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Morphology of the tendon of Todaro within the human heart in ontogenesis

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The tendon of Todaro, found in the right atrium of the heart, has considerable clinical importance in the fields of both cardiac surgery and invasive cardiology. The goal of this study was to examine the occurrence and degree of development of the tendon of Todaro in humans. Research was conducted on material consisting of 160 human hearts of both sexes from the age of 14 Hbd to 87 years of age. Classical anatomical methods were used and histological sections were prepared from 100 hearts of various age groups stained with Masson's method in Goldner's modification. The tendon of Todaro occurred in all examined hearts. In foetal hearts, in the area typical of the course of the tendon of Todaro, a very well-developed, white structure was observed, convexed into the lumen of the atrium. Histologically, this was young fibrous tissue with a characteristically large number of fibroblasts. Evenly in infants and newborns, a visible convex structure was also observed extending into the lumen of the right atrium, however, to a lesser degree than in foetuses. In the group of hearts of young adults, it was also possible to follow the course of the tendon of Todaro macroscopically. However, the older the heart was, the less the convex was visible, and in older adults it was completely invisible. In histological sections, it was observed that with ageing the number of connective tissue cells decreased, and fibres forming the lining increased. In the hearts of older adults the tendon of Todaro formed very small ribbons of connective tissue. Histologically, only small numbers of cellular elements were noticed. In the adult heart the examined tendon was located the deepest and did not connect to the endocardium. We can conclude that the tendon of Todaro is a stable structure, occurring in all examined hearts even when it is not macroscopically visible. Due to the morphological changes that affect the tendon of Todaro in human ontogenesis, for the cardiac surgeon, its relevance as an important topographical structure in the hearts of older adults is minimal.

key words: tendon of Todaro, right atrium, human ontogenesis, macroscopic anatomy, histology

INTRODUCTION

The tendon of Todaro [9], found in the right atrium of the heart, has considerable clinical importance in the fields of both cardiac surgery and invasive cardiology. It is relevant, among others, to interventricular septum defect procedures and in ablations of elements of the conductive system of the heart [2,4]. The tendon of Todaro has been a subject of a con-

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siderable investigation. However, individual studies on the topic are rather rudimentary, and even so, researchers' opinions vary regarding the etiology and purpose of this tendon. No anatomical research has been done on material on a large scale including many age groups. The goal of this study is to examine the occurence and degree of development of the tendon of Todaro in humans.

MATERIAL AND METHODS

Research was conducted on material consisting of 160 human hearts of both sexes from the age of 14 Hbd to 87 years of age. Hearts were fixed in a 10% formalin/98% ethanol solution. Only hearts showing no pathological changes or congenital disorders were considered. Material was divided into appropriate age groups (Table 1).

Classical anatomical methods were used as well as the transillumination method in the hope of better observation of the course of the tendon of Todaro [5]. The walls of the atrium were prepared by means of a stereoscopic microscope. Histological sections were prepared from 100 hearts of various age groups stained with Masson's method in Goldner's modification (Fig. 1).

Table 1. Break down of the material

Material (hearts)	Age	Number of hearts
Foetal	16–42 Hbd	51
Child newborn	5 min–1 mo.	21
Infant	2–11 mo.	9
Older child	2,5–16 years	16
Adult younger	19–46 years	29
Older adult	50–87 years	34
Total		160

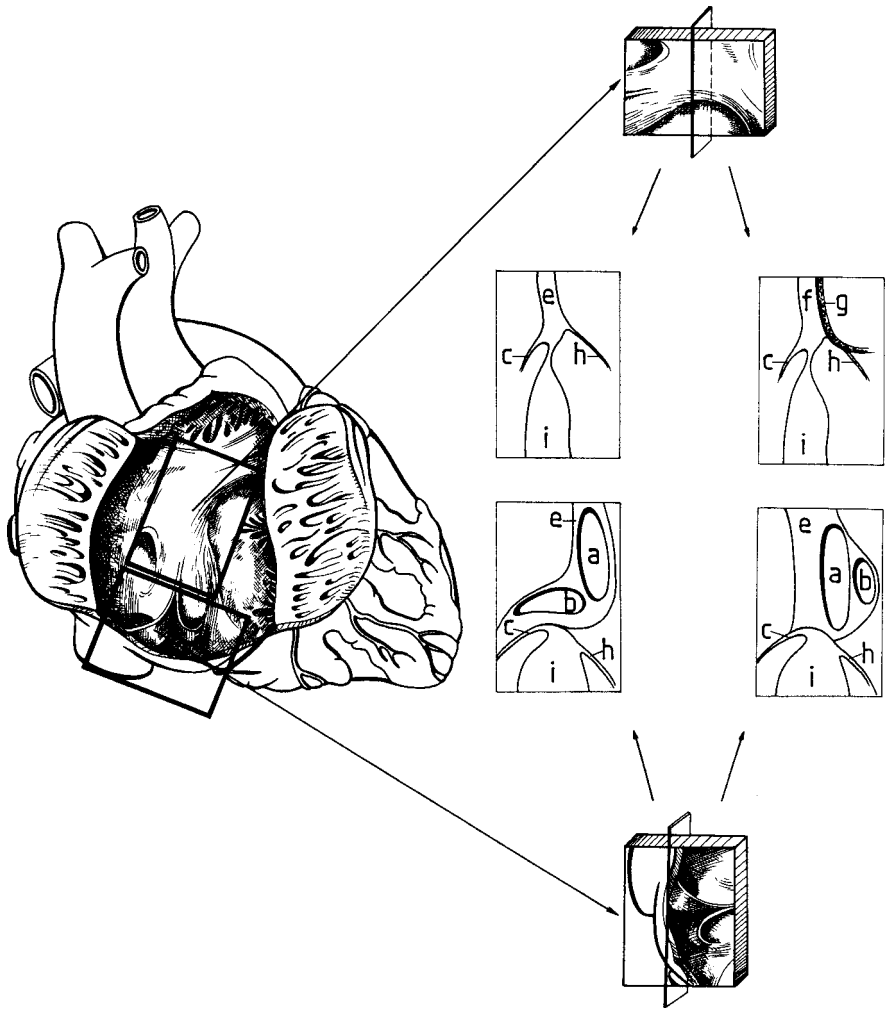


Figure 1. Diagram illustrating histological blocks containing the region with the tendon of Todaro and its division on specimens.
a — orifice of the vena cava inferior; b — lumen of the coronary sinus; c — septal leaflet of the tricuspid valve; e — interatrial septum; f — wall of the right atrium; g — aortic wall; h — anterior leaflet of the mitral valve; i — interventricular septum.

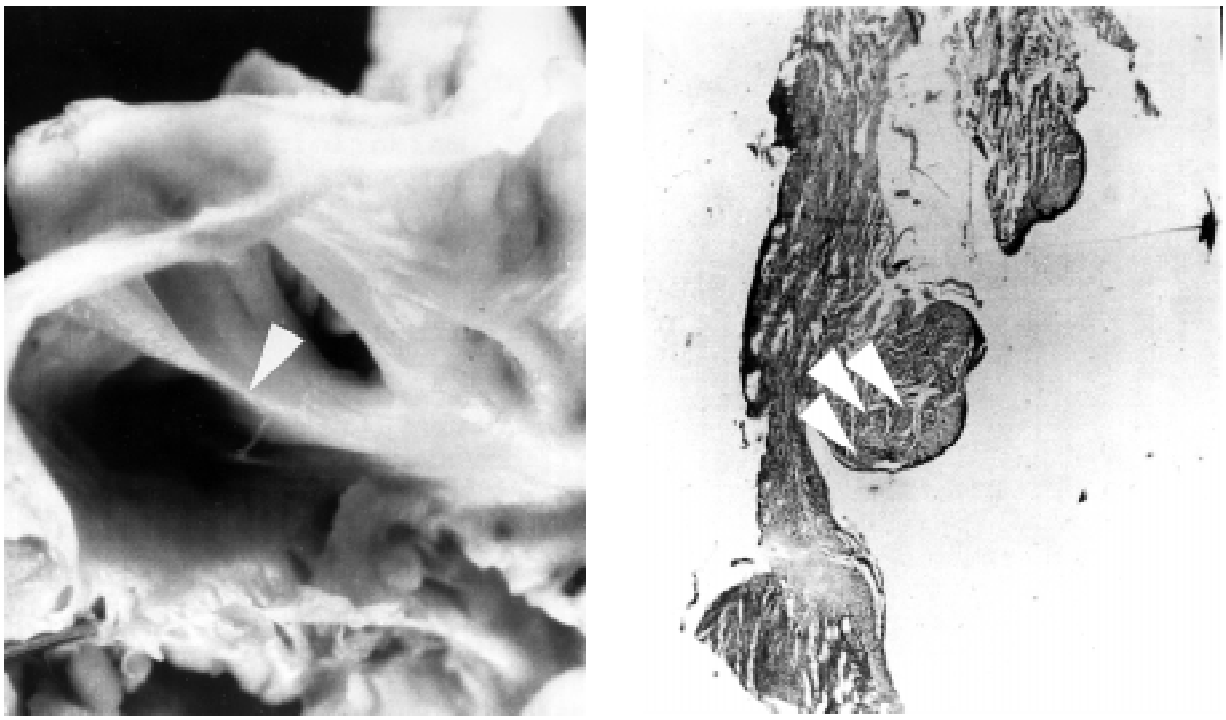
RESULTS

The tendon of Todaro occurred in all examined hearts. Its presence was determined by both macro- and microscopic methods. Although in foetal, infantile and young adult hearts macroscopic examination and preparation under a stereoscopic microscope was sufficient, the hearts of older adults (50–87 years of age) required histological examination.

In foetal hearts, in the area typical of the course of the tendon of Todaro, a very well developed, white structure was observed, convexed into the lumen of the atrium. The greater the rise of the endocardium, the younger in development the foetus was (Fig. 2A). Upon preparation, a superficially located funicular structure composed of connective tissue was noticed. Histologically, this was young fibrous tissue with a characteristically large number of fibroblasts. Upon section, the tendon usually appeared as a singular, uniform bundle of connective tissue, or was composed of 2–3 fascicles in a quite dense structure (Fig. 2B).

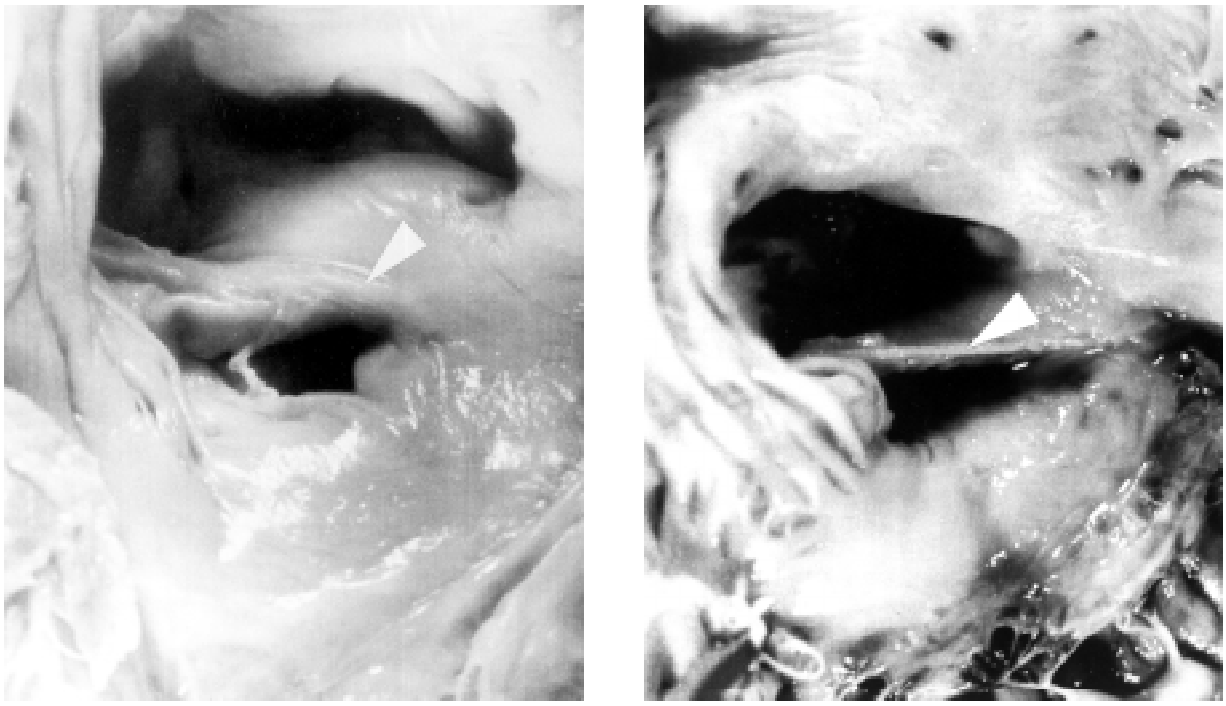
In the group of infantile hearts morphological changes were observed depending on the age of the examined heart. Even in newborns and infants, a visible convex structure was also observed extending into the lumen of the atrium, however, to a lesser degree than in foetuses. In the hearts of older children (2–16 years of age), a slightly raised and thickened endocardium was observed at the place of the course of the tendon (Fig. 3A). Histologically, fibres of the middle layer of endocardium ran to the tendon, similarly to the smooth muscle fibres of the atrium, and more exactly, from the inferior limbic fascicle (fasciculus limbicus inferior) (Fig. 3B). The number of these fibres was, as a rule, greater than in foetal hearts. In this group of hearts, the tendon did not seem to have such strong connections to the endocardium. Upon section the tendon appeared to be a bundle of connective tissue composed usually of 2–3 fascicles in a quite dense structure.

In the group of hearts of young adults it was also possible to follow the course of the tendon of Todaro macroscopically. However, the older the heart was, the less the convex was visible, and in older adults it was completely invisible. The endocardium in this area was smooth and did not stand out from its surroundings in any way. Upon preparation, it was shown to lie deeply beneath the endocardium between muscle fibres. It was very thin and difficult to prepare (Fig. 4A). In histological sections, it was observed that with age the number of connective tissue cells decreases, and fibres forming the lining increase. In the hearts of young adults the examined



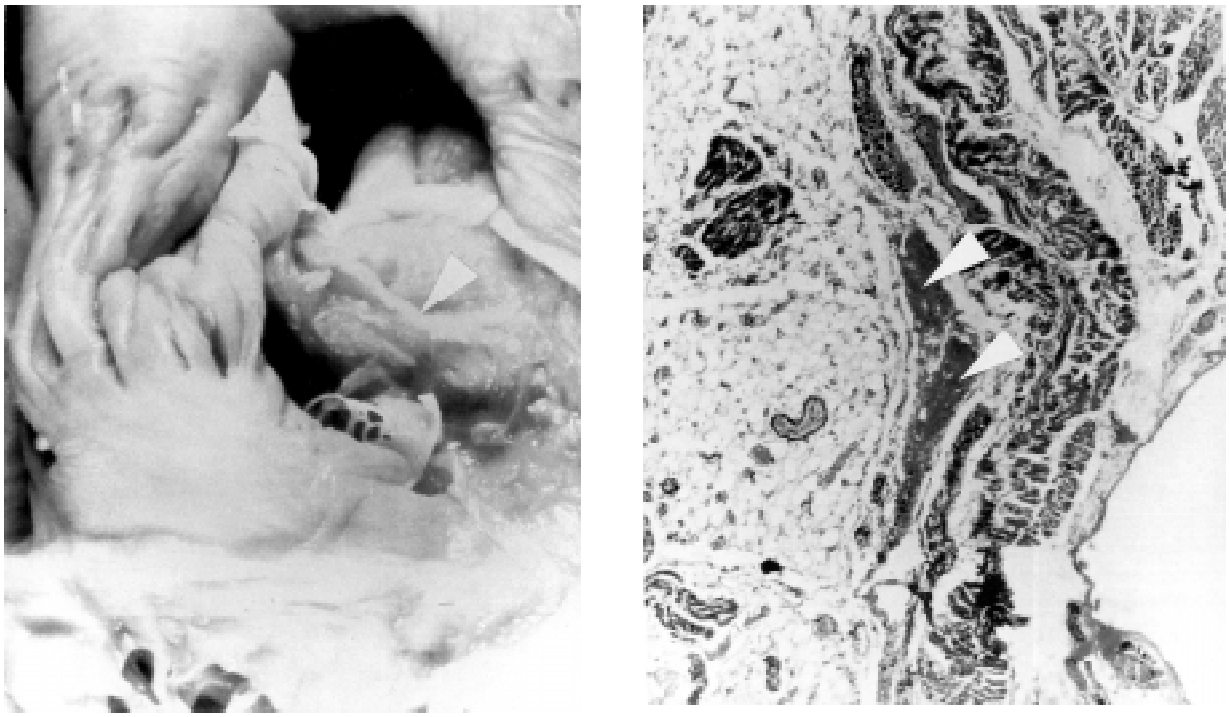
A B

Figure 2. The morphology of the tendon of Todaro (arrows) in the heart of the human foetus A) Macroscopic view (♂33-weeks of intrauterine life-old); B) Histological view (♂23-weeks of intrauterine life-old; magnification x 12).



A B

Figure 3. Macroscopic view the tendon of Todaro (arrows) in the heart of the human children. A) Unprepared, under fold of endocardium visible tendon (♂15-year-old); B) Prepared tendon (♂4-month-old).



A B

Figure 4. The morphology of the tendon of Todaro (arrows) in the heart of the human adults. A) Macroscopic view (♀85-year-old); B) Histological view (♀76-year-old; magnification x 44).

tendon usually took on the form of a varied multi-bundled structure (2–6 bundles), divided by atrial muscle, but well defined from its wall. In the hearts of older adults the tendon of Todaro formed very small ribbons of connective tissue (to approx. 10) most often running in interatrial adipose tissue (Fig. 4B). Histologically, only small numbers of cellular elements were noticed. In the adult heart, the examined tendon was located the deepest and did not connect to the endocardium. No convex into the atrial lumen was noticed.

DISCUSSION

The tendon of Todaro, due to its clinical significance as mentioned earlier, was the subject of interest for many researchers. Some were only interested in its anatomy, others took their observations from a clinical standpoint. Our research encompassed hearts of both pre- and postnatal periods. We observed its presence in all examined hearts using various methods from macroscopic to histological. Our observations do not always confirm the results achieved by other authors.

Voboril [11], who examined 155 human hearts from 4 months of foetal age to 94 years of age stated the occurence of the tendon to be 84.5% of his examined hearts. He examined 141 hearts macroscopically, and 14 microscopically. He did not give which age groups were examined histologically, and if the tendon was always visible. He did state, however, that the tendon was verly well developed in foetal hearts and infants, and involution occurs with age. Wolner [12] for example, examined considerably fewer hearts (35 hearts), of which the tendon occured in 91.4%. He did not give the exact age of the examined hearts, and paid greater attention to its topography and eventual function of the tendon. The Italian researchers Todaro and Versari [8,10], who were generally interested in the structure of the valve of the inferior vena cava in humans, and Scaffidi who was interested in animal hearts [7], stated that the tendon was a permanent structure and always occured within the Eustachian valve. In 1907, Walter Koch published his doctorate study based of the examination of 4 hearts of adults who died regardless of a correctly carried out reanimation procedure [3]. On the basis of his examinations, Koch stated the occurence of a sinus "fold" which developed from the merging of the Eustachian and Thebesian valves ("sinusfalte") further coursing as its extension in the form of a grey-white ribbon of fibres ("sinusstreifen"). This structure ran through the atrial septal wall, and then attached itself to the base of the posterior cusp of the tricuspid valve. Although he did not name the above mentioned fibrous fascicle as the tendon of Todaro, but he gave evidence that the fold almost always occurred permanently in all human hearts, even if they were macroscopically not well visible — which is concurrent with the results of our investigation. Probably Koch's publication became the motivation for the investigation of Hungarian pathologist Orsós [6], who approached it rather critically. He claimed, similarly to Koch, that the tendon occurred in all examined hearts. He did not call it the tendon of Todaro, and emphatically underlined that the fold, described by Koch, along the course of the tendon was not observed by him in any hearts. However, he stated that it was a fibrous bundle that was well visible through the endocardium as a white ribbon of fibres. Moreover, this ribbon was completely covered by endocardium and often ran into atrial muscle, and could be the reason for its invisibility. He also added that, the tendon's degree of development was related to individual differences. Our observations confirm the remarks of this author, even more, due to the fact that he examined the hearts of individuals who died of other causes than of diseases of the circulatory system (unlike the material of Koch's study).

It was determined that the tendon of Todaro is a permanent structure in humans, occuring in all hearts, and degree of its development depends on age. In human ontogenesis this structure undergoes involution, as in the hearts of foetuses and children, the tendon of Todaro is a visible element macroscopically; in the hearts of older adults its presence can only be confirmed using histological methods. The examined structure, in terms of morphology, is varied. In the hearts of foetoses and children it is a uniform, funicular structure lifting the endocardium. With age, it disintegrates, thins and as it is seen in the hearts of older adults, penetrates into the atrial wall.

We can conclude that, the tendon of Todaro is a permanent structure in humans, occuring in all hearts, and degree of its development depends on age. Due to the morphological changes that affect the tendon of Todaro in human ontogenesis, for the cardiac surgeon, its relevence as an important topographical structure in the hearts of older adults is minimal.

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