

Macroscopic and Microscopic Anatomy of the Ungual Cartilage: A Hemodynamic Flow Hypothesis of Energy Dissipation

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The anatomy of the unguis cartilage with its microvasculature provides insights into a hemodynamic flow mechanism for energy dissipation in the equine foot. Authors' address: Dept. of Anatomy, College of Veterinary Medicine, Michigan State University, East Lansing, MI 48824-1316. © 1997 AAEP.

1. Introduction

During ground impact of the equine foot, the generated forces can exceed the horse's weight several fold, which must be dissipated rapidly to minimize damage to bones and ligaments within the distal limb. Historically, several hypotheses—the pressure theory and depression theories—have been proposed that suggest that digital cushion absorbs the energies during ground contact to force the unguis cartilage (UC) abaxially.^{1,2} Recent biomedical studies have suggested that the digital cushion may not be as important in absorbing shock, as negative (rather than positive) pressures are recorded when the foot contacts the ground.² The present study in our laboratory was undertaken as a result of observing differences in the macroscopic structure of the UC and its relationship to the digital cushion and of finding an intricate vascular network within the UC. Together, these observations of the UC and digital cushion provide supportive evidence that energy dissipation in the equine foot is the result of a hemodynamic flow mechanism through the venous microvasculature of the UC.

2. Materials and Methods

One hundred and fifty feet from various breeds of horses euthanized for reasons other than foot problems were examined. The feet were sectioned in either the parasagittal, horizontal, or transverse planes at 0.5–0.7 cm and examined both macroscopically and microscopically in selective sections. In another 15 distal forelimbs, the medial palmar artery was catheterized and perfused with warm physiological saline prior to the infusion of 120 ml of India ink with 5% gelatin. The feet were then frozen, sectioned, and then processed for histological examination. In some feet (seven), the UC was processed for substance P receptor autoradiography in order to localize any potential peptidergic receptors regulating blood flow through the foot.

3. Results

The macroscopic morphology of the UC revealed that the UC varies considerably in its basic form and tissue composition and in its relationship to the adjacent connective tissue structures of the foot, such as the digital cushion. The observed differ-

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ences in the macroscopic anatomy of the UC and digital cushion were ones of gradations rather than of absolute differences in the tissue morphologies and compositions of these structures. On horizontal sections through the navicular bone level, a range of UC thickness was encountered from 0.150 in. (~0.38 cm) to more than 0.500 in. (1.27 cm), while the digital cushion varied in its tissue composition from adipose and loose or elastic tissues to the digital cushion's being composed of fibrous, hyaline, and fibrocartilaginous connective tissue. In transverse planes through the heel bulbs, the UC possessed an axial projection to overlie the epidermal ridge of the bars of the hoof. Although thin ligamentous attachments connect the UC to the deep digital flexor tendon dorsally, in robust feet with thick UC, this attachment was consistently composed of cartilage. Differences in the thickness of the cartilage were seen between feet from the forelimbs and hindlimbs of different animals as well as from the same animal. Certain breeds (Arabian and Morgan horses) consistently were found to have thick UC and a more fibrocartilaginous digital cushion than that of other breeds. In such feet the UC provided a rigid superstructure within the palmar foot to enclose the digital cushion, venous vasculature, and their associated palmar foot structures. In histological sections, the India ink-filled vessels contained within the UC consisted of numerous tortuous and straight, small venules paralleling a larger vein (veno-venous anastomoses) through the vascular channels of the UC. Only rarely did these small vessels appear to branch within the substance of the hyaline cartilage.

4. Discussion

The observations of the macroscopic and microscopic anatomy of the UC suggest that the macroscopic anatomies of the UC and digital cushion are more complicated than previously reported.^{3,4} The presence of a unique vasculature within the UC that also varies in its thickness indicates that these structures may be crucial to the dissipation of energy

within the equine foot. As a result of recent biomechanical studies,² our findings indicate that a hemodynamic flow mechanism exists in the palmar foot, which uses the UC with its numerous veno-venous anastomoses to dissipate transient high impact forces when the palmar foot and bars make contact with the ground. Such transient impact energies would be transmitted through the UC to the hemofluid compartment within the vasculature of the UC when the foot has contact with the ground. These energies would be rapidly dissipated by the rapid movement of blood through the vascular channels within the UC, similar to the principles of hydraulic fluid flow. Greater blood flow through the UC and the palmar foot would be increased by the high negative pressures within the digital cushion observed during ground impact. Such an arrangement of the UC and its microvasculature, as well as such microvasculature at other strategic sites, would provide an efficient and rapid mechanism for the dissipation of high transient energies during locomotion in the horse. Disturbances of this hemodynamic flow mechanism, either by disease states or by improper shoeing, would produce greater energies being transmitted to bone and ligamentous tissues, resulting in lameness.

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