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Light and Ultrastructural Study of the Chordae Tendineae in the Heart of the Ostrich *(Struthio camelus)*

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Abstract: The *chordae tendineae* of the heart are collagenous strands which extend from the apical margin of papillary muscles of the heart to the various areas on the ventricular surface of the valve leaflets. They convey the contraction of the papillary muscles to the valve and so prevent the latter's eversion. Eight hearts of the ostrich were collected, opened the left side of the heart and the length of the chordae tendineae were measured. Macroscopically they had interconnection and attached directly to the free edge of the left atrioventricular valve or tricuspid. Routine paraffin sectioning with special staining method and transmission electron microscopy method was done. Our results manifested that the chordae tendineae basically was connective tissue and covered by endocardium. The core connective tissue of chordae tendineae in the proximal part was loose connective tissue and in distal parts was dense irregular connective tissue whereas in the middle part it was dense regular connective tissue.

Key words: Chordae tendineae · Heart · Ostrich

INTRODUCTION

The chordal tendinous system of the heart is one of the most important functional systems involved in the circulation of the blood [1]. These strong cords spring from the tip of each papillary muscle. The right atrioventricular valve is formed by a single muscular cusp with no chordae tendineae in chicken, but the free border of tricuspid valve in left atrioventricular opening, carry a varying number of chordae tendineae [2].

Some literatures that were conducted on the chordae tendineae in the mammals and birds such as the determination of collagen fibril diameter and collagen type in human heart [3,4] rabbit and sheep hearts [3] SEM study of chordae tendineae in human [5-7] study of distal junction of papillary muscle in rat [8] morphogenesis of chordae tendineae in human [9] lymphatic capillary in chordae [10] structure of chordae tendineae in human [11,12], chicken [13] and horse [14] have been studied.

No information is available concerning histomorphometric study of chordae tendineae in the ostrich heart, thus this study described their morphological features.

MATERIALS AND METHODS

To follow-up this study 8 apparently healthy adult (age average: 1.5-2 years old) male ostrich were considered. Hearts were assigned from the slaughterhouse immediately after slaughter.

Histological Study: The chordae tendineae of left atrioventricular valve were dissected and the lengths of chordae tendineae were measured macroscopically and also their numbers were counted. The chordae tendineae were divided into proximal part (attach to the valve), middle part and distal part (attach to the papillary muscle). Subsequently each part was divided into two parts. One part was fixed in 10% buffer neutral formalin for light microscopy. The other part was fixed in 2.5% gluteraldehyde for transmission electrone microscopy (TEM) study.

All fixed specimens were processed and sectioned 6 µm through light microscopic analyses. Altimetry the sections were stained by using Hematoxylin-Eosin with pheloxine, Masson's Trichrome and Orcein-Van Gisson [15]. The diameters of chordae tendineae were measured by using of standard micrometric method.

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Electron Microscopic Study: The specimens washed in 0.1% phosphate buffer, post fixed in 1% osmium tetroxide, dehydrated through a graded ethanol series and epoxy propane and embedded in TAAB resin. The ultra thin sections were cut in transverse and longitudinal plane of the chordae, stained with uranyl acetate and lead citrate. Then they were observed under transmission electron microscopy (Philips CM10). The electronmicrograph were prepared and studied.

RESULTS

The macroscopic study revealed that, the left atrioventricular valve in the heart of ostrich, has three membranous cusps,as the dorsal, septal and the left cusps, which the septal cusp is the largest one.The link between papillary muscles and each valve leaflets in ostrich consists of 3-9 CT of 23.5±0.2mm lenght and approximately 0.45±0.02 mm diameter. Usually each valve leaflets receives the chordae tendineae from 2-3 papillary muscles, so that they spring from papillary muscle and often subdivide and some form interconnection together before their attachment to the leaflets of valve.The chordae tendineae attach directly to the free edge of ventricular surface of the leaflets (Fig. 1).

The light microscopic and transmission electron microscopic study confirmed the histological structure of chordae tendineae. Basically *chordae tendineae* was connective tissue composed of collagenous fibers, few elastic fibers and fibroblasts. The collagenous fibers of chordal core were arranged with their axis parallel to the long axis of the chordae. The *chordae tendineae* were covered by endocardium, which composed of a superficial layer of endothelial cells and an underlying layer of irregular connective tissue containing fibroblasts, collagenous fibers and a great number of elastic fibers that lie circumferentially. The number of elastic fibers diminishes toward the chordal core. The chordae`s endocardium is continuous with papillary muscle and valves leaflet. Endothelial cells are polygonal and contain fine filaments and small pinocytotic vesicles. They held together by interdigitating junctions (Fig. 2 and 3).

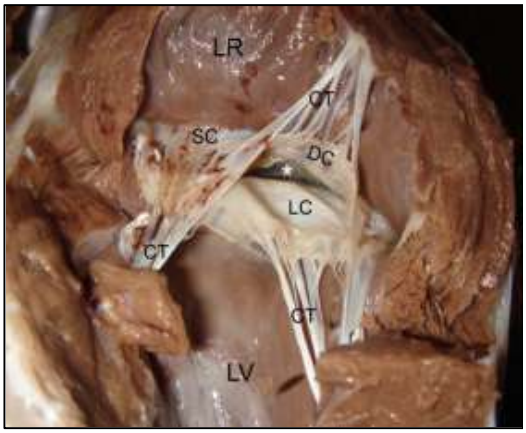

Fig. 1: Left side of heart of ostrich, opened by removal of part of left wall. left atrium (LR), left ventricle (LV), left atrioventricular orifice (*), chordae tendinae (CT), dorsal cusp (DC), left cusp (LC), septal cusp (SC).

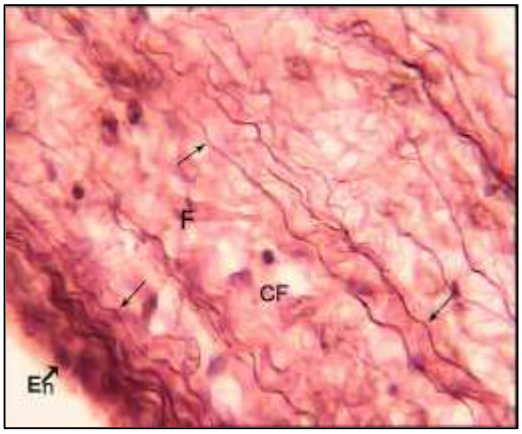

Fig. 2: Micrograph of chordae tendineae in ostrich showing elastic fibers (arrow) in the subendothelial connective tissue and in the center. Endothelium (En), collagenous fibers (CF) and fibroblast (F). Orcein-Van Gisson (×40).

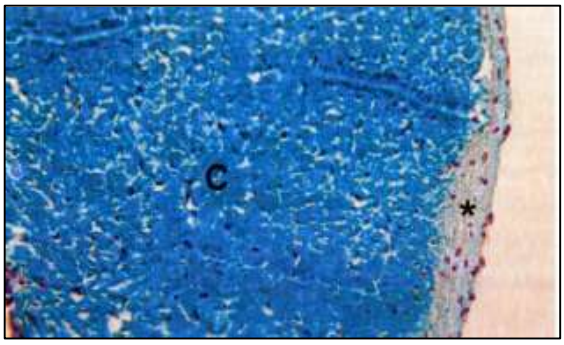

Fig. 3: Cross section of the chordae tendineae showing thin subendothelial connective tissue(*), chordal core (C). Blue Masson Trichrome (× 10).

The proximal part of chordal core consisted of dense irregular connective tissue in periphery and loose connective tissue in the center with delicate networks of lymphatic capillaries which were of different size caliber. Lymphatic capillaries were composed of continuous

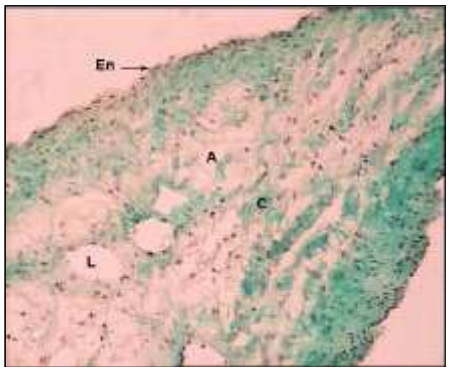

Fig. 4: Micrograph of the proximal part of the chordae tendineae, showing dense irregular connective tissue in periphery and loose connective tissue in the center (C) with lymphatic vessles (L), adipose cells (A) between the fibers and endothelium (En). Green Masson Trichrome (×400).

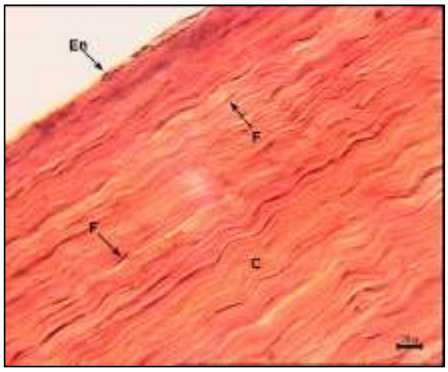

Fig. 5: Longitudinal section of the middle part of the chordae tendineae showing wave pattern of collagen. endothelium (En), fibroblast (F) and the core connective tissue(C). Orcein-Van Gisson (×400).

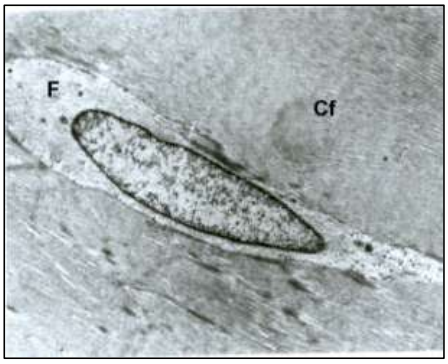

Fig. 6: Electronmicrograph of the middle part of the chordae tendineae, showing ovoid fibroblast (F) between rows of collagen fibrils (Cf) (×10920)

Fig. 7: Micrograph of the junctional area (J) of the chordae tendineae to Papillary muscle (PM), endothelium (En), purkinje fibers (P), H &E with pheloxine (×40).

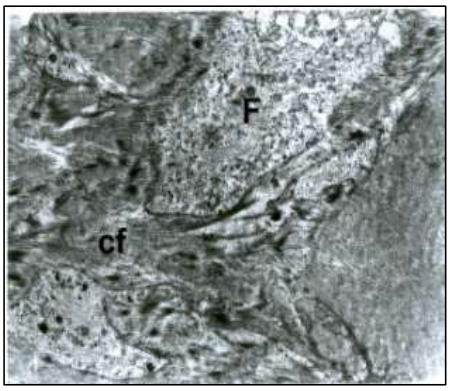

Fig. 8: Electronmicrograph of the junctional area of the chordae tendineae to valve showing the irregularity of collagen fibrils (Cf), fibroblast (F) (×10920).

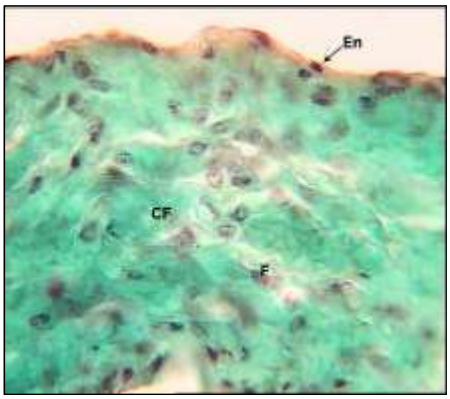

Fig. 9: Micrograph of distal part of the chordae, showing dense irregular connective tissue, collagen fiber (CF), Fibroblast (F) and endothelium (En). Green Masson Trichrome (×400)

endothelium which was surrounded by a thin layer of collagenous fibers. Also clusters of adipose cells were seen in the proximal part of the chordae tendineae (Fig. 4).

The structure of the middle part of the chordal core was dense regular connective tissue that collagenous fibers were arranged in compact, regular parallel rows and there were fibroblasts with ovoid nucleus between them. There were a few elastic fibers between collagenous fibers (Fig. 5 and 6).

The histological organization and density of Fibers in the junctional area of chordae tendineae to valve and papillary muscle was different. So that in the junctional sites, there is dense irregular connective tissue (Fig 7 and 8). Also the structure of the distal part of chordae tendineae was dense irregular connective tissue and fine networks of elastic fibers were observed (Fig. 9).

DISCUSSION

There were no papillary muscle and chordae tendineae on the right atrioventricular valve in the ostrich heart. The left atrioventricular or tricuspid valve complex of ostrich heart consists of functional units which include the annulus fibrosus, valve leaflets, chordae tendineae and papillary muscles. The mechanical properties of these functional units depend on the link between the muscle and the valve. This link is arranged in a branching network of tendinous cords which composed of collagen and elastic fibers. These fibers transmit contractions of papillary muscle to the valve leaflets [1,16,13].

The chordae tendineae in the ostrich heart has interchordal attachment and it's similar to that of chicken [13], human [17,18,11] human and swine [12] sheep and rabbit [3].

The chordae in the ostrich heart attach directly to the edge of the valve, but in the heart of human, their attachment is few millimeters back from the edge [19,13].

The chordae tendineae consists of a dense collagenous central core, surrounded by a layer of connective issue, that covered by flat endothelial cells. These results were similar on horse [14] and human [11].

The regular wave pattern of collagen in the chordal core of middle part in the heart of ostrich support the result in the heart of sheep and rabbit [3] mouse [20] human [5,11] goat and cattle [21] and horse [14]. This architectural arrangement is necessary for the tissue that is under constant dynamic stress. But in the heart of the kid, these architecture changes to the loose connective tissue in the periphery and dense irregular connective tissue in the core of the chordae [21] similar to proximal part of chordae in the ostrich.

Distribution of elastic fibers under the endothelium and a few longitudinal fibers in the core of the chordae tendineae between collagen fibers, partly agree with occasional endocardial elastic fibers in the dog's heart [22]. The presence of lymphatic capillary in proximal part of the chordae is similar to that of the human [10].

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