

# Unusual anatomical features of the right atrioventricular valve

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*Despite the great interest taken in the tricuspid valve, the anatomical literature on the subject still leaves much open to question. The aim of this study was to describe the natural foramina which are present in the leaflets of the tricuspid valve, as well as, well — founded onto — and phylogenetically lack of continuity of its attachment and the frenula of the tricuspid valve. We studied the frequency of occurrence and morphology of these features of the tricuspid valve in 107 adult hearts.*

**Key words:** tricuspid valve, human heart, right ventricle, morphology, frenulum, natural foramen

## INTRODUCTION

Despite the great interest taken in cardio-anatomy, the problem of the morphology of the atrioventricular ostia is still unresolved. Further investigation is particularly needed into the tricuspid valve, which is presented in existing research as a heterogeneous structure of great variability [7, 9, 11–14]. In this study we have described the natural foramina in the leaflets of the tricuspid valve, and well — founded onto — and phylogenetically lack of continuity of its attachment [1, 2]. These features may be responsible for the additional jets seen during echocardiography as well as the subclinical insufficiency of the tricuspid valve, which may be identified by means of recent techniques for imaging the heart. We have studied the incidence and morphology of frenula of the tricuspid valve, which occur in the region of the conal papillary muscle of the right ventricle and may be important for the geometry of the right ventricle during contraction [6]. These features were studied in 107 adult hearts.

## MATERIAL AND METHODS

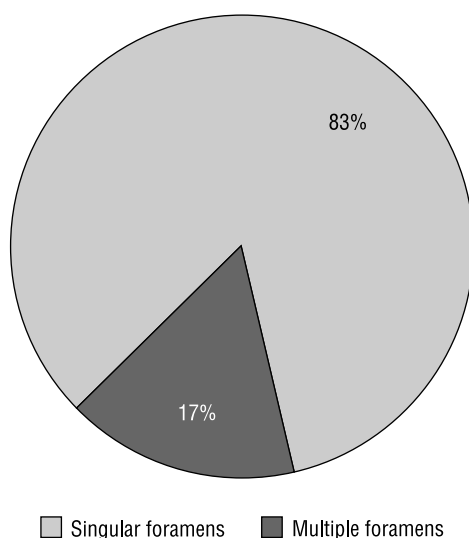
The study material consisted of 107 formalin-fixed adult human hearts of both sexes, 30 female and

77 male, aged from 18 to 90 years and without macroscopic developmental failures or pathological changes.

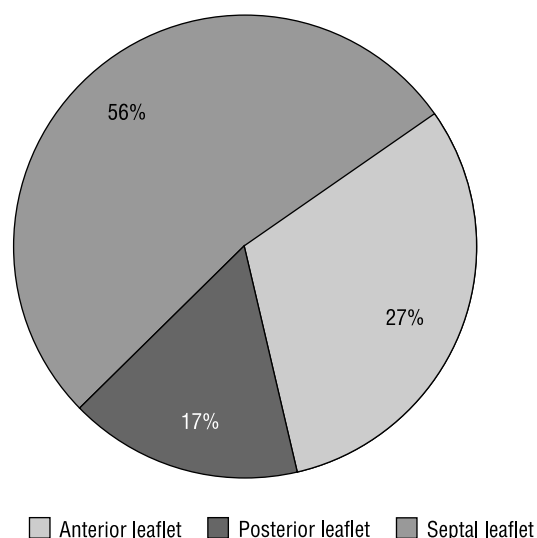
The hearts were opened from the side of the right atrium, the line of the cut running from the ostium of the superior cardinal vein to the right atrioventricular ostium. The right ventricles were opened with a V-shaped cut along the right margin and across the anterior wall of the right ventricle. The valves were usually cut in the region of the connection between the posterior and anterior leaflets. The valves were separated and transferred onto graph paper with attention given to the natural foramina of the tricuspid valve. The fields of the natural foramina were measured with a planimeter. Any discontinuity of the attachments and the complete circuit of attachment of the tricuspid valve were measured from the side of the right atrium. The valves were classified according to an earlier system [7, 11].

## RESULTS

The natural foramina located in the leaflets of the tricuspid valve were studied. We introduced the concept of "true" and "spurious" natural foramina of the tricuspid valve. Those surrounded by valve tissue from each side were regarded as true foramina.



**Figure 1.** Incidence of singular and multiple natural foramina of the tricuspid valve.

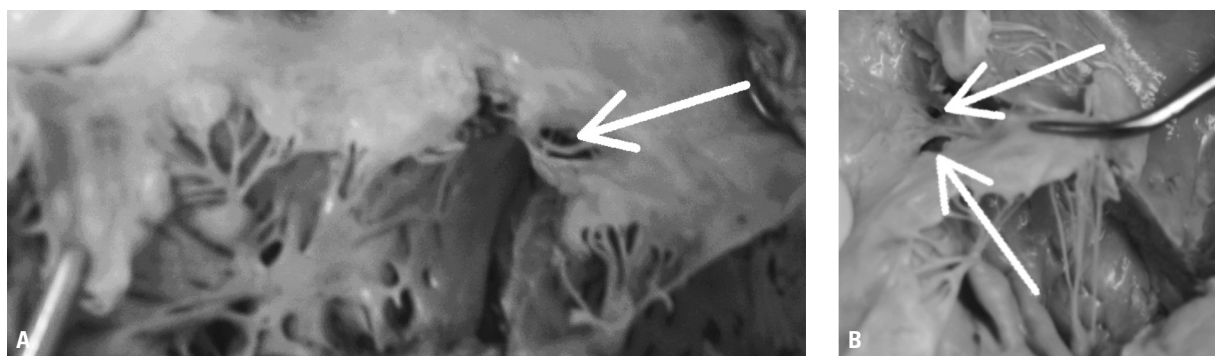


**Figure 3.** Incidence of natural foramina in particular leaflets of the tricuspid valve.

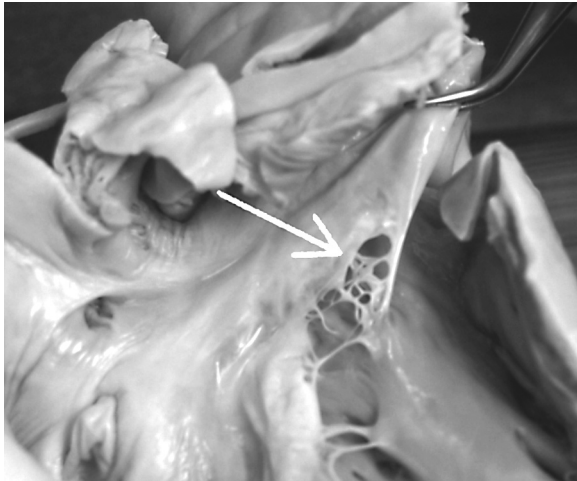
Foramina with crossing single fibres of valve tissue were treated as one foramen. Their distribution was studied. Natural foramina of the tricuspid valve were detected in 12 of the hearts (11.21% of the group studied). We observed 18 foramina. In 9 hearts (83.33% of the hearts with natural foramina) they occurred singly, while in 3 of the hearts (16.67%) they were multiple (Fig. 1). True natural foramina of the tricuspid valve are presented in Figure 2. Particular parts of the Figure 2A and B show examples of hearts with natural foramina. We found 5 foramina in the anterior leaflets (27.2% of all foramina), 3 in the posterior (16.66%) and 10 (55.55%) in the septal cusps (Fig. 3). The surface areas of the natural foramina of the tricuspid valve differed considerably in size, from 1 mm<sup>2</sup> to 12 mm<sup>2</sup>. The average surface area was  $5.57 \pm 6.86$  mm<sup>2</sup>.

As noted above, the concept of spurious natural foramina was introduced. This structure is part of a musculo-fibrous arcade, which has previously been described by Szostakiewicz-Sawicka [13, 14]. (We did not study its incidence as tendinous chords are to be the subject of a further paper). The concept referred to was introduced to differentiate natural foramina of the tricuspid valve from those parts of the musculo-fibrous arcade which are different in structure. The absence of this division in the literature of the subject may lead to all the structures being treated as one group. Figure 4 presents spurious natural foramina of the tricuspid valve co-existent with a membranous connection between the papillary muscle and the leaflet of the valve.

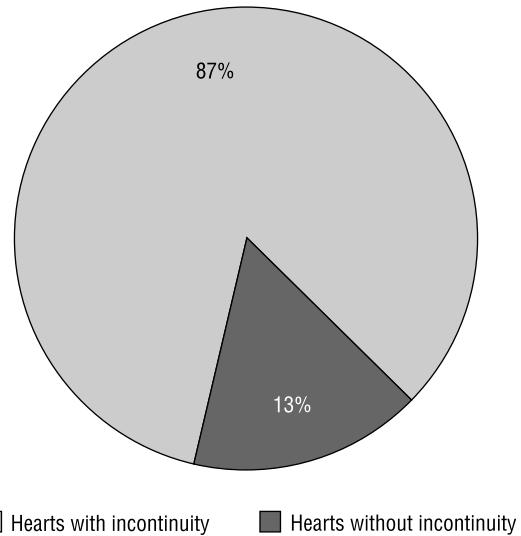
The word "commissure" does not exist in anatomical nomenclature but has been introduced by



**Figure 2.** Examples of natural foramina of the tricuspid valve. **A.** The arrow indicates that a natural foramen with apparent single fibres of tissue of the tricuspid valve is located in the anterior leaflet; **B.** The arrows indicate two natural foramina situated in the septal leaflet, which are located near the attachment of the valve.



**Figure 4.** Spurious foramen of the anterior leaflet of the tricuspid valve. The arrow indicates a spurious foramen of the anterior leaflet of the tricuspid valve.



**Figure 5.** Incidence of discontinuity of attachment of the tricuspid valve.

surgeons [3, 15]. We studied the incidence of commissures. The presence of a commissure was associated with continuity of attachment of the tricuspid valve. The absence of valve tissue between the two leaflets of the tricuspid valve was described as absence of a commissure. Commissures occurred in 96.86% of sites between all the cusps. Their length, measured as the distance between the attachment of the tricuspid valve and the intercuspidal incisure, ranged from 2 to 15 mm, with an average of  $6.33 \pm 2.59$  mm. Great variation is thus demonstrated and this is associated with great variation in the heights of the main and accessory leaflets of the tricuspid valve and its definition [12, 14].

We observed a lack of continuity in the attachment of the tricuspid valve. This was located in the region of the connection of the anterior with the septal or accessory leaflets. This site, in the neighbourhood of the *pars membranacea*, derives from 3 sources during embryonic development and is also the region connecting the two arms of the moon-shaped valve present in the lower vertebrae.

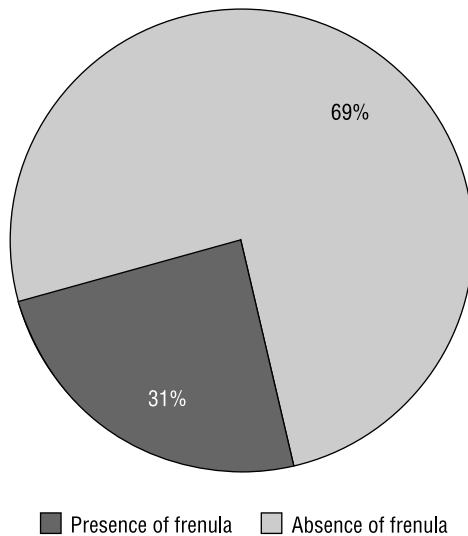
Lack of continuity in the attachment of the tricuspid valve was present in 14 of the hearts (13.08% of the group studied) (Fig. 5). The proportional ratio of discontinuity of the tricuspid valve was within the range 1 mm (0.93% of the circuit of attachment of the valve) to 12 mm (11.76% of the circuit), average 5.81 mm (5.19% of the circuit), SD 3.06 (3.02). Figure 6 shows an example of the discontinuity of the tricuspid valve. A natural foramen is additionally present in the anterior leaflet.

The valves were divided onto types according to an earlier classification [7, 11]. Lack of continuity in the attachment of the tricuspid valve was present in 3 valves of 11 (27.27%) of hearts of type 1, in 5 valves of 44 (11.11%) of type 2 and in 5 valves of 14 (13.16%) of type 3. We did not observe discontinuity of the tricuspid valve in types 0, 4, and 5.

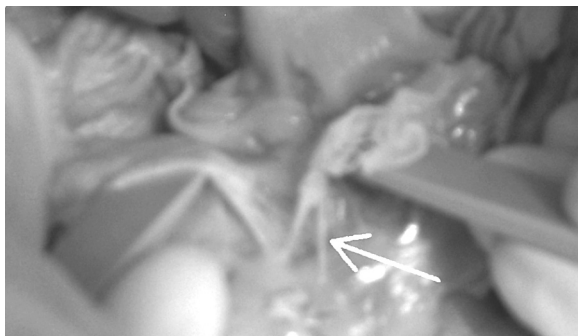
Attachment of the tricuspid valve may be strengthened by a separate additional membranous piece of tissue in the region of the conal papillary muscle. This is termed a frenulum, according to Szostakiewicz-Sawicka [14]. Frenula were present in 33 hearts of the group studied (30.84%) (Fig. 7). An example of a heart with a frenulum is shown in the photograph in Figure 8. The incidence of frenula when clas-



**Figure 6.** Discontinuity of attachment of the tricuspid valve. The two arrows show the length of the discontinuity of the attachment of the tricuspid valve.



**Figure 7.** Incidence of frenula of the tricuspid valve.



**Figure 8.** Example of a frenulum of the tricuspid valve.

sified by type was as follows: a frenulum was observed in 5 of 11 hearts (45.45%) of type 1, in 19 of 44 hearts (43.18%) of type 2, in 5 of 14 hearts (35.71%) of type 3, in 2 of 9 hearts (22.22%) of type 4 and in 2 of 3 hearts of type 5.

## DISCUSSION

The natural foramina present in the leaflets of the tricuspid valve were studied. Their surface areas varied from 1 mm<sup>2</sup> to 12 mm<sup>2</sup> and they were observed in 11.21% of the group studied. In 83.33% of the valves with natural foramina they were single, while in the remaining 16.67% the foramina were multiple. We also studied the location of natural foramina. All were found in the main leaflets of the tricuspid valve: 5 foramina were located in the anterior leaflets (27.2% of all foramina), 3 in the posterior (16.66%) and 10 in the septal cusps (55.55%). When our results were compared with those of Łukasze-

wska-Otto [9], we found a great discrepancy in the incidence of the foramina. According to her, the foramina are found in 20% of tricuspid valves. It may be impossible to discern these discrepancies in the specifications of the group studied. It is more probable, however, that Łukaszevska-Otto [9] classified musculo-fibrous arcades with natural foramina and that she is describing parts of arcades when referring to natural foramina in the descriptive part of her paper. In order to distinguish these structures, we have introduced the concept of "true" and "spurious" natural foramina of the tricuspid valve. The spurious natural foramen is a part of the musculo-fibrous arcade, morphologically similar to a true natural foramen, as described earlier by Szostakiewicz-Sawicka [13, 14].

In the group studied agreement was found with Łukaszevska-Otto's [9] study in the proportion of single to multiple foramina. She also found natural foramina in the accessory cusps and in commissures of the tricuspid valves. In our group of hearts we found natural foramina only in the main leaflets.

We also studied commissures. We regarded continuity of valve tissue between two cusps as the presence of this structure. From a study of all the neighbouring valvular leaflets we found commissures in 96.86%. Our results are similar to those of Łukaszevska-Otto [9], who found them in 94.61%. The length of the commissures varied from 2 mm to 15 mm, with an average of 6.33 mm. Łukaszevska-Otto's results were similar, from 5.4 mm to 15.5 mm. She performed a statistical analysis of the commissures between particular leaflets in different types of tricuspid valve. We did not do this in the light of the lack of proof that commissures in different types of tricuspid valve are analogous. This will be a subject of our further study.

In the group of hearts studied we observed a lack of continuity in the attachment of the tricuspid valve located over the anterior angle of the right ventricle between the anterior and septal or accessory leaflets. This variant was observed in 14 of 107 hearts (13.08%). The length of discontinuity varied from 1 mm to 12 mm, making up a percentage of between 0.93% and 11.76% of the circuit of attachment. We found differences in the incidence of this in the particular types of tricuspid valve: it occurred in 27.27% of hearts belonging to the type 1 group, in 11.11% of those belonging to the type 2 group and in 13.16% of those belonging to the type 3 group. We did not detect it in types 0, 4 and 5. We found no relationship between discontinuity of the tricuspid valve and the presence or absence of an

accessory cusp in this location. In the study of Szostakiewicz-Sawicka [14] lack of continuity of the tricuspid valve was present in 36% of the group studied and its length reached a maximum of 15 mm. Our results are similar as regards its length but not its frequency of occurrence. The proportion of valves of types 0, 4 and 5 in our group was higher than in Szostakiewicz-Sawicka's group, which may explain the difference. The appearance of a lack of continuity of the tricuspid valve may be associated with different times of development and different sources of tissue in the formation of the future septal and anterior leaflets during foetal life [1, 2, 5, 12]. It may also be an echo of a primitive moon-shaped right atrioventricular valve of the lower vertebrae. Despite the common occurrence of lack of continuity of the tricuspid valve, it does not seem to have an important clinical significance. We have found only one case study linking this variant with insufficiency of the tricuspid valve. The authors attached an intra-operative photograph of the valve with the tricuspid valve divided by the discontinuity [10]. This variant, together with the natural foramina of the tricuspid valve, may, however, be responsible for the occurrence of the additional jets seen in echocardiography.

The attachment of the tricuspid valve may be strengthened by a separate piece of additional tissue, termed, according to Szostakiewicz-Sawicka and Grzybiak [13] and Szostakiewicz-Sawicka [14], a "frenulum of the tricuspid valve". In our group of hearts it was found in 30.84% of hearts. When their incidence is compared with the results obtained by Szostakiewicz-Sawicka [14], differences can be noticed. According to this author frenula occur in 20% of human hearts. It is not easy to explain the differences between her results and ours. The group of hearts studied by her was small and was only a control group for comparison with the hearts of other primates. The issue has been neglected by many authors.

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