

Regional Venous Drainage of the Human Heart*

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Blood samples obtained from the coronary sinus in man contain venous blood draining from left ventricular myocardium. It is believed by many investigators that coronary sinus blood in man is composed almost entirely of left ventricular efflux. That this is true in the canine heart is firmly established (Rayford *et al.*, 1959). This principle has been widely accepted in the many studies which have been carried out using highly diffusible indicators to measure coronary blood flow, in which it is presumed that left ventricular flow per unit muscle mass is being measured (Gorlin, 1960).

The present study was designed to test the hypothesis that coronary sinus blood is composed primarily of left ventricular efflux. The methods employed are those of detailed analysis of the fine ramifications of the coronary venous system to determine in semiquantitative fashion the number of small vessels contributing to venous drainage from each segment of the myocardium.

METHODS

Nineteen human hearts were obtained at necropsy for these studies. Patients ranged in age from 19 to 75, with a mean of 46 years. There were 11 men and 8 women in the series. Death was due to neoplasm in 12, carbon monoxide poisoning in 3, trauma in 2, and to pneumonia and cerebral vascular accident in one case each. All hearts were normal on gross inspection except for one which showed uraemic pericarditis. This case was included because the anatomical findings were identical to those of other specimens.

Chambers and vessels of each heart were flushed with physiological saline, then injected with neoprene latex‡. This injection medium was chosen because it enables vessel dimensions to be well preserved without shrinkage (James, 1961; Smith and Henry, 1945). Since the

vessel casts thus formed were flexible, and very small vessels could be displaced from their original location, care was taken in handling and inspecting the specimens. The right heart chambers and coronary veins were injected through a plastic cannula sutured into the superior vena cava, following ligation of the pulmonary artery and inferior vena cava. Left heart chambers and coronary arteries were injected through a plastic cannula inserted into a pulmonary vein, following ligation of the aorta and non-perfused veins. Different colours of latex were employed for each side of the heart. In one case only, there was some mixing of colours due to leakage through a patent foramen ovale. Injection pressures were uniformly set at 30 mm. Hg, except in two instances in which the left chambers were injected at 100 mm. Hg. Pressure was maintained for 15 minutes following injection, the cannulae tied, and the hearts immersed in 10 per cent hydrochloric acid. After 48 hours digestion was complete and the remaining latex cast was removed from the acid bath and washed repeatedly. The finished specimen comprised the two solidly cast ventricles and the coronary vasculature (Fig. 1). This procedure was found to produce accurate filling of the coronary veins down to a level of 0.5 mm. diameter (Fig. 2).

For each specimen all of the 1.0 mm. diameter branches of the coronary venous system were enumerated and identified as draining left ventricular, right ventricular, intraventricular septal, or atrial myocardium. This type of analysis gives a semiquantitative estimate of the cross-sectional area of the small venous drainage bed for the human heart. The estimate does not include any small vessels such as Thebesian veins which do not drain directly into a larger trunk of the venous tree.

Measurements were also made of the size of the major trunks of the coronary sinus at their point of entry into that vessel. Cross-sectional area was computed from the formula for the area of an ellipse ($\text{area} = \pi ab$), setting the measured maximum and minimum transverse diameters of the vessels equal to a and b .

RESULTS

The venous drainage system of the heart is shown diagrammatically in Fig. 3. The major vessels depicted as draining into the coronary sinus were

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‡ Neoprene Latex No. 572, obtained from BB Chemical Ltd., Leicester.

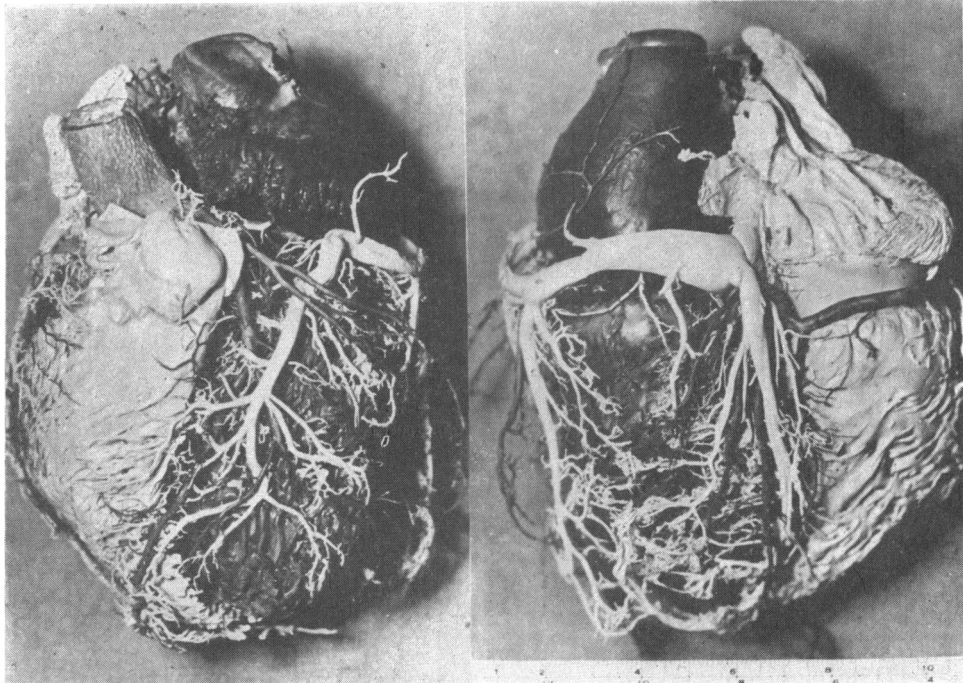


FIG. 1.—Example of a finished heart cast. Anterior view of the specimen on the left, and posterior view on the right. The right ventricle and coronary veins are cast in a light colour, and the left ventricle and coronary arteries are cast in dark colour.

invariably present with the following exceptions. (1) The minimal cardiac vein, a small branch of approximately 1.0 mm.² cross-sectional area, which drains the upper posterior right ventricle into the coronary sinus, was absent in 8 of 19 specimens. (2) The posterior cardiac vein might consist of one large vessel or of two or three smaller ones. (3) The anterior cardiac veins were quite variable in number and origin. Most typically all branches drained

into one orifice or two orifices situated close together just above the atrioventricular groove on the right antero-lateral aspect of the heart (Fig. 4). The only constant branch was the posterior vein of the right ventricle, which drains the postero-lateral aspect of the right ventricle.

Cross-sectional areas of the major venous trunks and the number of 1.0 mm. diameter radicles are presented in Table I. Although the total number of vessels draining each major segment of the ventricle was a reasonably consistent figure (Table II). The figures in Table II agree closely with published

TABLE I
DIMENSIONS OF MAJOR CORONARY VEINS
AND ENUMERATION OF
SMALL VESSELS DRAINING INTO EACH

	Mean cross-sectional area and range (mm. ²)	Mean no. of 1.0 mm. ² vessels draining into each, and range
<i>Coronary sinus</i>		
Middle cardiac vein	13 (6-25)	26 (16-50)
Great cardiac vein	15 (7-37)	21 (12-31)
Left marginal vein	6 (2-13)	8 (3-18)
Posterior cardiac vein*	5 (1-15)	5 (1-12)
Oblique vein of left atrium	—	1
Minimal cardiac vein (inconstant)	—	1
<i>Right atrium</i>		
Anterior cardiac veins	—	14 (7-26)

* Where several vessels were present the largest was analysed.

TABLE II
ENUMERATION OF SMALL CORONARY VEINS
ACCORDING TO VENTRICULAR SITE OF ORIGIN

Total No. of 1.0 mm. diameter radicles draining ventricular muscle	Per cent of total draining left ventricular free wall	Per cent of total draining intraventricular septum	Per cent of total draining right ventricle
74 ± 18* (range 51-129)	46 ± 4 (range 37-57)	24 ± 4 (range 18-34)	30 ± 5 (range 24-36)

* Mean ± standard deviation.

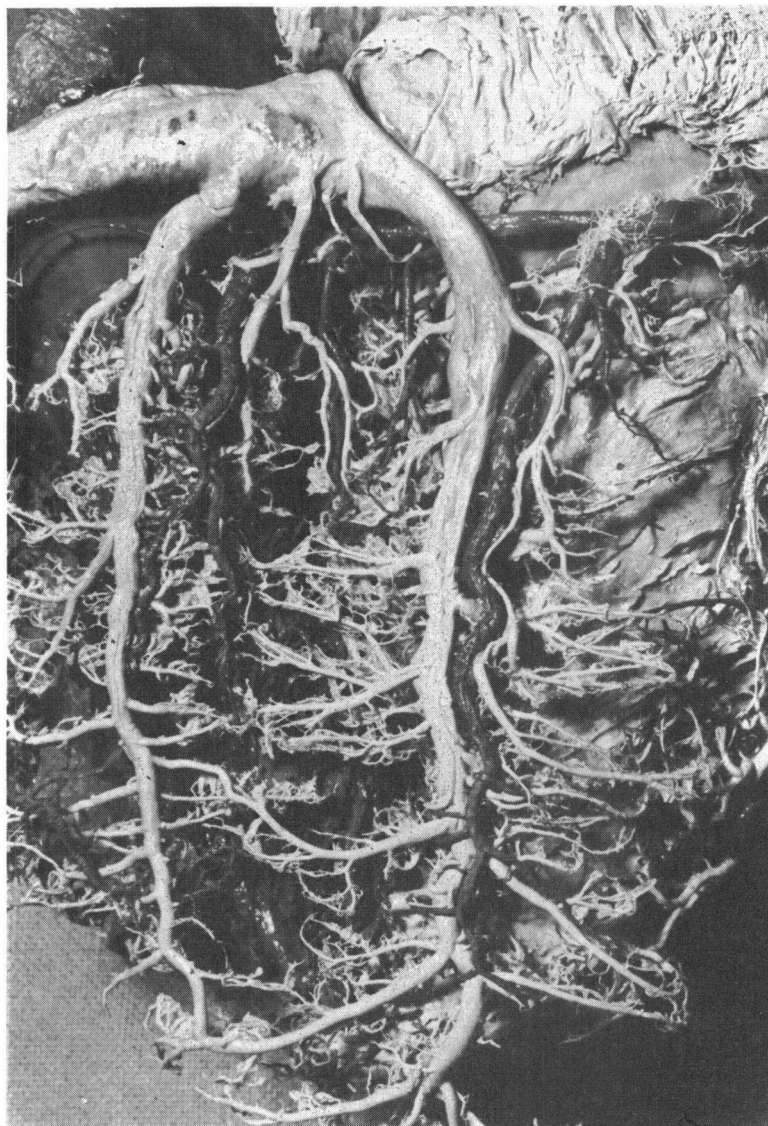


FIG. 2.—A close-up view of the posterior aspect of a specimen showing casting of the fine vessels of the heart. Veins are light-coloured, and arteries are dark-coloured. The large bulbous structure at the top left of the photograph is the coronary sinus. The two large vessels on the left and in the centre of the photograph are the posterior cardiac vein and the middle cardiac vein.

data giving relative weights of left ventricular free wall, right ventricle, and intraventricular septum (Fulton, Hutchinson, and Jones, 1952). This fact agrees with the concept that venous vascularity is a function of muscle mass.

The site of origin of vessels draining into coronary sinus is summarized in Table III. Again the total number of radicles was quite variable, but the percentage of radicles draining from each segment

of myocardium into coronary sinus did not vary over 20 per cent. Since the intraventricular septum functions primarily as part of the left ventricle, it can be surmised that the vast majority of radicles draining into the coronary sinus are of left ventricular origin ($83 \pm 4\%$). Most blood specimens taken from the coronary sinus are sampled from a site distal to the origin of the middle cardiac vein. Excluding the drainage of this vessel, $86 \pm 5\%$ of

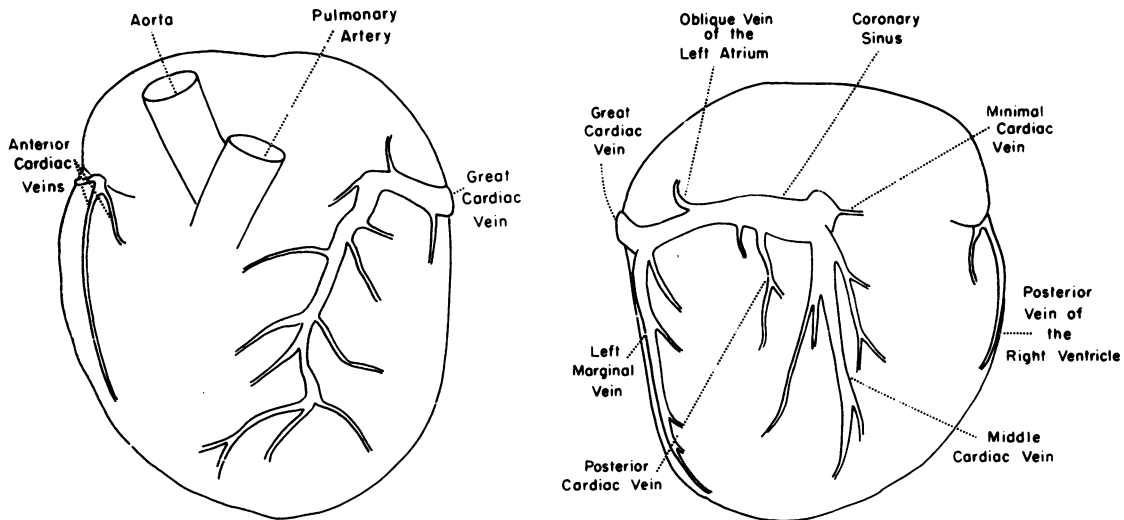


FIG. 3.—Schematic representation of the venous system of the heart, based on the configuration of the specimen shown in Fig. 1. This specimen had a very small posterior cardiac vein, and a diminutive minimal cardiac vein.

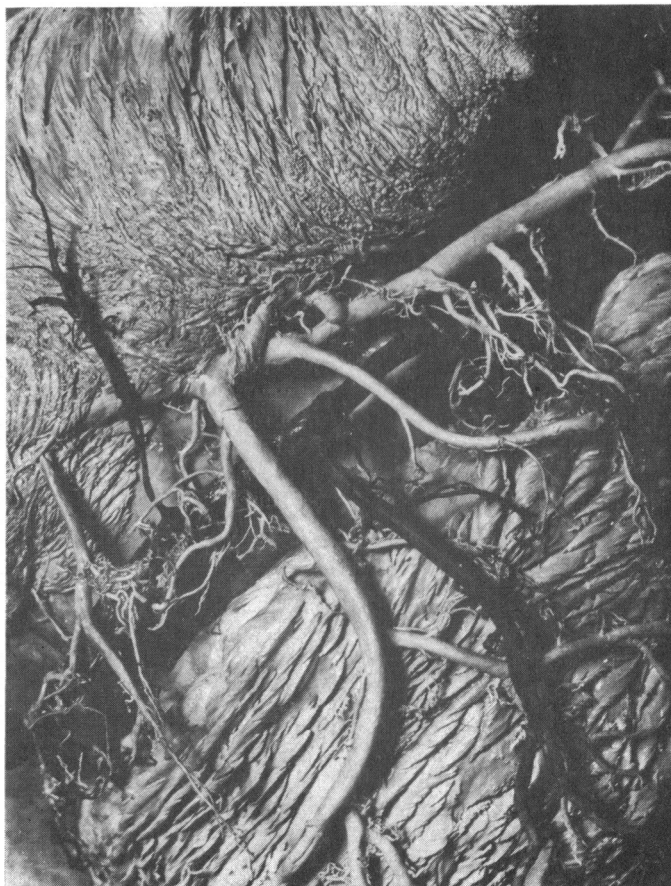


FIG. 4.—Typical arrangement of the entry site of the anterior cardiac veins (cast in a light colour) into the right atrium. The antero-lateral aspect of the right side of the heart is shown. The atrioventricular groove runs diagonally across the photograph with the atrium above and the right ventricle below it. The vessel cast in a dark colour is the right coronary artery.

small radicles were calculated to arise from left ventricular free wall or intraventricular septum.

It is also of interest to note what percentage of the small venous drainage bed of the left ventricle drains into the coronary sinus. In every specimen all small branches draining the left ventricular free wall emptied into the coronary sinus as did $91 \pm 5\%$ of the intraventricular septal drainage. The calculated combined drainage of these two beds was $96 \pm 2\%$.

TABLE III
ENUMERATION OF SMALL CORONARY VEINS
DRAINING INTO CORONARY SINUS
ACCORDING TO VENTRICULAR SITE OF ORIGIN

Total No. of 1.0 mm. diameter radicles draining into coronary sinus	Per cent of total draining left ventricular free wall	Per cent of total draining intraventricular septum	Per cent of total draining right ventricle
$65 \pm 15^*$ (range 47-111)	52 ± 5 (range 46-63)	31 ± 5 (range 17-36)	17 ± 4 (range 6-19)

* Mean \pm standard deviation.

COMMENTS

This analysis suggests that coronary sinus drainage of the human heart is comprised primarily of efflux from the left ventricular myocardium. In addition, the left ventricular myocardium is drained almost exclusively by the coronary sinus. Relative flow through these various radicles under dynamic conditions may, of course, differ from the observed relative cross-sectional area of the small venous system. For example, it has been demonstrated in the dog heart that relative magnitude of flow from coronary sinus and extracoronary sinus sources may be altered to some extent by haemodynamic and pharmacological interventions (Lafontant, Feinberg, and Katz, 1962). Nor does the method described take into account flow from very small venous channels such as Thebesian vessels, though

this is probably only a small fraction of left ventricular venous efflux (Lendrum, Kondo, and Katz, 1945). The study does, however, provide a clear anatomical basis for use of coronary sinus samples in studies of left ventricular coronary flow and metabolism.

SUMMARY

The coronary sinus of the human heart drains 96 per cent of the small veins arising from left ventricular and intraventricular septal myocardium. Furthermore, only 17 per cent of the small veins draining into the coronary sinus arise outside the left ventricular system. These findings offer support for the use of coronary sinus blood samples as being highly representative of left ventricular efflux in studies of human patients.

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