Anatomic Variations of the Orifice of the Human Coronary Sinus

By Herman K. Hellerstein, M.D., and J. Lowell Orbison, M.D.

Anatomic variations of the orifice of the human coronary sinus now have practical significance since the advent of catheterization of the coronary sinus. Six main types of variation of the valve of the coronary sinus of 150 hearts are described. The difficulties encountered in catheterization of the human coronary sinus are probably due to obstruction offered by large membranes, bars and networks, and less frequently due to the presence of a large eustachian ridge. On the basis of this study, catheterization of the human coronary sinus should be possible in a maximum of 75 per cent of the cases.

MEASUREMENT of the coronary blood flow and myocardial metabolism has been made possible by the technic of catheterization of the coronary sinus in the intact dog and man. Detailed knowledge of the structure of the right atrium, and particularly of the variations and anomalies of the venous valves of the right atrium of the human heart (eustachian valve or the valve of the inferior vena cava, and the thebesian valve or the valve of the coronary sinus) now has practical significance. The failures reported in a large per cent of the attempts to catheterize the human coronary sinus can be explained on anatomic bases. Since in previous studies the anatomic variations of the human coronary sinus were not considered from the viewpoint of their possible influence on catheterization, we believe it desirable to study anew the variations in the orifice of the human coronary sinus in a large series of adult hearts.

MATERIALS AND METHODS

We have studied the eustachian and thebesian valves and the orifice of the coronary sinus in 150 hearts chosen at random from the large collection of formalin fixed specimens at the Institute of Pathology, Western Reserve University. The hearts had been opened in the customary routine manner, so that the eustachian valve was usually sectioned near the middle by an incision extending between the orifices of the venae cavae. In examining the eustachian valve, special care was taken to reappose the cut edges, and examine its structure from the lateral aspect of the opened right atrium. The thebesian valve and orifice of the coronary sinus were intact in each case.

All descriptions and measurements of the valves were made with the heart held in a position similar to that occupied in the intact body—the superior and inferior venae cavae in an axis parallel to the longitudinal axis of the body, with the longitudinal axis of the heart (base to apex) semihorizontal. Observations made in recent autopsies confirmed the correctness of the above position (fig. 1). When the free wall of the right ventricle and the anterior lateral aspect of the right atrium are removed from a heart in situ, the following relations are observed: the free margin of the eustachian valve is concave and is directed cephalad, and the attached margins extend roughly from dorsal to ventrum, parallel to the median sagittal plane of the body. The orifice of the coronary sinus is to the left and below the medial extremity of the valve of the inferior vena cava and in the space between the latter and the edge of the right atrioventricular orifice. The form and the position of the thebesian valve will be described in detail later. The right atrioventricular ring forms an acute angle with the long axis of the body. Hence, the longitudinal axis of the heart (center of the base to the apex) forms an obtuse angle with the long axis of the body. These details are presented because in previous reports descriptions and measurement were given for a heart held with the long axis vertical.

The following measurements were made: maximum and minimum diameters of the coronary orifice; maximum height of the thebesian valve (from attached to free edge); and width of the eustachian

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ridge in the vicinity of the orifice of the coronary sinus. These measurements have relative value only, since the hearts had been preserved in formalin, which produces significant shrinkage. In the living patients, the values undoubtedly are greater. Other observations included heart weight and objective evidence of congestive failure: dilatation of the heart, flattening of the columnae carnae, ascites, pleural effusion and passive hyperemia of liver, lungs and spleen.

The maximum diameter of the orifice of the coronary sinus was obtained by inserting gently a tapered glass tube and measuring the diameter with a vernier caliper to the nearest millimeter. The minimum diameter was that of the orifice not covered by the thebesian valve. Thus if the thebesian valve was a large simple fold, and covered the entire orifice, the minimum diameter was considered to be zero, while the maximum diameter was perhaps 6 mm., since it admitted such a probe when the free edge of the valve was lifted anteriorly (ventrad).

As each specimen was examined, the ease of catheterization was estimated, taking into account the obstruction offered by the eustachian ridge and the thebesian valve, and the diameters (maximum and minimum) of the orifice of the coronary sinus.

**Observations**

A comparison of the age, sex and color distribution of the subjects from whom this series of 150 hearts were obtained with a previous study of 2000 consecutive autopsies indicated that the hearts studied are representative of the adult autopsy population encountered at the Institute of Pathology. Seventy-seven per cent were white, and 23 per cent Negro; 61 per cent males, 39 per cent females; the ages ranged from 24 to 84 years, with 67 per cent of the cases between 50 and 79 years of age. The incidence of congestive heart failure was also similar—24 per cent. The slight difference between the previous and present series is due to the exclusion of children in the latter.

**Location of the Orifice of the Coronary Sinus.**

The orifice of the coronary sinus with its valve lies directly below the medial extremity of the eustachian valve, and in the space between

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**Fig. 1.** Heart in situ. The anterior wall of the chest, right atrium and right ventricle were removed without disturbing the position of the heart. Note that the orifice of the coronary sinus, partly covered by a semilunar membrane (T, thebesian valve), is situated to the left and below the medial extremity of the eustachian valve, E. On the right, the catheter tip has entered the orifice of the coronary sinus and is directed dorsad. F.O., fossa ovalis; SVC and IVC, superior and inferior vena cava, respectively.
the latter and the rim of the right atrioventricular ring. This saccular space or depression has been called the appendix auricularis posterior of His, or the subeustachian sinus of Keith. In 1 case, however, there were two orifices of the coronary sinus: one was dimin-

<table>
<thead>
<tr>
<th>TABLE 1.—Variations of the Thebesian Valve (150 Cases)</th>
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<tbody>
<tr>
<td>Absent ................................................................ 22 14.7</td>
</tr>
<tr>
<td>Thebesian valve absent ........................................ 12</td>
</tr>
<tr>
<td>Both thebesian and eustachian valves absent ............. 10</td>
</tr>
<tr>
<td>Small Crescentic Membrane ................................... 57 38.0</td>
</tr>
<tr>
<td>Simple nonfenestrated ......................................... 47</td>
</tr>
<tr>
<td>Simple nonfenestrated with strands, threads .............. 5</td>
</tr>
<tr>
<td>Simple fenestrated ............................................. 3</td>
</tr>
<tr>
<td>Double crescentic ............................................... 2</td>
</tr>
<tr>
<td>Large Membrane ................................................ 46 30.7</td>
</tr>
<tr>
<td>Nonfenestrated .................................................. 34</td>
</tr>
<tr>
<td>Nonfenestrated with strands .................................. 1</td>
</tr>
<tr>
<td>Fenestrated ...................................................... 10</td>
</tr>
<tr>
<td>Circumferential fenestrations only ........................ 1</td>
</tr>
<tr>
<td>Bar, Broad Fibrous Bands, with Strands ................. 8 5.3</td>
</tr>
<tr>
<td>Transverse bar .................................................. 5</td>
</tr>
<tr>
<td>Vertical bar ...................................................... 2</td>
</tr>
<tr>
<td>Oblique bar ........................................................ 1</td>
</tr>
<tr>
<td>Threads, Strands, Networks .................................. 8 5.3</td>
</tr>
<tr>
<td>Strands ............................................................ 7</td>
</tr>
<tr>
<td>Network ............................................................. 1</td>
</tr>
<tr>
<td>Common Eustachian and Thebesian Valves ................. 9 6.0</td>
</tr>
<tr>
<td>Thebesian crescentic ........................................... 3</td>
</tr>
<tr>
<td>Thebesian semilunar, nonfenestrated ....................... 2</td>
</tr>
<tr>
<td>Thebesian semilunar, fenestrated ........................... 1</td>
</tr>
<tr>
<td>Thebesian network (with Chiari, 2) ......................... 3</td>
</tr>
</tbody>
</table>

in the heart of a patient in whom a Beck aorta–coronary sinus anastomosis was made because of severe obliterator coronary arteriosclerosis. In this particular case, this anomaly had clinical significance, since its patency constituted an aortic–left atrial communication, and precluded the maximum benefit of the operation.

Variations of the Thebesian Valve. The structure of the thebesian valve varies anatomically more than that of the eustachian valve, but may be readily classified into six anatomic groups (table 1). Our classification is modified from that used by Wright, Anson and Cleveland, and lends itself more readily in evaluating the feasibility of catheterization than the more detailed classification of Yater. In later observations on the hearts of several hundred routine autopsies, the thebesian valves were of similar types.

(1) The thebesian valve was absent in 14.7 per cent (22 cases) (fig. 3). The coronary sinus communicated directly with the right atrial cavity. In 10 of the 22 cases, the eustachian valve was also absent.

(2) In 38 per cent (57 cases), the thebesian valve consisted of a narrow rim, ridge or membrane, attached to the right and inferior region of the orifice of the coronary sinus (fig. 4). The valve was crescentic, and its free edge was concave, anterior, and directed cephalad. The height of the valve (from free to attached edge) averaged 2.6 mm., with a range of 1 to 5 mm. In each instance the valve covered less than half of the orifice of the coronary sinus, and certainly could not have prevented the regurgitation of blood from the atrium into the coronary sinus. By the same token, in these cases, catheterization of the coronary sinus would be feasible. In 3 cases of this group, there were fenestrations, usually multiple, varying in shape from circular to oval, and with diameter from 0.5 to 2 mm. In 5 cases there were single or multiple fine strands or threads in addition to the crescentic fold. These threads ran horizontally, and were attached to the superior (cephalad) region of the coronary orifice. In 2 cases there was a double crescentic fold in the right inferior region of the coronary
Fig. 2. A-10158. Unusual heart with two orifices of the coronary venous system; one in the right atrium (RA) and the other in the posterior wall of the left atrium (LA) just above the mitral ring. Note that the eustachian ridge is absent.

Fig. 3. A—10036. Thebesian valve is completely absent. The diameter of the orifice of the coronary sinus measured 9 mm.

Fig. 4. A—11018. Thebesian valve is a narrow crescent, measuring 2 mm. in maximum depth.
Fig. 5. A—11019. Thebesian valve is a large membrane (9 mm. in depth) with large fenestrations at the free margin. The maximum diameter of the coronary orifice was 7 mm.

Fig. 6. A—9800. Thebesian valve is a large membrane with circumferential perforations, and covers the orifice of the coronary sinus completely.

Fig. 7. A—10075. Thebesian valve is a complex membrane with multiple fenestrations and strands. The maximum diameter of the coronary orifice was 3 mm.
orifice. There was a common origin at the right rim of the orifice, and two insertions in the lower left rim (10 o'clock, and 3 and 5 o'clock respectively).

3. In 30.7 per cent (46 cases), the thebesian valve was large, and also consisted of a broad, thin, transparent membrane, forming a virtually complete cover for the coronary orifice (figs. 5 to 7). The attached edge also was in the right inferior region of the coronary orifice, and the free edge was directed anteriorly, cephalad and toward the left. In this group, the thebesian valve could function as a true valve. The height of the valve averaged 7.1 mm. with a range of 5 to 12 mm. In 10 cases there were single or multiple fenestrations scattered throughout the membrane. The fenestrations usually were less than 2 mm. in diameter. In 1 unusual case, the fenestrations were situated around the total circumference of the valve (fig. 6). Because the thebesian valve in these cases covered the coronary orifice, catheterization would have been extremely difficult. However, if the catheter made an oblique angle, and if the thebesian valve were distended maximally into the atrium, the orifice might conceivably be negotiated. The maximum orifice in these circumstances has an average diameter of 8.6 mm.

4. In 8 cases (5.3 per cent), the thebesian valve was represented by a thin fibrous bar across the coronary orifice. Usually the bar was transversely oriented, measured 3 to 5 mm. in width, and was also accompanied by several thin strands and threads (fig. 8).

5. In 8 cases (5.3 per cent), the thebesian valve consisted of fine strands only; in 1 case, the strands formed a network in the orifice of the coronary sinus (figs. 9, 10). In 1 case, sev-

Fig. 8. A—9995. Thebesian valve consists of a transverse bar (4 mm. in width) and several strands.

Fig. 9. A—9990. Thebesian valve consists of strands which are continuous with the eustachian valve.

eral fine threads originated at the apex of a small triangular membrane in the inferior margin of the orifice of the sinus.

6. In 9 cases (6.0 per cent) there was a common valve for the caval and coronary sinus orifices (fig. 11). The thebesian valve was common with the eustachian valve. In 3 cases the thebesian valve was crescentic, in 3 semilunar, and in 3 cases the thebesian valve consisted of a delicate network. In 2 of the last 3 cases this comprised part of a Chiari's network.
Variations in the Diameter of the Orifice of the Coronary Sinus. There is a considerable range in the diameter of the orifice of the coronary sinus. The maximum diameter depends upon the presence and configuration of

the thebesian valve, and is related to the presence of diffuse cardiac hypertrophy and dilatation, and clinical congestive heart failure. The maximum diameter in those cases where the thebesian valve was absent had an average value of 11.1 mm., with a range of 7 to 19 mm.; the average diameter in the group with small crescentic folds was 9.9 mm., with range of 7 to 15; and the mean maximum diameter of the group with large semilunar folds was 8.6 mm. with a range of 5 to 13 mm. Thus, the mean maximum diameter varied inversely with the extent of the thebesian valve.

In table 2, the relationship between the presence of congestive heart failure and the size of the maximum diameter is illustrated.

<table>
<thead>
<tr>
<th>Number of Cases</th>
<th>Non-failure</th>
<th>Failure</th>
<th>Total Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Heart (Gm.)</td>
<td>303</td>
<td>568</td>
<td>150</td>
</tr>
<tr>
<td>Range of Heart Weight (Gm.)</td>
<td>180-730</td>
<td>240-1040</td>
<td>180-1040</td>
</tr>
<tr>
<td>Mean Maximum Diameter of Orifice of Coronary Sinus (mm.)</td>
<td>9.27</td>
<td>10.7</td>
<td>9.63</td>
</tr>
<tr>
<td>S. D. of Mean Diameter of C. S.</td>
<td>2.23</td>
<td>2.33</td>
<td>2.2</td>
</tr>
<tr>
<td>Range of Mean Diameter of C. S.</td>
<td>3-15</td>
<td>6-19</td>
<td>3-19</td>
</tr>
</tbody>
</table>

The hearts which had failed tended to have larger coronary orifices. This would imply that the dilatation of the heart, including the right atrium, which occurs in congestive heart failure was accompanied by a dilatation of the coronary sinus orifice. However, another, and probably more important, factor must be considered: the relation of the heart weight to the size of the coronary orifice. In table 3, it is clearly shown that a larger per cent of hearts 400 Gm. or more in weight failed than those
less than 400 Gm. The mean maximum diameter of the orifice of the coronary sinus is greater in the hearts above 400 Gm. Furthermore, in the group with hearts over 400 Gm., the mean diameter was greater in those who failed than those who did not: 10.6 and 9.9 respectively. Although the differences are small, we believe that there is a trend for the larger hearts, and hence those which are more likely to fail, to have larger orifices of the coronary sinus.

Variations of the Eustachian Valve. The eustachian valve (valve of the inferior vena cava) varies considerably also. The eustachian valve is usually a muscular and membranous fold in the right atrium which arises in the region of the lower extremity of the crista terminalis, and extends inferomedially to a point below the fossa ovalis, where fusion occurs with the muscular ridge of the sinus septum.

The valve of the inferior vena cava showed the same types of variations described by others 8, 9: absent, fibrous ridge, simple intact or fenestrated membrane, cobweb network of threads, Chiari's network, and common eustachian and thebesian valves. In 75 per cent of the cases the eustachian valve was a simple valve whose depth was less than 10 mm. 8 In the present study, we have been more interested in the structure of the medial extremity of the eustachian valve than in the variations of the valve leaflet, since the former is more important in determining the feasibility of catheterizing the coronary sinus. We recall that the orifice of the coronary sinus is located directly below and medial to this portion of the valve of the inferior vena cava. In the subsequent discussion we shall refer to this portion as the eustachian ridge.

In 32 cases (21.3 per cent) the eustachian valve was absent and the eustachian ridge was smooth and nonprominent. In 10 of the 32 cases the thebesian valve was also absent. The approach to the orifice of the coronary sinus in these cases would be unimpeded.

In 71 cases (47.3 per cent) the eustachian ridge was firm, fibrous, and measured in depth from 1 to 6 mm., with an average of 2.4 mm. In 38 cases (25.4 per cent) the ridge was membranous, and tended to be wider, with a mean of 3.5 mm., and a range of 1 to 8 mm. In 8 cases, there was a large fenestrated membrane in this region, overhanging the coronary ostium. The maximum width in the region of the coronary sinus was 21 mm. Since the interstices measure 1 to 2 mm., a cardiac catheter conceivably might become entangled therein. In 1 case there was an extensive network continuous with a large fenestrated fold of the eustachian valve, thebesian valve and Chiari's network.

Chiari's Network. In 5 cases, a Chiari's network was present, fulfilling the following requirements: a network of fine or coarse fibers in the right atrium; its attachments extending from the interatrial septum or the upper portion of the crista terminalis to the thebesian and the eustachian valves or to the region of the orifices of the coronary sinus and the inferior vena cava. In 2 cases, both the thebesian and eustachian valves were absent. In 2 cases the thebesian valve was a large network and continuous with a similarly fenestrated eustachian membrane. Each connected to the Chiari's network. In 1 case the thebesian valve was crescentic and the eustachian a narrow membrane (3 mm. deep). In none of these cases were there thrombi lodged in the fibers of the network. 11

Discussion

Relation of Anatomic Variations of Venous Valves of Right Atrium to Ease of Catheterization of Coronary Sinus in Man

Only 25 per cent of deliberate attempts to catheterize the coronary sinus in man are successful 7 while inadvertent catheterization of the coronary sinus may occur in 16 per cent of routine consecutive right heart catheterization. 15 The failures have been ascribed to the presence of an elevated eustachian ridge present in man, but not in dogs. 6, 7 Our present study however clarifies some of the above difficulties, by focusing attention on the variations of both the eustachian ridge and thebesian valves. The latter we believe are more important, since the eustachian ridge is broad and overhangs the orifice of the coronary sinus in less than 25 per cent of the cases. In 75 per cent of all cases, the eustachian ridge measures
less than 10 mm. in height. The technic by which the tip of the catheter can be maneuvered under fluoroscopic control to a position medial (left) to the medial extremity of the eustachian valve and the orifice of the coro-
nary sinus has been developed by Goodale and associates.1, 2

Upon reviewing the anatomic features of the eustachian ridge, it becomes evident that a high per cent of failures must be attributed to other causes, namely, variations of the thebesian valve. In our series, we believe that even though the tip of a catheter could be placed (under fluoroscopic control) into the region of the orifice of the coronary sinus, intubation would have been impossible in 37 cases (24.7 per cent) because the coronary orifice was completely covered by a membrane. On the other hand, intubation definitely would have been successful in those cases where the thebesian valve was entirely absent (14.7 per cent), or small, crescentic and covering less than half of the coronary orifice (38 per cent), a total of 52.7 per cent. In the remainder (22.6 per cent), successful catheterization would have required dextrous manipulation to enter obliquely a small orifice in the cases with large membranes or bars and strands, and to avoid becoming entangled in networks. Cath-
eterization of the last group would probably be purely fortuitous. Since this study was completed, Levine and Goodale6 have reported success in catheterizing the human coronary venous system in 17 of 30 patients (56.7 per cent). They attribute their failures to prominence of the eustachian ridge, and state that the thebesian valve has never appeared to interfere with coronary sinus intubation in their patients. However, in about one-third of all human hearts, the coronary sinus is covered by a large membrane, as shown by the present study, and the observations of Wright, Anson and Cleveland.8

Dispersing or Mixing Effect of the Thebesian Valve

The variations of the thebesian valve may explain the great variations in oxygen content in the blood obtained at different levels in the right atrium and right ventricle. Coronary sinus blood has a low oxygen content, from 3 to 7 volumes per cent2 while mixed caval blood contains normally 12 to 15 volumes per cent. If the poorly saturated coronary venous blood enters the right atrium in a stream, as it would do in the complete absence of a thebesian valve, poor mixing in the right atrium is likely, with streamline flow into the right ventricle. On the other hand, if a large fold is present, the coronary venous blood would be deflected to the left, behaving like a jet directed against a single cusp vane or curved fixed vane (fig. 12).13 If fenestrations are present, the blood would be sprayed into the right atrium just above the tricuspid valve (fig. 12). In the cases with transverse or vertical bars, the mixing of blood would resemble a jet impinging on a flat plate (fig. 12). Since coronary venous flow is greatest during ventricular systole the spraying action would be greatest at this time. The mean velocity of coronary venous blood passing through the orifice of the coronary sinus can be roughly estimated to be about 3 cm. per second, if one assumes (1) the cardiac output is 5 liters per minute; (2) coronary arterial flow is 5 per cent cardiac output; (3) the coronary sinus carries 60 per cent of the total coronary flow; (4) the

Fig. 12. Effect of variations of thebesian valve on mixing on coronary venous blood. Discussed in text.
mean diameter of the coronary sinus is 10 mm. (area 0.7854 square cm). The differences in pressure in the right atrium and the coronary sinus have not been considered in the above calculations. The velocity would likewise be altered, increasing particularly where the orifice is significantly smaller than the sinus (as in the case of a membrane partially covering the coronary sinus).

**Summary**

The anatomic variations of the orifice of the coronary sinus were studied in 150 formalin preserved hearts. There were six main types of variation of the valve of the coronary sinus (thebesian valve): (1) absent in 14.7 per cent, (2) small and crescentic in 38 per cent, (3) large and covering the entire orifice of the coronary sinus in 30.7 per cent, (4) bars and bands in 5.3 per cent, (5) threads and networks in 5.3 per cent, and (6) common eustachian and thebesian valves in 6.0 per cent. In one case, the coronary vein emptied into both atria by way of separate orifices. A true Chiari's network was found in 5 hearts.

The mean maximum diameter of the orifice of the coronary sinus was 9.6 mm., with standard deviation 2.2 mm. The size of the orifice was definitely related to the configuration of the thebesian valve, heart weight and the presence of congestive heart failure.

The anatomic variations of the orifice of the coronary sinus were considered to be important from the standpoint of catheterization, mixing of coronary venous blood, and, in one case with two orifices, from the standpoint of benefit from the Beck operation (aorta–coronary sinus anastomosis).

The difficulties encountered in the catheterization of the human coronary sinus are probably due to obstruction of the orifice by large membranes, bars and networks in 47.3 per cent of the cases and by a broad overhanging eustachian ridge in less than 25 per cent of the cases. Considering the anatomic variations of the venous valves of the right atrium in this series, catheterization of the human coronary sinus should be possible in a maximum of 75 per cent of the cases and very unlikely in the remainder.

**REFERENCES**


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