AN X-RAY MICROSCOPIC STUDY OF THE BLOOD SUPPLY TO THE VALVES OF THE HUMAN HEART

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Descriptions of the presence of blood vessels in the valves of human hearts vary. Using routine histological, injection, and clearing techniques, the majority of authors have described vessels in the attached portion of the cusp, but differ on the incidence of this observation and its relation to completely normal histological valve structure. Thus Gross (1921) demonstrated blood vessels in 6 per cent of normal mitral valves from birth until the ninth decade of life, and reported that this finding possibly had some relation to the incidence of endocarditis in the vascularized valves. This view was supported by several authors (Kugel and Gross, 1926; Kugel, 1928; Ritter, Gross, and Kugel, 1928; Gross and Kugel, 1931). Gross and Friedberg (1936a, b) thought that any vascularized heart valve was probably abnormal.

In a critical review of the observations of previous authors and from an examination of human and animal heart valves, Gross (1937) thought that the majority of human heart valves were avascular, and emphasized the need for careful interpretation of any vascularity and the presence of previous histological damage. Winternitz, Thomas, and LeCompte (1938) examined normal and diseased valves by injection and clearing techniques, and reported vessels in the normal cusps of atrioventricular valves, which had an endocardial origin.

Harper (1945) investigated human and rabbit heart valves by injection and vital staining techniques; he showed that human heart valves were “largely avascular”, that vessels in diseased valves were of inflammatory origin, and that new blood vessel formation could be induced in rabbits after the injection of aleuronate.

The present work gives an account of the blood supply to the valves of the human heart, using the Coslett Nixon X-ray projection microscope. This technique gives an opportunity for examining small arterioles and capillary beds without histological preparation in contrast to the routine histological, injection, and clearing techniques of previous investigations.

MATERIAL AND METHODS

Fifty normal human hearts were obtained within 12 hours of death and examined in equally distributed 5-year groups between the 15th and 80th years. After perfusion with saline at 37° C. for 2 hours, the hearts were injected with micropaque (particulate diameter 0.5 μ or less) through the ascending aorta, at manometrically controlled physiological pressures.

X-ray projection micrographs were recorded on Ilford Contrasty Plates with an exposure time of 10 minutes. The microscope was operated at 15 kV and 40 microamperes, a copper target providing the x radiation.

All the valves were examined histologically after injection and radiography to exclude the presence of previous disease, even in the presence of a negative history of cardiac involvement.
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RESULTS

It was clear from the micrographs that the arterial supply to the atrio-ventricular, aortic, and pulmonary valves originated from terminal atrial and ventricular branches of the coronary arteries.

Atrio-ventricular Valves. (a) Tricuspid Valve. Of the 50 tricuspid valves examined, only 8 were shown to have vessels in their attached margin, and came from the age-group of 35–50 years. The picture was the same in these 8 cases: arterioles 40–80 \( \mu \) in diameter lay in the attached margin of all the cusps and divided to distribute a capillary network in the proximal 3 mm. of the cusp (Fig. 1). In this group no vessels could be demonstrated arising from the endocardial surface or along the chordæ tendineæ from the papillary muscles. It was found that when a cusp was vascularized, the adjacent cusps showed equal vascularity.

(b) Mitral Valve. Of the 50 mitral valves examined, 5 were shown to have vessels in their attached margins, and all these specimens came from hearts in which the tricuspid valve was vascularized. Both cusps were equally supplied, the picture consisting of arterioles, 30–60 \( \mu \) in diameter, which distributed a capillary plexus to the proximal 2 mm. of the cusps (Fig. 2). No vessels were found in the chordæ tendineæ.

(c) Aortic Valve. In this group, 12 of the 50 aortic valves examined were shown to have a blood supply, all the specimens coming from the 20–40 year age-group. In each case arterioles, 30–40 \( \mu \) in diameter, lay at the attached margin and distributed a capillary network to the proximal 3 mm. of the valve cusps (Fig. 3). The distribution was equal in all the cusps.

(d) Pulmonary Valve. Twelve specimens had vessels in the cusps of the pulmonary valve, and came from the same hearts in which the aortic valve was vascularized. In each case arterioles, 20–30 \( \mu \) in diameter, lay at the attached margin of the cusps and divided to supply the proximal 3 mm. of the cusp with a capillary plexus (Fig. 4).

(e) Papillary Muscles. In all the specimens examined the papillary muscles were vascularized.

FIG. 1.—Micrograph* of the septal cusp of the tricuspid valve from a subject aged 35 years. Note the arterioles (a) at the attachment of the cusp (b) dividing to distribute a capillary plexus (p) to the proximal part of the cusp (P). Distal part of the cusp (D) is avascular. (\( \times 47 \)).

FIG. 2.—Micrograph of the anterior cusp of the mitral valve from a subject aged 40 years. Note the arterioles (a) at the attachment of the cusp (b) dividing to distribute a capillary plexus (p) to the proximal part of the cusp (P). Distal part (D) is avascular. (\( \times 55 \)).

* All micrographs are of full thickness specimens. Long axis of valve cusp and papillary muscle (1–a).
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Fig. 3.—Micrograph of the aortic valve from a subject aged 25 years. Note the arterioles (a) at the attachment of the cusp (b) dividing to distribute a capillary plexus (p) to the proximal part of the cusp (P). Distal part (D) is avascular. (×70.)

Fig. 4.—Micrograph of the pulmonary valve from a subject aged 30 years. Note the arterioles (a) at the attachment of the cusp (b) dividing to supply a capillary plexus (p) to the proximal part of the cusp (P). Distal part (D) is avascular. (×70.)

Adjacent to the attachment of the chordae tendineae to the papillary muscles, arterioles, 60–80 μ in diameter, lay along the long axis of the papillary muscle in closely assembled parallel groups. On reaching the apex of the papillary muscle, the arterioles looped back on their course in a “hairpin” manner, an occasional vessel being distributed from the convexity of the loop for a short distance. This pattern was unchanged in the specimens showing vessels in the heart valves (Fig. 5).

DISCUSSION

Staining methods are particularly suitable for investigating adaptive changes in vascular patterns under varying conditions, giving a true picture of the actual physiological state of the circulation at that time. Injection methods, in contrast, present the vascular pattern at its maximum capacity, and are suitable for purely anatomical investigations. Consequently, with the technical advantages of x-ray microscopy, the blood supply to the valves was studied by this method.

On the other hand, techniques that require staining of red cells depend upon the uniform filling of the capillaries with red cells at the time of death, and failure to demonstrate vessels by Pickworth’s method (sodium nitroprusside and benzidine stain) may be due to lack of blood within the vessels. Demonstration of vessels by showing alkaline phosphatase in endothelial cells (Scharrer, 1950) does not allow the pattern of the vessels to be appreciated, in contrast to the routine x-ray micrograph.
The present study has shown that the atrio-ventricular, aortic, and pulmonary valves, may have blood vessels in their cusps.

As indicated by the x-ray microscope 16 per cent of the tricuspid valve cusps were vascularized, 10 per cent of the mitral, 24 per cent of the aortic, and 24 per cent of the pulmonary valve cusps.

The criterion for regarding an area as avascular was the repeated failure to introduce the injection medium into vessels when capillary beds were filled elsewhere in the same specimen under similar conditions.

In any interpretation of a valve cusp being vascularized care must be taken to ensure that there is no histological abnormality in the specimen. In this series the cusps that were reported as vascular came from hearts with a negative clinical history, and where there was no histological evidence of the various degrees of healing that may occur after valvular endocarditis.

The observation by Winternitz et al. (1938) that vessels may originate from the endocardial surface of the valve cusps was not confirmed.

In contrast to the estimate by Gross (1921) that 6 per cent of the cusps of mitral valves were vascularized, this series has shown that 10 per cent of mitral cusps possess blood vessels. The two figures are reasonably close, and it is suggested that the improved technique of x-ray microscopy may be demonstrating more vessels in contrast to the routine histological, injection, and clearing techniques used previously.

The "hairpin" pattern of the arterioles in the papillary muscles was characteristic. Though an occasional vessel arose from the convexity of the loop and approached the chordæ tendineæ for a short distance, no vessels could be demonstrated in the chordæ.

As indicated by the x-ray microscope there was no evidence of alteration in the pattern of the vessels in the cusps that were vascularized with age.

**SUMMARY**

The blood supply to the valves of the heart and great vessels was studied by the Coslett Nixon X-ray projection microscope.

Vascularization was found in 16 per cent of the cusps in the tricuspid valve, in 10 per cent of the mitral cusps, and in 24 per cent of the aortic and pulmonary cusps.

A characteristic arteriolar pattern, which was "hairpin" in nature, was described in the papillary muscles.

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**REFERENCES**


