original radius of the rod at the starting point. The increasing area ratio (InAR) was calculated from the absolute increasing cross sectional area of the tapered rod during the test divided by the original area of the rod at the starting point. Custom-made MATLAB programs were used to calculate the slopes of the linear part of the curves between the original force and displacement, normal force and InRR and InAR. Statistical analyses were performed with SPSS 13.0 (SPSS Inc., Chicago, Illinois, USA) software. The results were expressed as mean (±standard deviation, SD). The analysis of variance (ANOVA) test was used to compare the means of variables among humans, dogs, rabbits and rats. Differences were considered significant at a p<0.05 level.

RESULTS:
Table 1 shows the results for rod radius at the start point, and the length and thickness of the transverse carpal ligaments in the four species. Carpal tunnels in humans were the longest and thickest among four species, while those of rats were the shortest and thinnest.

Figure 1 shows the results for the dependent variables. Comparing the results of the slopes of the linear part of the curves from the original force vs. displacement of the rod, normal force vs. InRR and InAR, the variables all showed significant differences among the four species (p<0.001). The features of the compliance for dog carpal tunnel were closest to the human.

DISCUSSION:
This study showed that the compliance of carpal tunnels among humans, dogs, rabbits and rats are different. Comparing the means of the slopes (original force vs. displacement, normal force vs. InRR and InAR), we found that carpal tunnels of humans have the most stiffness, while those of rats have the least. When we use animal models of CTS, we should consider the compliance difference, as a larger pressure might be needed to develop CTS in animal models. The results of this study may be helpful in developing more relevant animal models of CTS.