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A study of the atrial arteries in man

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INTRODUCTION

Several techniques have been used to display the arterial supply of the atria (Gross, 1921; Spalteholtz, 1924; James & Burch, 1958; DiDio & Wakefield, 1972; Lienhard, 1972; Huu, Leroy & Tiercelin, 1973). These include:

(i) Coronary artery injection with coloured resin and subsequent tissue corrosion (Stern, Ranzenhofer & Liebow, 1954; James & Burch, 1958; Tompsett, 1970; Huu *et al.* 1973). This has the considerable disadvantage that the long slender vessels are easily broken.

(ii) Injection of the coronary arteries with coloured gelatin with subsequent dissection of the vessels (DiDio & Wakefield, 1972). This is technically difficult because of the small size of the vessels concerned.

(iii) Injection of contrast medium combined with stereoscopic X-ray studies (Gross, 1921; Schlesinger, 1938). This introduces the problem of superimposition of vessels.

(iv) Injection of the coronary arteries with coloured gelatin and subsequently clearing the tissues of the heart so that the vessels can be seen (Spalteholtz, 1924; Lienhard, 1972). This last technique was chosen for the present study. The major disadvantage of the method is the poor visual definition of vessels passing deep into the thicker parts of the myocardium, but this is not relevant to the thin atrial walls. The advantages include maintenance of the general anatomy of the heart, and good definition of even the smallest atrial arteries.

MATERIALS AND METHODS

Hearts from 40 male and female human cadavers were used, the majority of the patients having died from conditions unrelated to the heart. In two cases coronary thrombosis was found to have been the cause of death: the sites of thrombosis were obvious in the cleared hearts, but the atrial arteries were healthy. The age range of the patients was 11 to 92 years, the majority being in the fifth and sixth decades.

The hearts were obtained within 36 hours of death, particular care being taken to keep the atria intact. The aorta was cannulated and the coronary arteries perfused with 5 % formalin at a pressure of 100 cm of water. This flushed all the blood from the coronary arteries and also fixed the heart in standard anatomical position. The coronary arteries were then cannulated as close to their origin as possible. This was done by dissecting around the coronary arteries but leaving them attached to the aorta, and then passing an encircling thread around them. A flanged polythene cannula was then introduced into each coronary ostium and tied in place. Coloured gelatin was injected into the arteries, red into the right and yellow into the left. The gelatin was then fixed in 5 % formalin, and the hearts dehydrated in alcohol until complete dehydration was achieved in 100 % alcohol. Final clearing was carried out in methyl salicylate B.P. It was found that dehydration and clearing could be completed in 10 days.

Each specimen was then photographed both in monochrome and colour from five different aspects, showing in turn the antero-superior surface, the anterior surface a little from the right, the posterior surface from the right side, the left surface, and the diaphragmatic surface. Photography had to be carried out with the heart immersed in methyl salicylate because the clarity diminished once the heart was removed from the fluid. The coloured photographs afforded easy naked-eye definition of the regional supply of the respective coronary arteries. From these photographs and the original specimens, diagrams of each heart with its coronary vessels were made.

The hearts were drawn diagrammatically using a projection in which the heart was positioned with the right side uppermost and the left side below. The major epicardial, atrial and ventricular arteries were drawn onto this diagram in each case. Smaller arterial ramifications were omitted for clarity. With this limited series of hearts statistical analysis is impracticable, and so absolute numbers are used, with percentages given in brackets.

Throughout this description the sinu-atrial node is referred to as the S.A. node and the atrio-ventricular node as the A.V. node. The right coronary artery is referred to as the R.C.A. All atrial branches arising from the left coronary artery (L.C.A.) took origin from the circumflex branch. In this paper the latter is defined as commencing at the point where the main stem of the left coronary artery gives off the anterior inter-ventricular branch.

RESULTS

Despite considerable variation in origin and distribution of the atrial arteries, the hearts could be classified into six groups with reference to the arterial supply to the atria, S.A. and A.V. nodes (Table 1).

Group 1. (Fig. 1). There were 11 (27·5 %) hearts in this group. The S.A. and A.V. nodes were supplied by the R.C.A. The whole of the right atrium and a substantial part of the left atrium were supplied by the R.C.A. The left auricular appendage and the immediate surrounding area were supplied from the circumflex artery by a series of small branches. It is to be noted that the left auricular appendage was supplied in this way in all 40 hearts.

Group 2. (Fig. 2). There were 10 (25 %) hearts in this group. The S.A. and A.V. nodes were supplied by the R.C.A. Most of the right atrium and a part of the superior surface of the left atrium were also supplied by the R.C.A. The bulk of the left atrium was supplied by a relatively large branch of the circumflex artery. The consistent series of small vessels from the circumflex artery supplied the left auricular appendage.

Group 3. (Fig. 3). There were 7 (17·5 %) hearts in this group. The S.A. node was supplied by the circumflex artery and the A.V. node by the R.C.A. The S.A. nodal artery always supplied the crista terminalis region of the right atrium down as far as the inferior vena cava regardless of where this branch took origin. The rest of the right atrium was supplied by branches of the R.C.A. The left atrium was almost entirely supplied by branches of the circumflex artery.

Group 4. (Fig. 4). There were 5 (12·5 %) hearts in this group. The S.A. node and most of the right atrium were supplied by the R.C.A. The A.V. node, part of the right atrium adjoining this, and a substantial portion of the left atrium were supplied by the circumflex artery.

Table 1. *Summary of arterial blood supply to the atria*

Group	Number of hearts (total 40)	S.A. node supply	A.V. node supply	Predominant supply of R.A.	Predominant supply of L.A.
1	11 (27·5 %)	R.C.A.*	R.C.A.	R.C.A.	R.C.A.
2	10 (25 %)	R.C.A.	R.C.A.	R.C.A.	C.
3	7 (17·5 %)	C.†	R.C.A.	R.C.A. + C.	C.
4	5 (12·5 %)	R.C.A.	C.†	R.C.A. + C.	C.
5	4 (10 %)	C.	R.C.A.	R.C.A. + C.	R.C.A. + C.
6	3 (7·5 %)	C.	C.	R.C.A. + C.	C.

* R.C.A. = Right coronary artery.
† C. = Circumflex artery.

Table 2. *Summary of the arterial blood supply to the nodal tissue*

	Arterial supply	Number of hearts
S.A. & A.V. node	R.C.A.	21 (52·5 %)
S.A. & A.V. node	C.	3 (7·5 %)
S.A. node A.V. node	C. R.C.A.	11 (27·5 %)
S.A. node A.V. node	R.C.A. C.	5 (12·5 %)

Table 3. *Site of origin of the* S.A. *nodal artery*

Site of origin	Number out of 40	Total out of 40
1st part of R.C.A. (anterior)	19 (47·5 %)	R.C.A.
2nd part of R.C.A. (intermediate)	6 (15 %)	26 (65 %)
3rd part of R.C.A. (posterior)	1 (2·5 %)	
1st part of circumflex	11 (27·5 %)	Circumflex
2nd part of circumflex	3 (7·5 %)	14 (35 %)

Group 5. (Fig. 5). There were 4 (10 %) hearts in this group. The S.A. node and adjoining part of the right atrium were supplied by the circumflex artery. The remainder of the right atrium, A.V. node and a large part of the left atrium were supplied by the R.C.A. The left auricular appendage and the superior part of the left atrium were supplied from the left, the latter from the S.A. nodal artery.

Group 6. (Fig. 6). There were 3 (7·5 %) hearts in this group. The S.A. node and the adjoining part of the right atrium were supplied by the circumflex artery. The latter also supplied the A.V. node, the adjoining part of the right atrium and all the left atrium. The remainder of the right atrium was supplied by the R.C.A.

The origin of the S.A. nodal artery varied considerably (Tables 2 & 3). However, in almost every case the artery encircled the base of the superior vena cava and made a complete anastomotic ring (Fig. 7) (Keith & Flack, 1907; Gross, 1921; Crainicianu, 1922; James & Burch, 1958; Lienhard, 1972; Huu *et al.* 1973). Branches from this ring consistently passed down the crista terminalis towards the inferior vena cava. The S.A. nodal artery arose from the R.C.A. in 26 (65 %) of the hearts and from the circumflex artery in 14 (35 %). These figures are in agreement with those of other workers (Gross, 1921; Spalteholtz, 1924; James & Burch, 1958; Huu *et al.* 1973).

The following abbreviations are used in Figs. 1–13: A.I., Anterior inter-ventricular artery; L.A., Left atrium; L.A.Ap., Left auricular appendage; R.A., Right atrium; R.A.Ap. Right auricular appendage; P.T., Pulmonary trunk; P.V., Pulmonary veins. In Figs. 1–6 the parallel interrupted lines indicate the diaphragmatic surface of the heart.

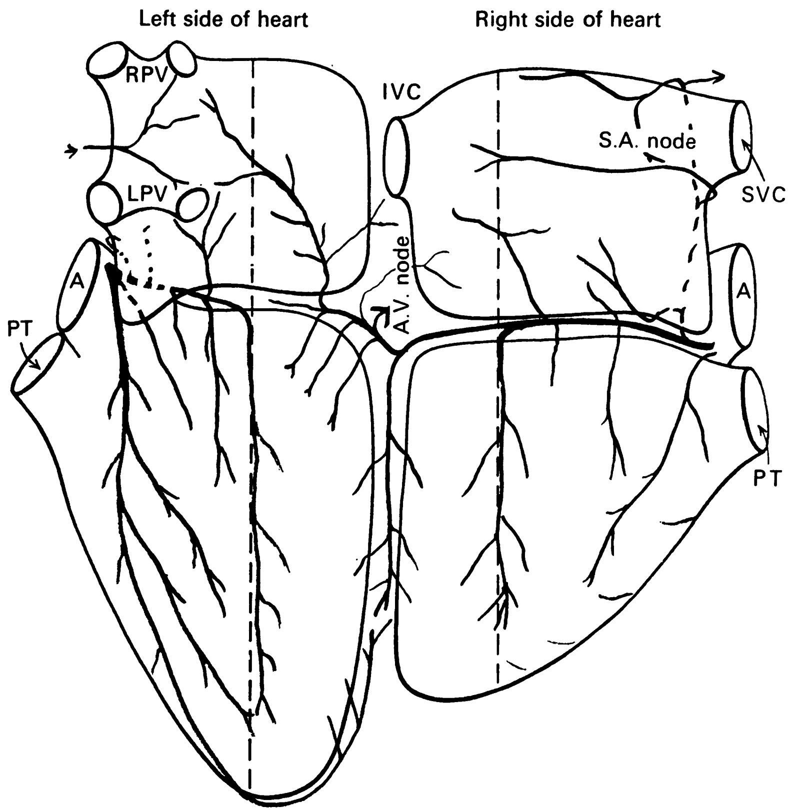

Fig. 1. Diagram illustrating atrial blood supply in Group 1 hearts.

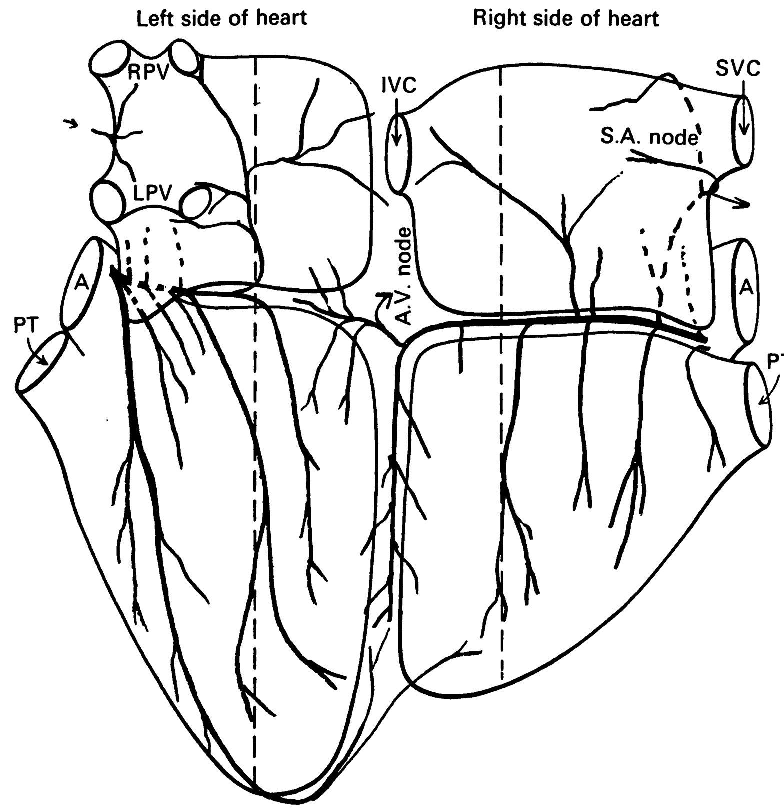

Fig. 2. Diagram illustrating atrial blood supply in Group 2 hearts.

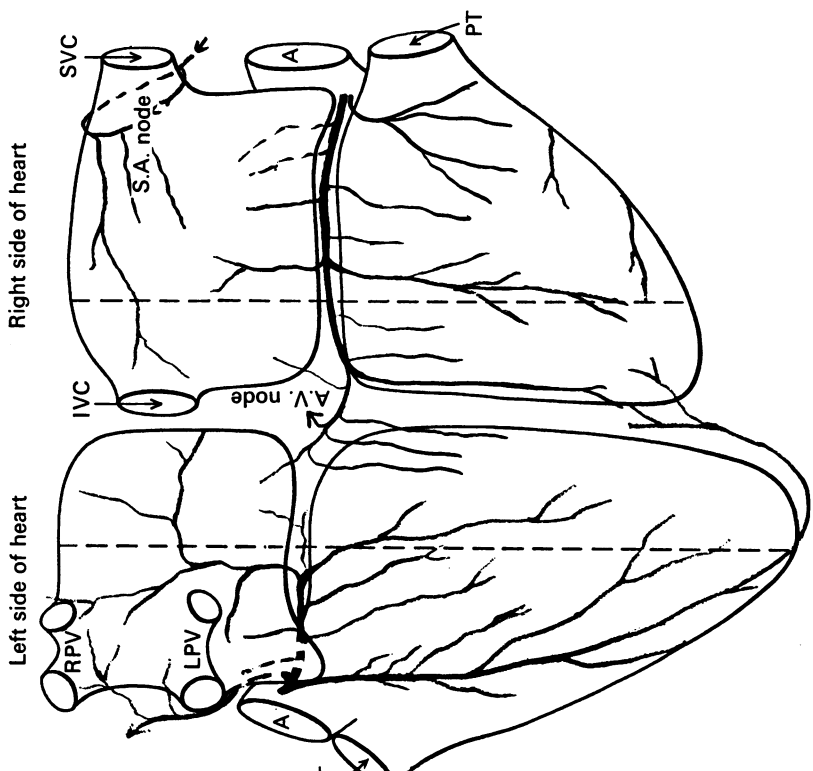

Fig. 3. Diagram illustrating atrial blood supply in Group 3 hearts.

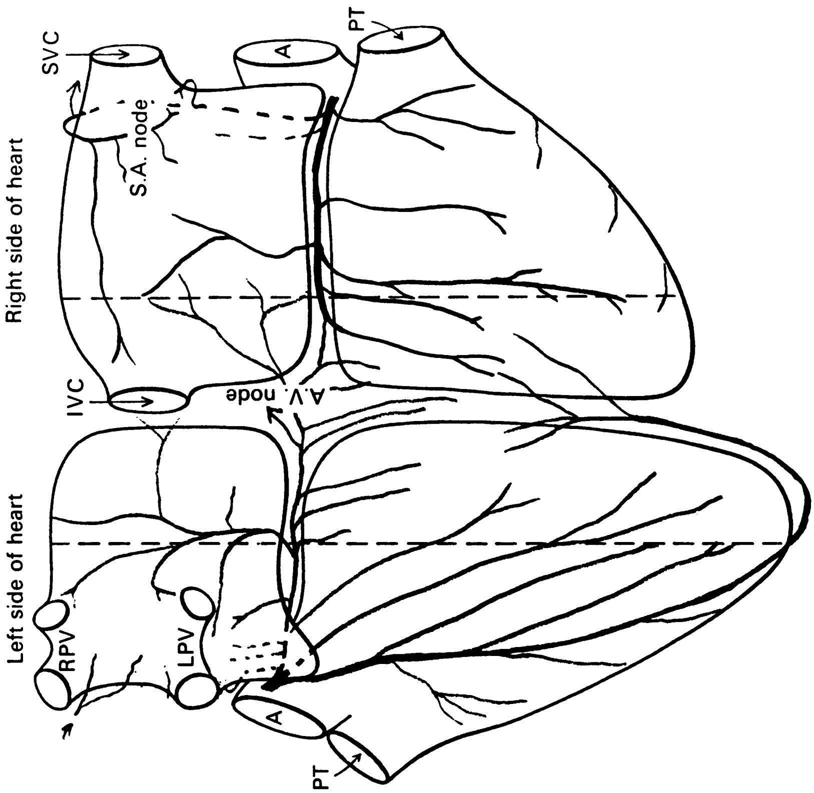

Fig. 4. Diagram illustrating atrial blood supply in Group 4 hearts.

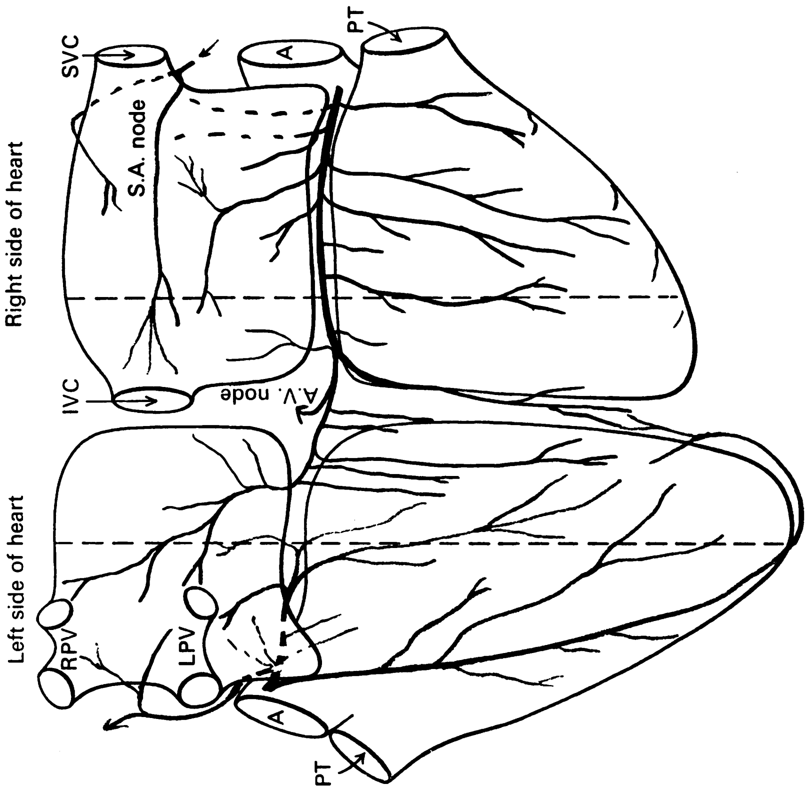

Fig. 5. Diagram illustrating atrial blood supply in Group 5 hearts.

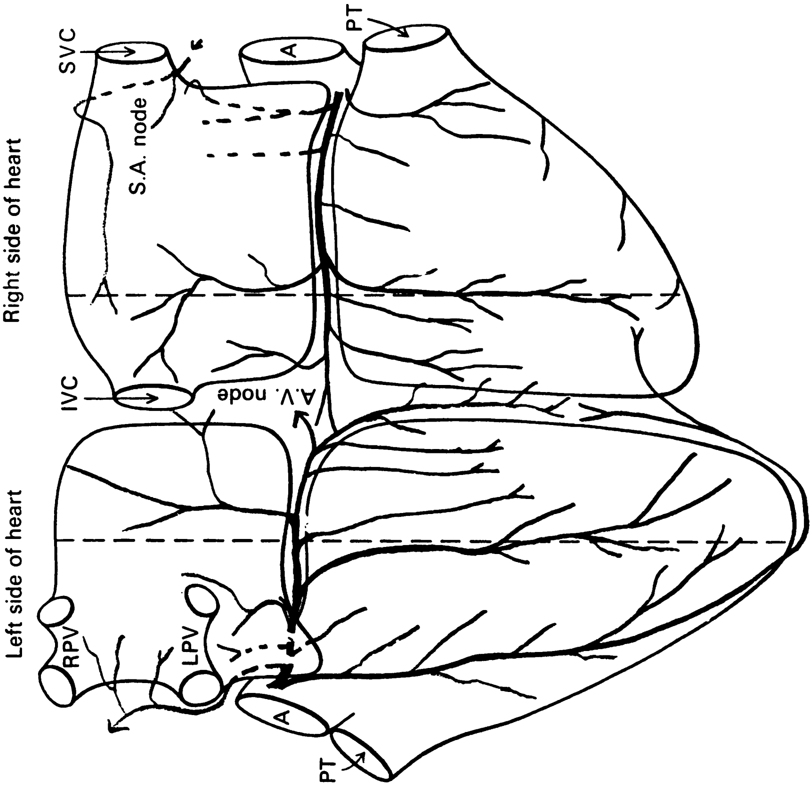

Fig. 6. Diagram illustrating atrial blood supply in Group 6 hearts.

The most common site of origin of the S.A. nodal artery was from the first one or two centimetres of the R.C.A. (Table 3, Fig. 7). The artery passed between the right auricular appendage and the aorta, giving branches to the inter-atrial septum. A branch then passed onto the superior surface of the left atrium between the left and right pulmonary veins (Figs. 1, 7). The vessel continued by dividing into two and encircling the base of the superior vena cava. The size of the two limbs was not always equal, and in these cases the major component of the limb passed either clock-wise or anti-clock-wise around the superior vena cava. As previously described, branches from the ring passed down over the right atrial wall (Fig. 7).

In 6 (15 %) of the hearts the S.A. node received its supply from the intermediate (lateral) part of the R.C.A. The vessel passed along the anterior and lateral wall of the right atrium to reach the superior vena cava (Fig. 8). Such a branch was found in the majority of the hearts. Usually it arose at or just before the margin of the heart where the anterior surface turns onto the diaphragmatic surface (acute margin), but in the majority of specimens it fell short of the S.A. node.

Two hearts in the series received a balanced blood supply to the S.A. node from this vessel and from a branch of the first part of the R.C.A.

In one heart the S.A. nodal artery arose from the terminal (posterior) part of the R.C.A., passed over the postero-lateral surface of the left atrium, between the left pulmonary veins and the left auricular appendage, and over the superior surface of the left atrium to the superior vena cava (Fig. 9). This unusually long course has been described by Mouchet & Noureddine (1926).

When the S.A. nodal artery arose from the circumflex artery, the most common site for its origin was from the first part of this artery (Table 3). The vessel passed over the superior surface of the left atrium, giving branches to it and then ended by encircling the superior vena cava (Fig. 10). In a much smaller percentage (7·5 %) of cases, the S.A. nodal artery arose from the second (intermediate or lateral) part of the circumflex artery (Table 3). It passed down towards the inferior surface of the left atrium and then turned upwards between the left pulmonary veins and the left auricular appendage over the superior surface of the left atrium to end by encircling the superior vena cava (Fig. 11).

The arterial blood supply of the A.V. node arose in 32 (80 %) of the hearts from the R.C.A. in the posterior atrio-ventricular sulcus at a point just beyond the origin of the posterior inter-ventricular artery. This region of the heart is referred to as the crus. Frequently this was a double vessel. The usual description of it arising from the apex of an inverted 'U' loop of the R.C.A. was confirmed in many instances (Fig. 12), although this was not always very obvious. The middle cardiac vein (posterior inter-ventricular vein) was superficial in this vicinity. The A.V. nodal artery passed up into the inter-atrial septum, deep to the coronary sinus, to supply the A.V. node and the surrounding myocardium.

In 8 (20 %) of the hearts the A.V. nodal artery arose from the terminal part of the circumflex artery at the crus of the heart. In every case where this occurred the posterior inter-ventricular artery was formed by the circumflex artery turning into the posterior inter-ventricular sulcus (Fig. 13). The R.C.A. supplied only a small proportion of the diaphragmatic surface of the heart in these cases.

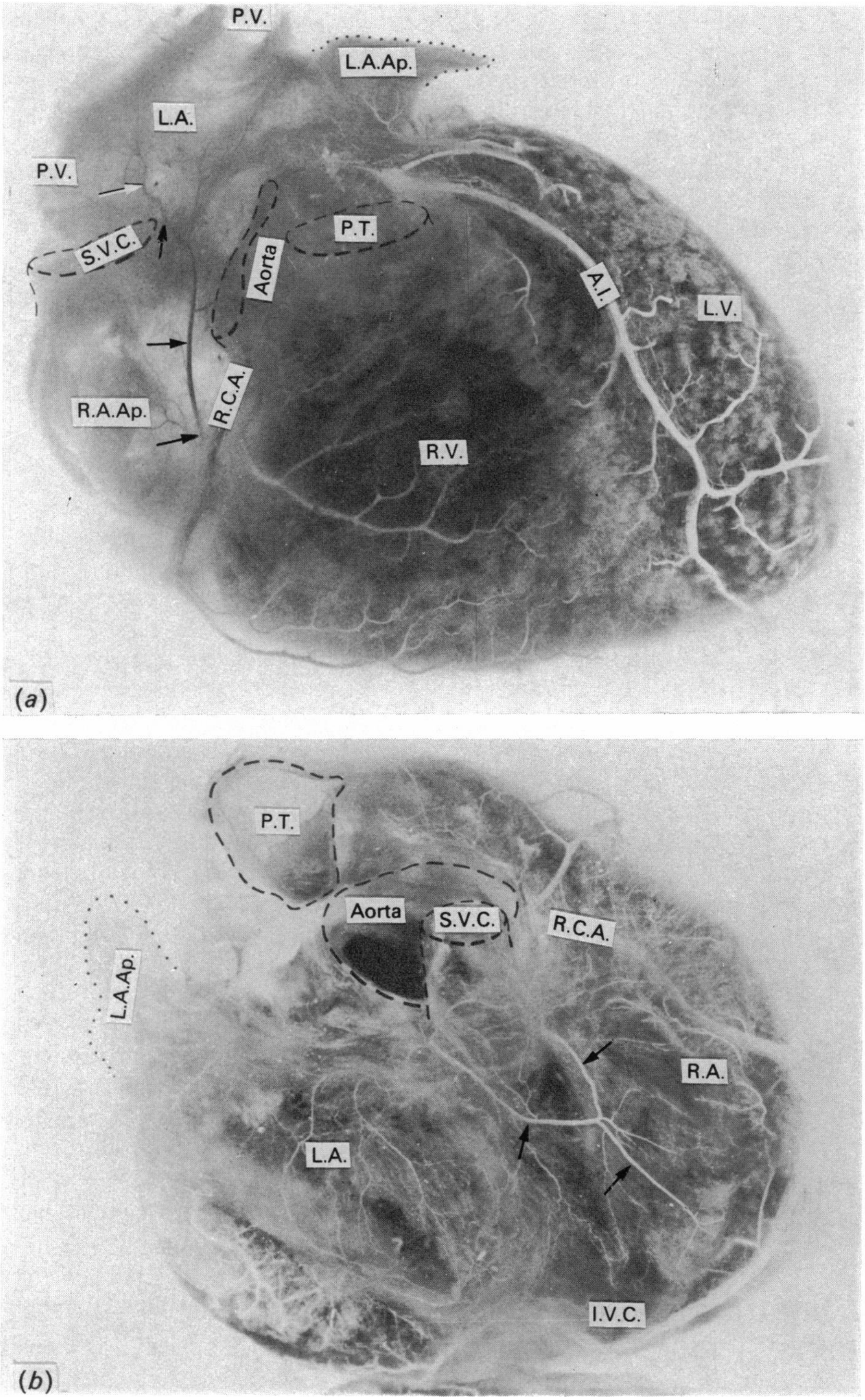

Fig. 7. Two views of the same heart. Arrows indicate the course of S.A. nodal artery. White arrow indicates the branch of S.A. nodal artery to the left atrium. (*a*) antero-superior view; (*b*) viewed posteriorly from the right.

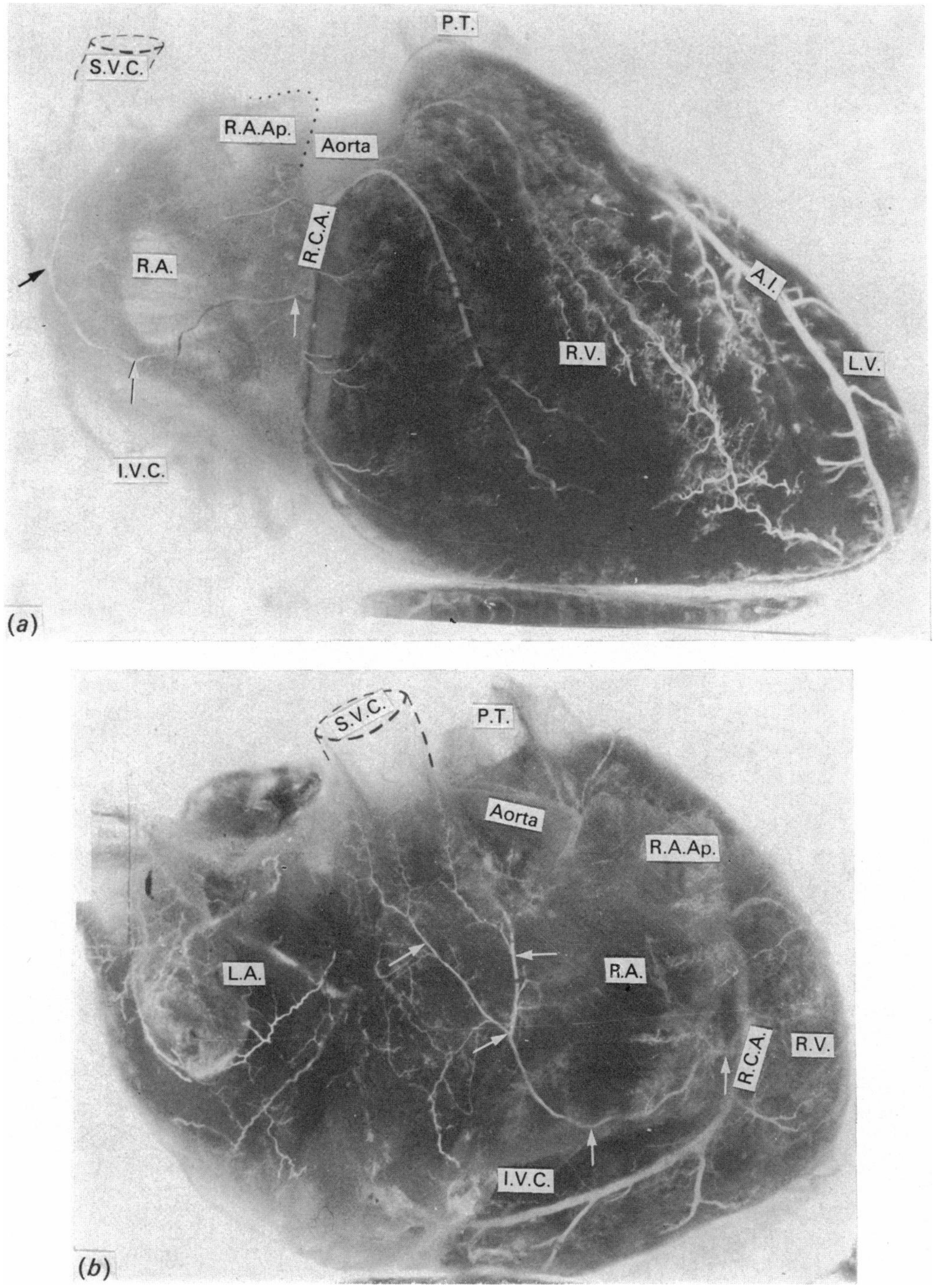

Fig. 8. Two views of the same heart. Arrows indicate the course of the S.A. nodal artery. (*a*) viewed anteriorly from the right; (*b*) viewed posteriorly from the right.

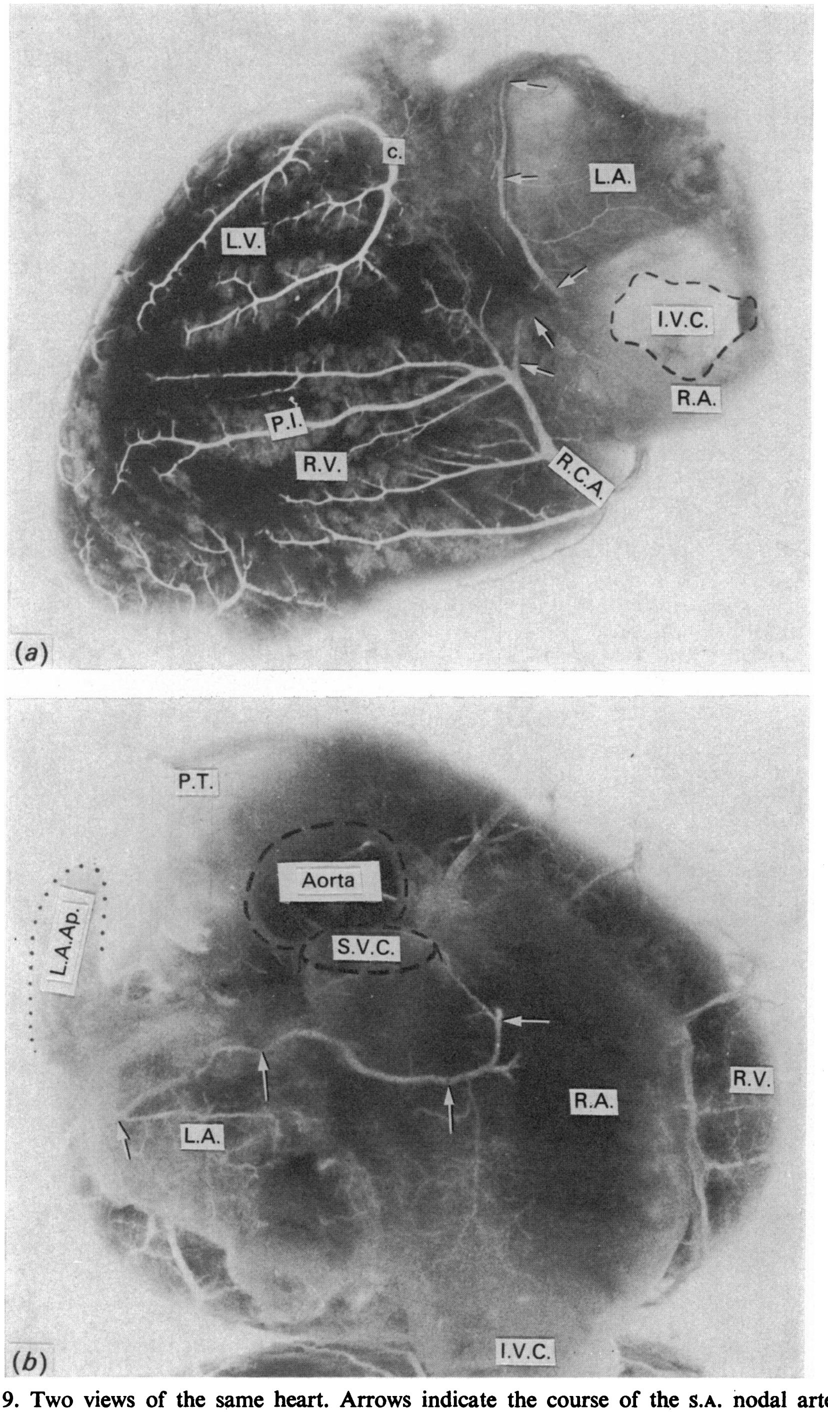

Fig. 9. Two views of the same heart. Arrows indicate the course of the S.A. nodal artery. (*a*) viewed from diaphragmatic surface; (*b*) viewed posteriorly from the right.

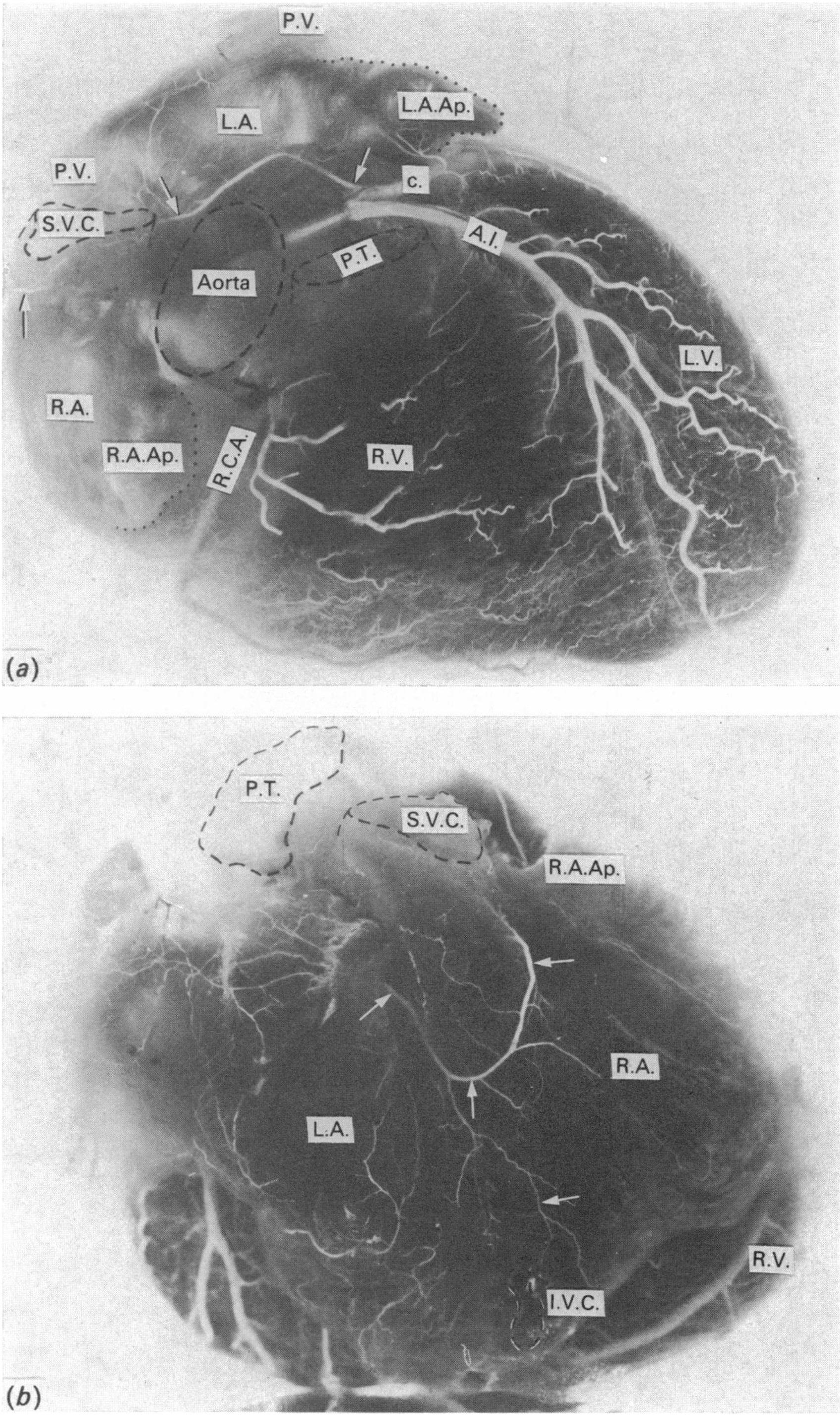

Fig. 10. Two views of the same heart. Arrows indicate the course of the S.A. nodal artery. Note that the major limb goes around the superior vena cava anti-clock-wise. (*a*) antero-superior view; (*b*) viewed posteriorly from the right.

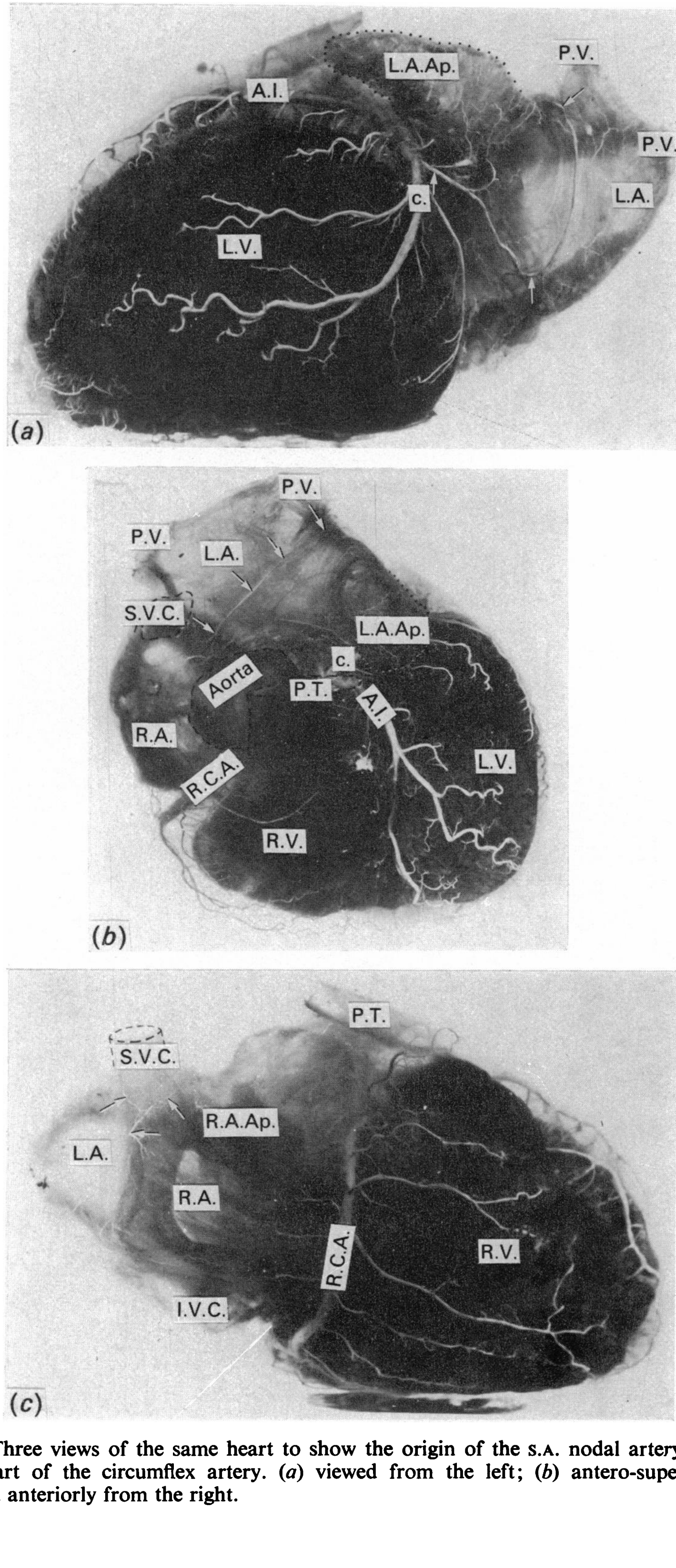

Fig. 11. Three views of the same heart to show the origin of the S.A. nodal artery from the second part of the circumflex artery. (*a*) viewed from the left; (*b*) antero-superior view; (*c*) viewed anteriorly from the right.

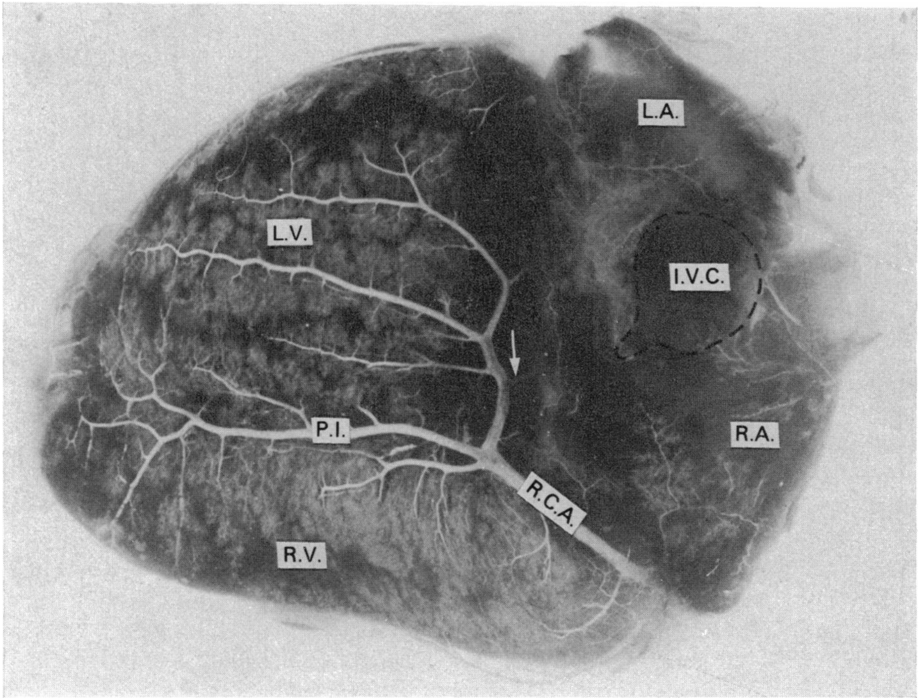

Fig. 12. Diaphragmatic view of the heart to show A.V. nodal artery (white arrow). The 'U' loop of the R.C.A. is visible. Note how much of this surface of the heart is supplied by the R.C.A.

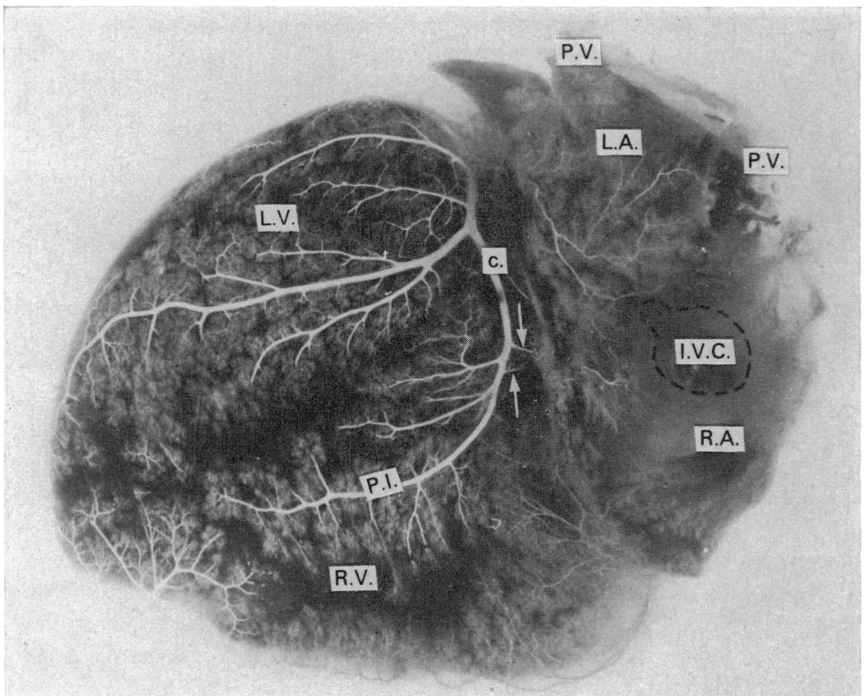

Fig. 13. Diaphragmatic view of the heart to show the A.V. nodal artery arising from the circumflex artery. Note that it is double in this instance (white arrows). There is no 'U' loop of the parent vessel in this case.

DISCUSSION

With such wide variation in the origin and size of the atrial arteries, terminology is difficult. It is proposed that the following vessels may be recognized and named:

(i) The sinu-atrial nodal artery (S.A. nodal artery), whatever its site of origin.

(ii) The atrio-ventricular nodal artery (A.V. nodal artery), whatever its site of origin.

The two nodal arteries were the biggest and the most constant branches, even if their actual origin was variable. Their territory of supply is very important: their nomenclature should be based on the areas they supply rather than on their site of origin.

It is interesting to reflect on why these nodal vessels are so large. There is no reason for supposing that the metabolism of nodal tissue is greater than that of other cardiac tissues. The large size is probably related to the fact that nodal arteries also supply a considerable volume of surrounding myocardium. There is no obvious explanation of the variable origins of these arteries.

The case for naming other atrial arteries is less strong. However, three vessels were frequently present, and were up to 1 mm in diameter in most cases. Moreover their origin was reasonably constant, and this may justify their being given names. The suggested names are:

(i) The left lateral atrial artery. This arises from the second (intermediate or lateral) part of the circumflex artery. It was found to be a relatively large branch in 25 (62·5 %) of the hearts (Figs. 2, 3, 4, 6). On occasion it was responsible for the supply of the S.A. node (Fig. 11). More frequently it passed posteriorly to supply the bulk of the lateral and posterior surfaces of the left atrium. When this vessel was small the right posterior atrial artery took over its territory of supply (*vide infra*).

(ii) The right posterior atrial artery. In 15 (37·5 %) of the hearts this artery was found to be large (Figs. 1, 5). It arose from the R.C.A. in the posterior atrio-ventricular sulcus, and supplied the posterior surface of the left atrium. When this vessel was large the left lateral atrial artery was small. It has been noted that the right posterior atrial artery supplied the S.A. node in one heart.

(iii) The right lateral atrial artery. There was nearly always a relatively large atrial artery arising from the R.C.A. in the region of the acute margin of the heart. In 6 (15 %) of the hearts it was responsible for the supply of the S.A. node (Fig. 8), and in two others it shared in its supply. In the remainder of the hearts this artery was smaller and fell short of the S.A. node.

These findings broadly agree with those of James & Burch (1958). The rest of the numerous atrial arteries were too small and too variable to justify naming.

Little mention has been made of potential sites of anastomosis between these atrial arteries. In one of the pathologically involved hearts there was a demonstrable anastomosis between the arteries (from left and right coronaries) supplying the S.A. node. However, failure to demonstrate anastomoses between atrial branches of the left and right coronary arteries or between different atrial branches of the same coronary artery in injected specimens does not imply that such anastomoses do not exist. It is probably safe to assume that where two vessels come close to each other, whether from the right or left, there is some degree of potential anastomosis. As the anastomotic ring around the base of the superior vena cava invariably arose from a single vessel, it is difficult to explain its function.

With regard to the blood supply of the atrial appendages the following generalizations can be made. The left auricular appendage and the surrounding myocardium were invariably supplied from the circumflex artery, usually by a series of small vessels (Figs. 1–6). The right auricular appendage was supplied from the R.C.A. When the S.A. nodal artery arose from the first part of the R.C.A. (almost 50 %) it was in close proximity to the right auricular appendage and lay in the sulcus between the base of the appendage and the aorta (Fig. 7). This is of some importance to the cardiac surgeon, as it would be undesirable to include this vessel in a ligature.

The inter-atrial septum received its blood supply from a variety of sources, but especially from the S.A. and A.V. nodal arteries. The S.A. nodal artery always supplied the crista terminalis region of the right atrium, often as far down as the inferior vena cava. This artery also supplied the superior surface of the left atrium in most cases (Fig. 7). The A.V. nodal artery, whether from the right or left, always arose in the region of the crus of the heart, usually at a point deep to the middle cardiac vein (posterior inter-ventricular vein).

SUMMARY

The arterial blood supply to the atria of 40 human hearts has been studied using a clearing technique which leaves the anatomy of the heart intact.

The general arrangement of the atrial arteries is described. The arterial supplies to the S.A. and A.V. nodes are considered in more detail as these are probably the most important and most consistent vessels found.

In over 50 % of the hearts both the S.A. and A.V. nodes were supplied from branches of the right coronary artery. In only 7 % were both nodes supplied by branches of the left coronary artery. In the remainder the S.A. node was supplied by one coronary artery and the A.V. node by the other, in either combination.

The actual site of origin of the S.A. nodal artery varied considerably, but the single most common site (47 %) was from the first part of the right coronary artery. The second most common site was from the circumflex branch of the left coronary artery (27 %).

The site of origin of the A.V. nodal artery was predominantly from the terminal part of the right coronary artery (80 %), the remainder being supplied from the left.

Some of the relatively large atrial vessels not primarily concerned with the supply of nodal tissue are described. A nomenclature has been suggested both for these and for the nodal arteries. There were many small and variable vessels that defied classification.

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REFERENCES

CRAINICIANU, A. (1922). Anatomische Studien über die Coronararterien und experimentelle Untersuchungen über ihre Durchgängigkeit. *Virchow's Archiv für pathologische Anatomie und Physiologie und für klinische Medizin* **238**, 1.

DIDIO, L. J. A. & WAKEFIELD, T. W. (1972). Origin, classification, nomenclature and incidence of the atrial arteries in normal human hearts, with special reference to their clinical importance. *Acta cardiologica* **27**, 565.

GROSS, L. (1921). *The Blood Supply to the Heart in its Anatomical and Clinical Aspects*. New York: Hoeber.

Huu, N., Leroy, J. P. & Tiercelin, A. (1973). Artères des oreillettes chez l'homme. *Bulletin de l'Association des Anatomistes* **57**, 159.

James, T. N. & Burch, G. E. (1958). The atrial coronary arteries in man. *Circulation* **17**, 90.

Keith, A. & Flack, M. (1907). The form and nature of the muscular contractions between the primary divisions of the vertebrate heart. *Journal of Anatomy and Physiology* **41**, 172.

Leinhard, G. (1972). La vascularisation du noeud de Keith et Flack chez l'homme. *Archives d'Anatomie, d'Histologie et d'Embryologie* **55**, 361.

Mouchet, A. & Noureddine, A. (1926). Sur l'artère de l'atrio-necteur. *Annales d'anatomie pathologique et d'anatomie normale médico-chirurgicale* **3**, 41.

Schlessinger, M. J. (1938). An injection plus dissection study of coronary artery occlusions and anastomoses. *American Heart Journal* **15**, 528.

Spalteholtz, W. (1924). *Die Arterien der Herzwand.* Leipzig: Hirzel.

Stern, H., Ranzenhofer, E. R. & Liebow, A. A. (1954). Preparation of vinylite casts of the coronary vessels and cardiac chambers. *Circulation Research* **4**, 223.

Tompsett, D. H. (1970). *Anatomical Techniques.* Edinburgh: Livingstone.