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Arterial supply of, and arterial preponderance in, the human interventricular septum

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SUMMARY

Purpose of the study: To determine the pattern of arterial supply of, and eventual arterial preponderance in, the human interventricular septum (IVS).

Material and methods: 100 human heart specimens (84 cadaveric specimens and 16 corrosion casts) were studied macroanatomically. In 20 cases, the coronary arteries were injected with barium sulphate and red gelatin. The intramural courses of septal arteries were exposed in 38 cases. Radiographs of the IVS were made in 8 cases.

The IVS was divided into superior and inferior parts; each part was subdivided into anterior, middle, and posterior sections; additionally, there was an apical section. In order to determine the nature of the arterial supply, the extramural portions of the septal branches were first dissected and evaluated; then, the intramural courses were traced.

Results: The septal branches derived from arteries distributed in the coronary and interventricular sulci of the heart. The strongest of the septal arteries, the *anterior descending septal artery (ADSA)* or *main septal artery*, originated from the *anterior interventricular artery (AIA)* and was found in 72 cases. Its stem exhibited an average length of 16 mm and then bifurcated into superior and inferior or trifurcated into superior, inferior and deep (left) branches. These branches supplied the middle superior and middle inferior sections of the IVS.

The moderator band and anterior papillary muscle of the right ventricle received twigs from the inferior branch of the *ADSA* and from the fourth or fifth anterior septal arteries.

The small *left superior septal artery,* which originated from the AIA but was not always present, supplied the anterior superior section of the IVS. The *right superior septal artery,* which derived from the initial part of the right coronary artery (RCA), nourished the middle superior section of the IVS (in cases in which the latter was not supplied by branches from the *ADSA*). The *posterior septal arteries* (including branches of the atrioventricular node artery) arose from the posterior interventricular artery (PIA) and supplied the superior and inferior posterior sections of the IVS. Apical branches derived from the terminal AIA and supplied the apical section.

The most conspicious peculiarity was a stout *right superior septal artery (RSSA)*, which in some instances supplied more than just the middle superior section of the IVS, reaching the moderator band and right anterior papillary muscle. Another peculiarity was the ectopic origin of one of the posterior septal arteries from the right marginal artery or even the stem of the RCA (frequency: 18 cases).

Evaluation: In 92 cases a preponderance of the left coronary artery was evident because the *anterior septal branches* were frequent and large (among them the stout and long *ADSA*). A balanced type of arterial supply was found in 5 cases when the *RSSA* appeared to be as strong as the *ADSA*. A preponderance of the right coronary artery was found in 3 cases when the proximal RCA released a stout and long (“dominant”) *RSSA* without the existence of a main septal artery.

Key words: Heart – Interventricular septum – Arterial supply – Human

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Introduction

The interventricular septum (IVS) of the human heart is of vital importance in that it (1) separates the left from the right ventricle and (2) contains the main tracts of the conducting tissue that plays such an essential role in the achievement of a normal cardiac rhythm (Fehn et al., 1968; McAlpine, 1975). Even a minor septal infarction, therefore, poses two risks: (1) lethal septal perforation and (2) life-threatening disturbance of the conducting system.

Most septal branches derive from the anterior interventricular artery (AIA). The rest stem from the posterior interventricular artery (PIA) (Paulin, 1964; McAlpine, 1975; Morettin, 1976; Allwork, 1979; Anderson, 1982; Williams et al., 1989; von Lüdinghausen, 2003). In accordance with the principle of coronary preponderance on the surface of the heart, the PIA and its posterior septal branches originated from the RCA in 90% of all cases examined by von Lüdinghausen (1975) and Hadziselimovic (1982), and in 10% from the LCA. Where the arterial supply of the IVS alone is concerned, the numerous and stout septal branches of the AIA are of remarkable significance; thus, it is possible to speak of a preponderance of the LCA in the septum, or a 'left' preponderance. However, in view of the results of our studies (von Lüdinghausen and Ohmachi, 2001) and the findings reported in the literature (Allwork, 1979; Anderson and Becker, 1982; Topaz and Vetrovec, 1996) we have reason to believe that the supply of the IVS may occasionally be dominated by arteries other than the branches of the AIA. This could influence the thoughts and strategies of cardiologists and radiologists.

The purpose of this study is thus (1) to define the frequency, source, and courses of the arteries supplying the various parts (sections) of the IVS, (2) to describe the relationship between septal arteries and the layers of the IVS (3) to determine any arterial preponderance in the IVS itself, and (4) to evaluate the occurrence and distribution patterns of the septal branches in the light of clinical, developmental and comparative anatomy.

Material and methods

This investigation was carried out on a total of 100 heart specimens (from individuals of both sexes and between 39 and 91 years of age at death). 84 heart specimens were obtained during routine dissection courses (1998-2003). First, the extramural portions of the septal branches were dissected. In 30 (of the 84) specimens the coronary arteries were injected with a mixture of red gelatin and radiopaque dye. In 15 injected specimens and in 25 uninjected specimens the dissectable intramural courses of the interventricular arteries were meticulously exposed using magnifying glasses and operative microscopes. Post-mortem angiographies of the septal arteries were carried out on 10 heart specimens.

For better evaluation of the arterial supply, the IVS was divided into a superior and an inferior part, each of which was in turn subdivided into anterior, middle (subaortal) and posterior sections; additionally, there was an apical section (Fig. 1). Subsequently, 16 corrosion casts were prepared from vascular fillings made from fresh human heart specimens, whose the aortic roots and coronary arteries were injected manually with a resin (red methyl-methacrylate, Kulzer, Germany). The specimens originated from the autopsy room, 1971-1973, Department of Pathology, University of Munich. Injection pressure was not calculated during the procedure.

The photographs were taken with a Nikon camera using Kodak ASA 200 film. All scales in the figures are shown in millimetres.

Abbreviations:

Anterior descending septal artery	ADSA
Anterior interventricular artery	AIA
Atrioventricular node artery	AVNA
Circumflex artery	CA
Interventricular septum	IVS
Left coronary artery	LCA
Left superior septal artery	LSSA
Posterior interventricular artery	PIA
Posterior superior septal arteries	PSSA(s)
Posterior inferior septal arteries	PISA(s)
Right coronary artery	RCA
Right superior septal artery	RSSA

Septal arteries are print in *italics*.

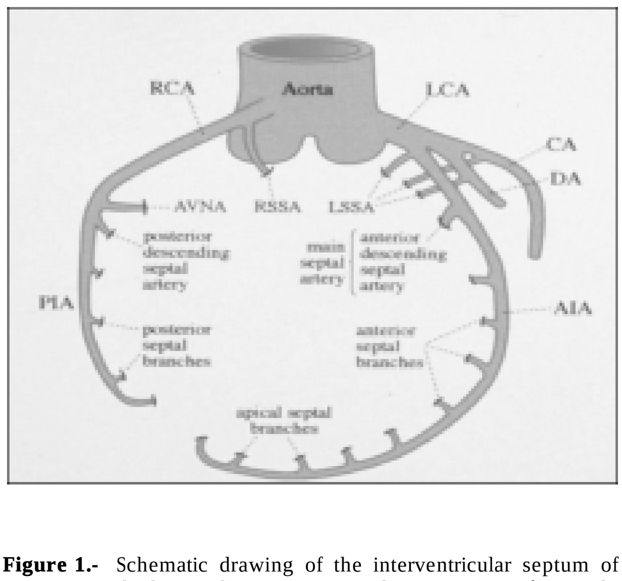

Figure 1.- Schematic drawing of the interventricular septum of the human heart, its parts and sections (seen from right lateral).

RESULTS

Coronary dominance and origin of septal branches

The septal arteries arise from the left and right coronary arteries, which are epimurally distributed and known to vary in diameter and length, thus supplying a variable amount of left and right ventricular myocardium (Fig. 2).

The greatest diversity of occurrence of the various arteries can be seen on the diaphragmatic surface of the heart. Accordingly, there is a dominance of the RCA or a balanced pattern of arterial distribution when the PIA is a branch of the RCA (frequency: 90% of the cases studied) and a dominance of the LCA when the PIA is a branch of the CA (frequency: 10% of the cases studied) (Figs. 3, 4).

Here, the origin of the *posterior septal arteries* is influenced by coronary dominance, because in 90% of our cases they are branches of a right PIA and in 10%, of a left PIA

In contrast to these findings, the anterior septal branches consistently derive from the AIA but exhibit remarkable variations in strength and length.

Epimurally, the anterior interventricular artery (AIA) was found to be duplicated along part of its length in 25 cases studied. There was duplication of the posterior interventricular artery (PIA) in 33 cases and triplication in 1 case. Each of these vessels released septal branches that supplied the right and left myocardial layers of the IVS (Fig. 5).

The stems of septal arteries and the sites of ramification were preferentially found in the right ventricular layer of the IVS. From there, abundant smallest twigs reached the left ventricular layer of the IVS.

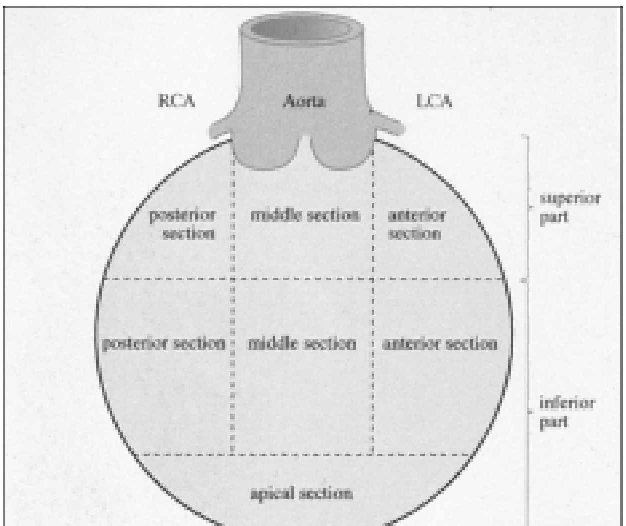

Figure 2.- The origins of the extramural portions of the superior, anterior, and posterior septal arteries of the human heart (seen from dextro-lateral).

THE ARTERIES SUPPLYING THE SECTIONS OF THE SUPERIOR PART OF THE IVS

The *anterior descending septal artery (ADSA*) or *main septal artery*

The second or third anterior septal artery was remarkably stout in appearance (in 72 cases) and was designated the *anterior descending septal artery (ADSA)* or *main septal artery*. The *ADSA* originated near the junction of the AIA and *RC* or from a point within the first two centimetres of the AIA on the left side of the bulb of the pulmonary trunk; it entered the IVS behind the pulmonary valve. Running at an acute angle of between 45 and 80° to the AIA, the stem of the *ADSA* pierced the myocardium of the interventricular sulcus. Occasionally its point of origin was covered by a muscular strand or myocardial bridge (Figs. 5, 6). The stem of the *ADSA* exhibited an average length of 16 mm and an external diameter of between 1.5 and 2.0 mm, and initially coursed within the right ventricular layer of the IVS.

It bifurcated into superior and inferior branches, or trifurcated into superior, inferior and deep (left) branches. The superior branch was directed towards the left ventricular ostium and supplied the middle section of the superior part of the IVS, while the inferior branch passed through and supplied the middle section of the inferior part. The deep (left) branch ramified to supply the left ventricular layer of the IVS. In most cases the inferior branch of the *ADSA* released a small artery that supplied the moderator band and the anterior papillary muscle. This artery was designated the *moderator band artery* (Figs. 6, 7).

PECULIARITIES

The *ADSA* was found to have no stem nor to exhibit an early division in 14 cases; in these specimens, two smaller *ADSAs* arose from the AIA at the same site.

Small twigs from the inferior branch crossed over the anterior septal branches in 15 cases.

The superior branch of the *ADSA* crossed over the *right superior septal artery (RSSA)* in 13 cases (Fig. 8).

The *moderator band artery* derived directly from the AIA in 3 cases.

The *moderator band artery* branched off from one of the anterior septal branches in 4 cases.

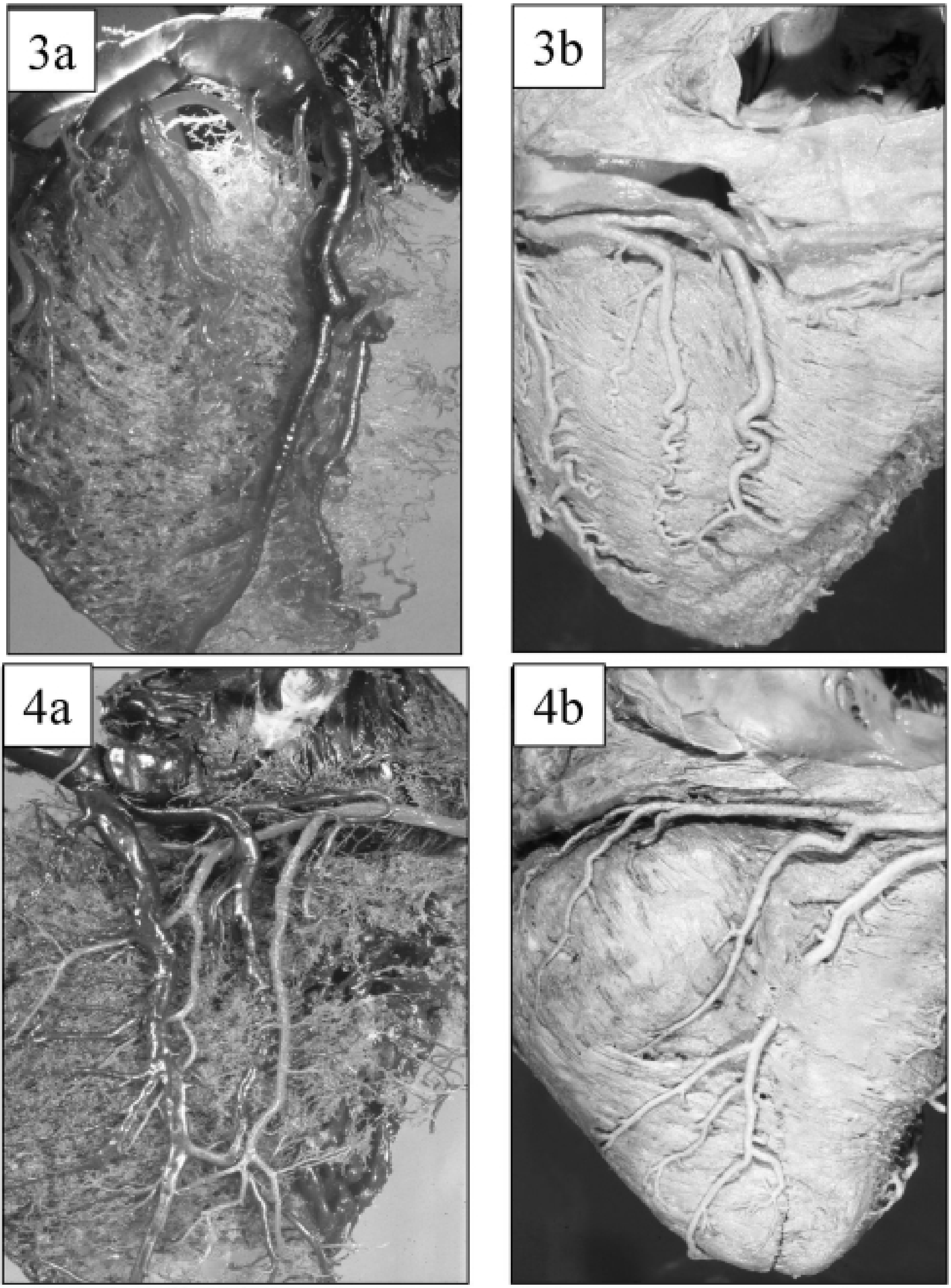

Figure 3 and 4.- Various forms of a dominant left (3 a, b) and a right (4 a, b) coronary artery as seen on the diaphragmatic surface of corrosion casts (3a,4a) and cadaver specimens (3 b, 4 b).
Right coronary dominance (frequency 90%): the branches of a dominant RCA are distributed on the posterior wall of the left ventricle. The CA terminates as a left marginal branch (4 a, b). Early division of a dominant RCA at the level of the right cardiac margin into PIA and the posterior branch of the left ventricle.
Left coronary dominance (frequency 10%): A dominant CA (LCA) releases a strong PIA, whereas the RCA is hypoplastic (3 a, b).

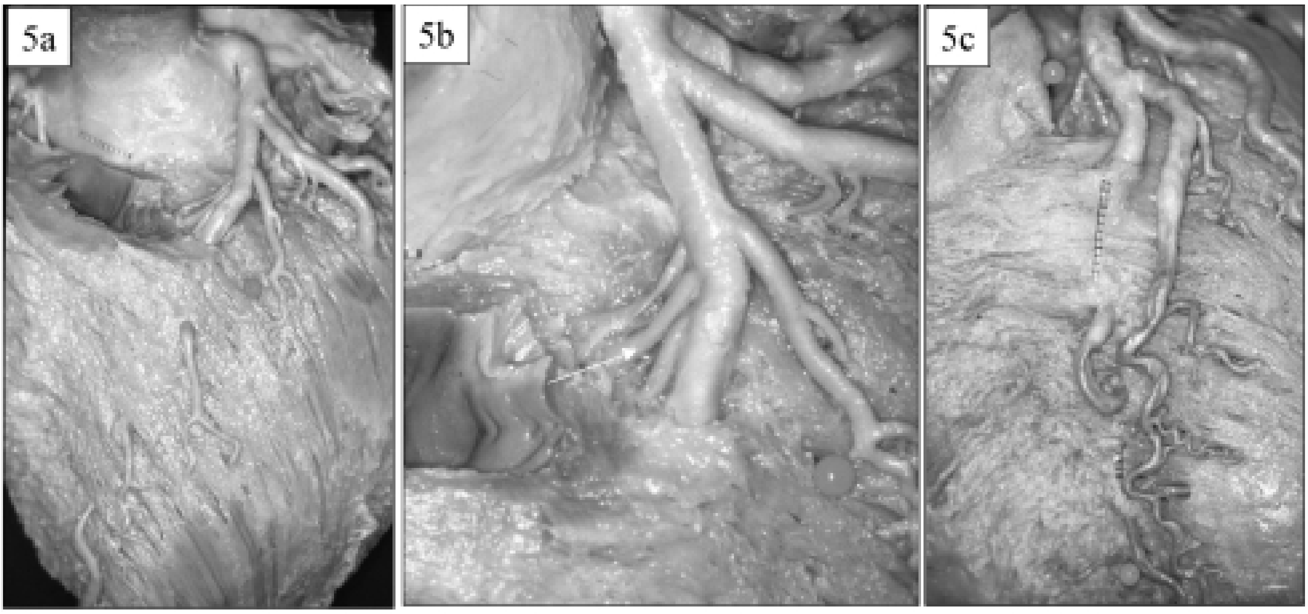

Figure 5 a, b, c.- Sternocostal surface of the heart showing a long (**5 a**) and short (**5 c**) intramural course of the AIA. The AIA releases three anterior septal branches –among them the main septal artery (**5 b** arrow). Further anterior septal branches are not visible. **5 c**: During intramural courses the origin of septal branches is almost hidden. Duplicity of the AIA.

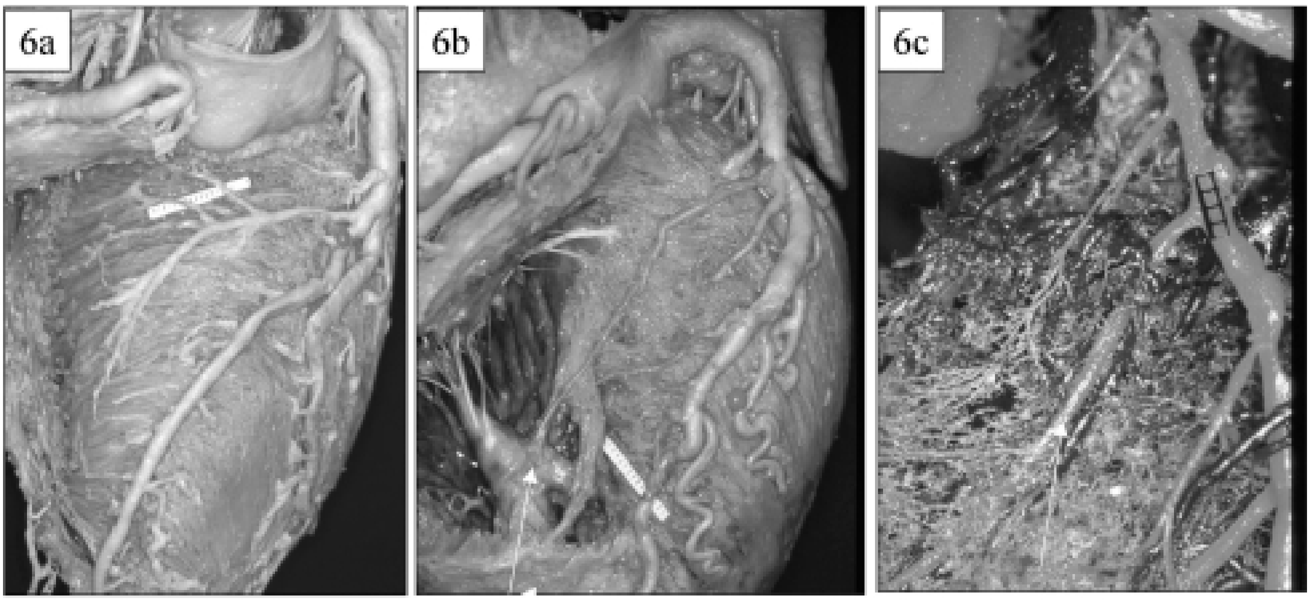

Figure 6 a, b, c.- Arterial supply of the interventricular septum as seen in cadaver specimens (**a, b**) and in a corrosion cast (**c**). **a**: A dominant ADSA releases superior branches for the middle section of the superior part. The inferior branch supplies the middle section of the inferior part of the interventricular septum. **b**: In this case the moderator band artery (arrow) is the third branch of the AIA. The small single artery reaches the myocardium of the trabecula septomarginalis (moderator band) and the right papillary muscle and, from there, begins its terminal arborization. **c**: The AIA releases five septal branches which serve the myocardium of the anterior sections of the interventricular septum. The ADSA is the third branch (arrow).

The moderator band was supplied by two or three arteries from various sources (*AIA*, *ADSA*, fourth anterior septal branch) in 3 cases.

FURTHER ARTERIES SUPPLYING THE SUPERIOR SECTIONS OF THE IVS

A small artery originating as the first branch of the proximal AIA coursed to the ***anterior section*** of the IVS. It was found in 54 of the cases and was designated *LSSA*. Its intramural dissectable part was up to 30 mm in length and supplied not only the adventitial tissue of the left surface of the bulb of the aorta and the pulmonary trunk**,** but also the anterior section of the superior IVS.

The ***middle section*** of the IVS was supplied by the superior branch of the *ADSA* (in 48 cases), by the *RSSA* (in 18) or by both arteries at

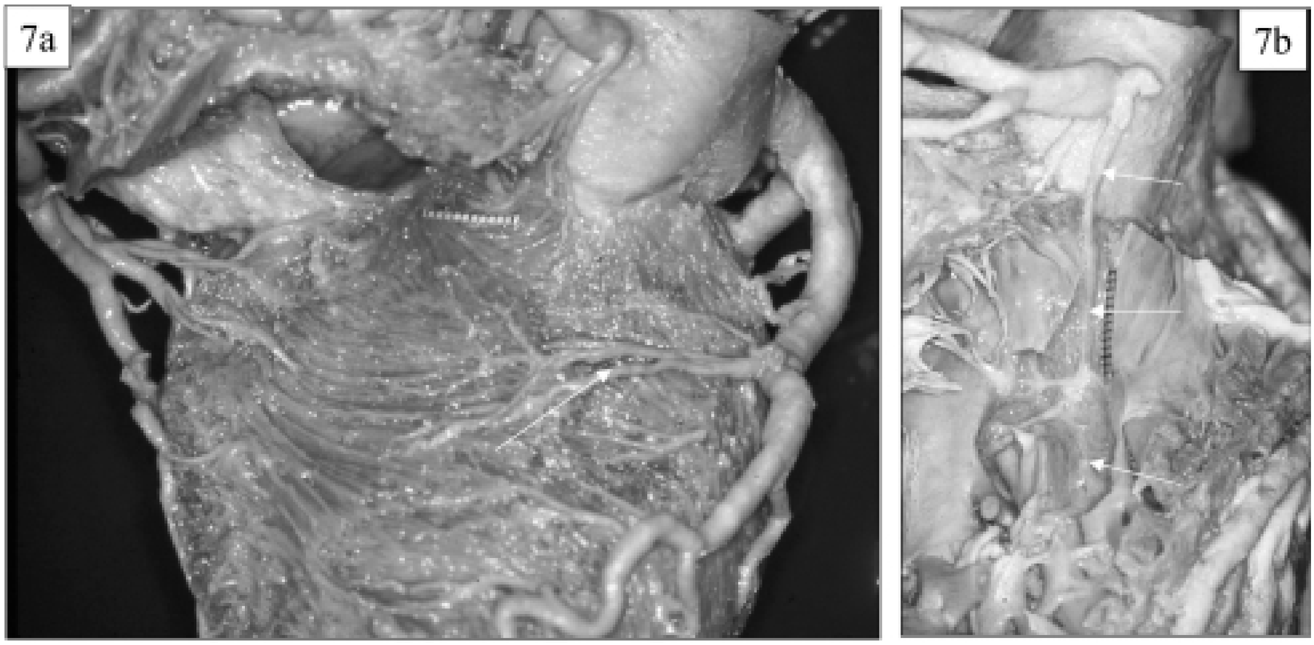

Figure 7 a, b.- Interventricular septum of cadaver specimens (seen from dextro-lateral) showing the arteries of the superior part. **a**: The AIA releases the ADSA/MSA (arrow), the initial RCA releases the RSSA, and the terminal RCA releases the PSSAS, among them the AV node branch. **b**: The stem of the RCA releases a strong RSSA (arrows)- After an extramural course, the RSSA ramifies intramurally and supplies the myocardium of the crista supraventricularis and the adjacent interventricular septum.

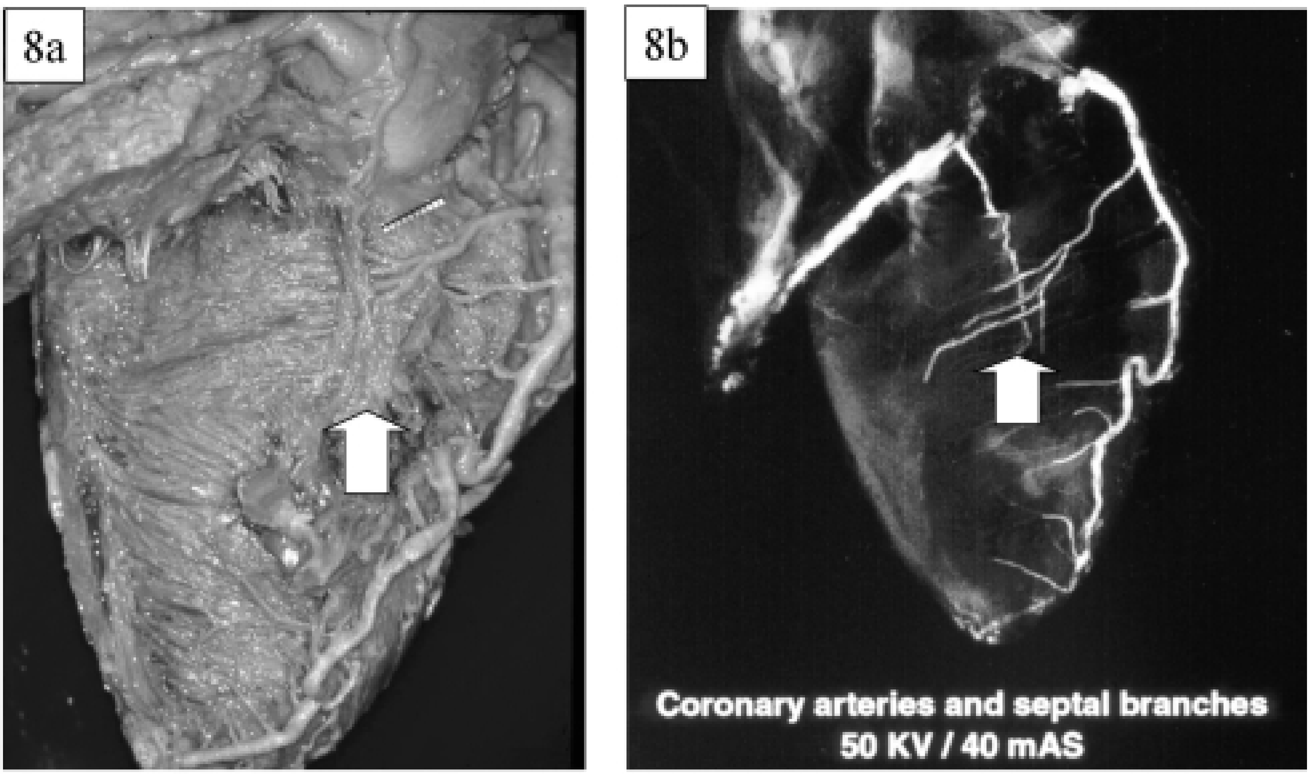

Figure 8 a, b.- The arterial supply of the interventricular septum of a cadaver specimen.
a: Dissection of the RSSA and LSSA of equal length and diameter. The terminal branches of the two arteries show a crossing manoeuvre (arrow). **b**: x-ray study of the same specimen. The arteries have been injected post-mortem with a radiopaque dye (arrow).

once (in 34). A dissectable RSSA derived from the proximal 5 mm of the stem (in 38 cases), and in 4 specimens from the ostial area of the RCA.

From its origin, an *RSSA* was found to follow an initial extramural course along the bulb of the aorta, giving off small branches to the periaortic connective tissue, and then a subsequent intramural course in the subaortic myocardium, the myocardium of the right outflow area and major parts of the crista supraventricularis.

The arteries supplying the ***posterior section*** arose from the initial part of the PIA and were

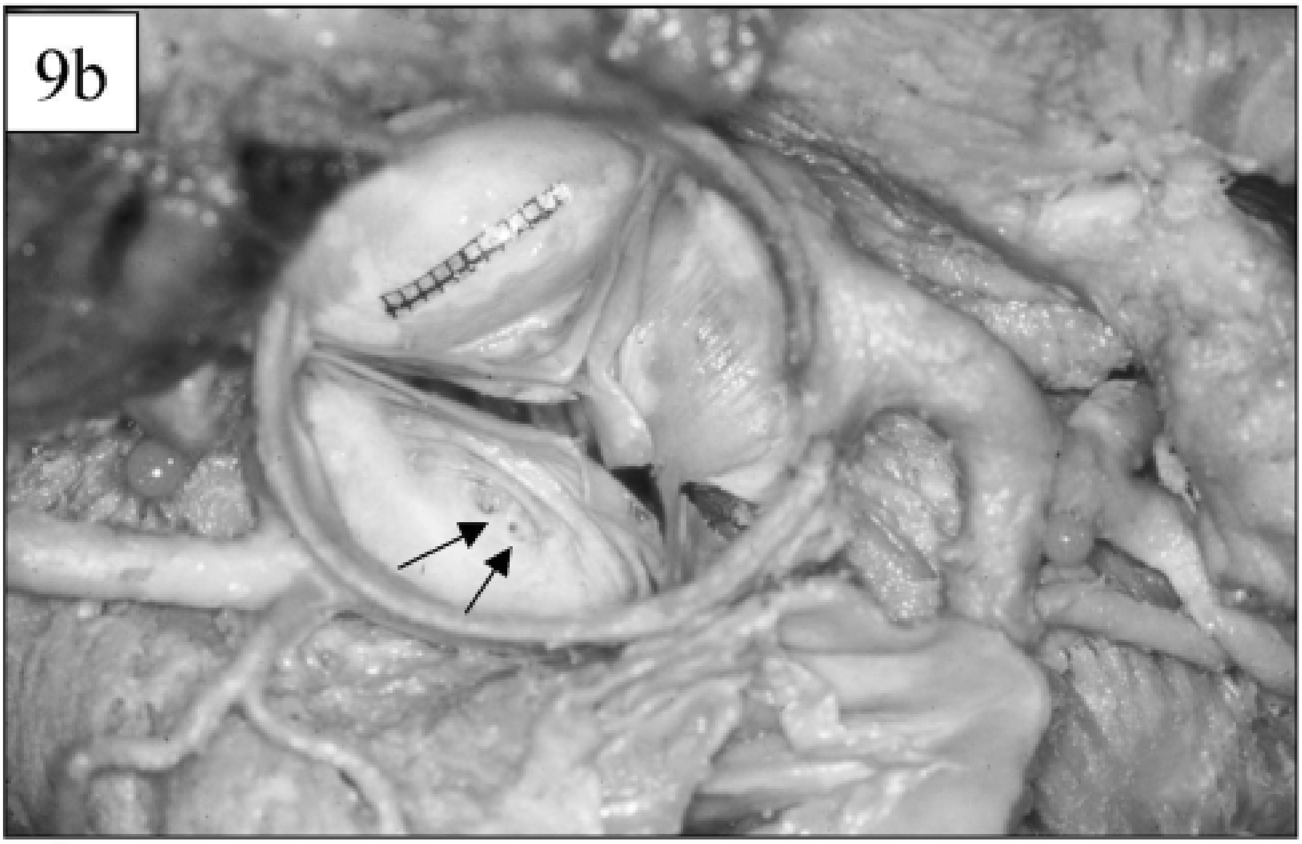

Figure 9 a, b.- Cast (**a**) and cadaver specimen (**b**) of the aortic bulb showing an ectopic "early" origin of a RSSA.
a: Right sided surface of a cast of the aortic bulb showing the right aortic sinus. At the lateral wall of the right aortic sinus a small RSSA arises and courses downward.
b: Aortic valve (seen from above) with its cusps, sinuses, and the stems of the RCA and LCA. At the bottom of the right aortic sinus just above the attached base of the cusp, two tiny ectopic ostias of RSSAS (arrows) can be seen.

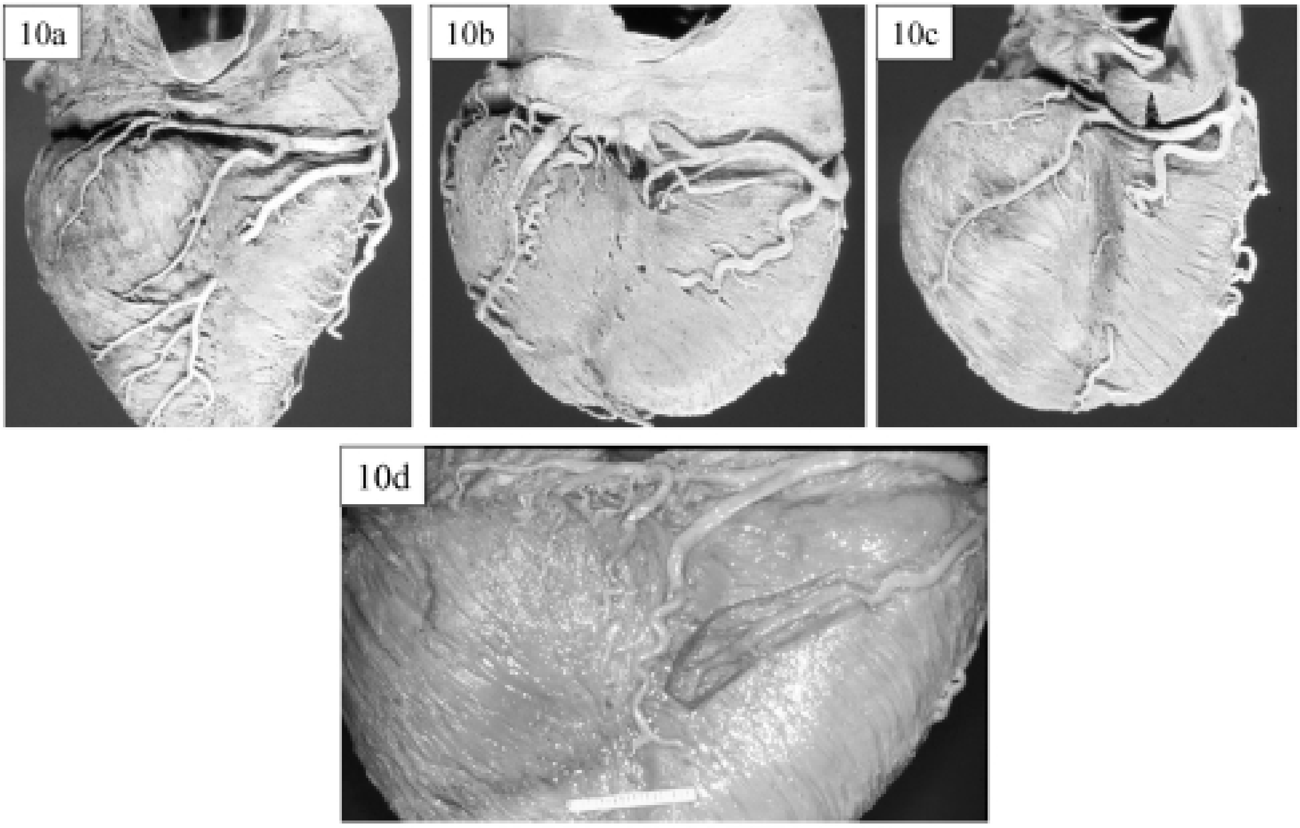

Figure 10 a, b, c, d.- Diaphragmatic surface of cadaver specimens showing various forms of "early" origin of the PIA. In some specimens, a few posterior septal branches originate from a epimurally coursing PIA (**a, b, c**); others originate from an intramurally coursing PIA (**d**).

designated *posterior superior septal arteries (PSSAs*); among them was the *atrioventricular node artery (AVNA)*, which in the region of the crux cordis bifurcated into a small superior branch (running to the posterior fibrous trigonum and AV node) and a tiny inferior twig to the posterior septal myocardium. Therefore, the inferior branch of the *AVNA* was counted among the group of *PSSAs*. One inferior branch may derive directly from the proximal PIA.

The *RSSA* had an average dissectable length of about 30 mm and an average external diameter of 1 mm.

In 18 of the cases examined, an *RSSA* crossed anteriorly to the branches of the anterior septal artery, or to the branches of the main septal artery during its intramural course.

Peculiarities

There was duplication of the *LSSA* in 4 cases; it derived from the anterolateral artery in 3 cases and from the circumflex branch of the LCA in 2 cases.

In 1 case, three *LSSAs* were found, originating from the AIA, anterolateral artery and circumflex branch, respectively.

In 3 cases there was a strong and long (dominant) *RSSA* of substantial appearance arising from the stem of the RCA; the dissectable lengths were 35, 36 and 48 mm respectively and the external diameters about 1.2 mm. Each long *RSSA* entered the subaortic part of the IVS, followed the course of the right bundle, and reached the myocardium of the moderator band (trabecula septomarginalis) and anterior papillary muscle of the right ventricle. It appeared to nourish *in toto* the right ventricular layer of the IVS.

In 2 cases (one a cadaveric specimen and the other a cast) the *RSSA* had an "early" (ectopic) origin in the floor of the right aortic sinus; these vessels measured 16 and 17 mm in length and 0.2 and 0.4 mm in diameter respectively (Figs. 7 b, 8).

Arteries supplying the inferior part of the IVS and its sections

The ***anterior and apical sections*** of the IVS were supplied by anterior and apical septal branches from the terminal AIA. The posterior section was supplied by branches of the terminal PIA. The dissectable lengths of these branches

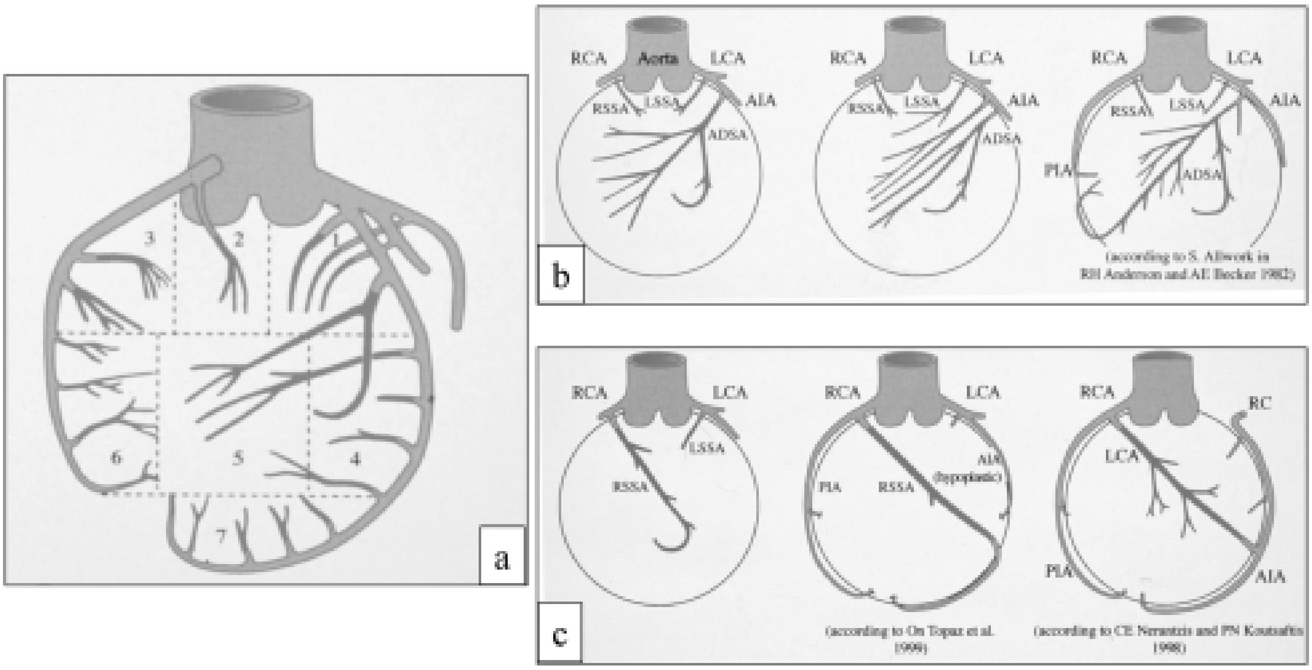

Figure 11 a, b, c.- Schematic drawings showing the septal arteries (seen from dextro-lateral):
a: the most frequently found distribution pattern of the extra- (light) and intramural (dark) parts of the septal arteries: the anterior superior septal branches, among them the ADSA, supply the anterior superior section 1; the right superior septal branch(es) supply the middle superior section 2; the posterior superior septal branches(es) supply the posterior superior section 3; the anterior inferior septal branches supply the anterior inferior section 4; the terminal branches of the ADSA supply the middle inferior section 5; the posterior inferior septal branches supply the posterior inferior section 6; the apical branches supply the apical section 7.
b: Dominance of the anterior septal arteries (frequency 92%). The ADSA may be duplicated. A unique case has been reported by Allwork (1982): a dominant ADSA exhibits a long transseptal course, reaches the posterior interventricular sulcus, and replaces parts of the PIA.
c: A dominance of the RSSA was seen in 4% of the cases studied. It may replace the anterior ADSA. Unique cases showing dominant RSSAs that, after a long transseptal course, replace parts of the AIA (case of Topaz et al., 1999) or the entire LCA (case of Nerantzis and Koutsaftis, 1998).

measured up to 18 mm, with external diameters of less than 1mm.

A superficial twig of the inferior branch descended on a straight, perpendicular course towards the moderator band, the right bundle branch, and anterior papillary muscle. It was designated the *moderator band artery*. This artery crossed the other, deeper branches of the *ADSA* in 12 of the cases examined.

The posterior inferior section was supplied by 2 or 3 tiny *posterior inferior septal arteries* (*PISAs)*. These branches derived from the terminal PIA and pierced the myocardium of the posterior interventricular sulcus; their dissectable intramural length was between 8 and 10 mm.

Peculiarity

In 6 cases a *PISA* branched off from the right marginal artery or directly from the RCA at the right margin. This septal artery exhibited a long epimural course over, and occasionally an intramural course in, the diaphragmatic wall of the right ventricle, and finally reached the posterior interventricular sulcus (Fig. 10).

Preponderance of septal arteries

In 92 cases there was a preponderance of the LCA, given that the majority of septal branches were branches of the AIA (among them the *ADSA*).

In 5 cases there was a balanced septal supply, due to the fact that the *ADSA* and the *RSSA* were approximately of the same length and calibre.

In 3 cases examined there was a preponderance of the RCA, due to the presence of a long and strong *RSSA*, which supplied a large part of the myocardium of the IVS (Fig. 11).

Discussion

The interventricular septum (IVS) plays an essential role in left and right ventricular function: (1) as a dividing wall between the left and right ventricle, (2) as a carrier of the conducting system and (3) as a carrier of numerous intercoronary anastomoses (Farrer-Brown and Rowles, 1969; Paulsen and Vetner, 1973; McAlpine, 1975; James et Burch, 1958; Williams et al., 1989; Topaz et al., 1992b; Topaz and Vetrovec, 1996). Consequently, a patient suffering from anteroseptal infarction is threatened by two –often lethal– complications: (1) septal transmural necrosis and perforation, (2) the rupture of anterior papillary muscles and valve insufficiency, and (3) disturbances in the conducting system (Morettin, 1976; Anderson and Becker, 1982; Haupt et al., 1983; Cabin et al., 1987).

The sources of septal arteries

Most textbooks and atlases show only anterior and posterior septal branches; the former from the AIA, the latter from the PIA (McAlpine, 1975; Williams et al., 1989; Waller and Schlant, 1994; Putz and Pabst, 2000).

The septal arteries may derive from more than just these two sources. Possible sources are (all in% of occurrence according to studies by von Lüdinghausen and Ohmachi (2001), von Lüdinghausen (2003) and our present results):

(1) the AIA, which gives rise to the anterior septal arteries, among them the *LSSA*, the *ADSA*, the *AISAs*, and the *ASAs* (100%)
(2) the proximal stem and ostial area of the RCA, which gives rise to the *RSSA* (44%)
(3) the right aortic sinus, which may give rise to the *RSSA* (3%)
(4) the middle part of the RCA, which gives rise to one or two *PISAs* (18%)
(5) the terminal PIA, which releases the *PSSAs* and *PISAs* (100%)

The possibility of various origins of the *RSSA* has also been referred to by Rodriguez et al. (1961), Topaz et al. (1992a, 1992b), and Topaz and Vetrovec (1996).

The middle part of the RCA may give off one of the *PISAs*. According to our knowledge of the literature, a *PISA* arising "too early" from the middle "marginal" part of the RCA in human hearts has not previously been reported.

The origin of the septal branches from five different sources is a variance with the right or left coronary preponderance generated by the distribution pattern of the coronary arteries on the surface of the heart.

Left superior septal artery (LSSA)

The first branch of the AIA is the *LSSA*, which was found in 54 of the cases studied. According to the anatomical and radiological findings of Beam et al. (1981), Gensini (1984), and Topaz and Vetrovec (1996), the LSSA may arise from the stem of the LCA, or the proximal parts of the diagonal, circumflex or even the left marginal artery.

Anderson and Becker (1982) illustrated a post-mortem angiograph in which the *LSSA* originated from the proximal anterolateral branch of the LCA.

The *anterior descending septal artery* (ADSA) or *main septal artery*

The *ADSA* –the strongest of the anterior septal branches– was found in 64-72% of cases examined by McAlpine (1975), Reig et al. (2001) and by us. This artery is synonymously named *anterior perforator artery* (McAlpine 1975) or *first septal perforator branch* (Haupt et al., 1983). Its stem was found by McAlpine (1975), and Reig et al (2001) to be between 10 and 15 mm in length, with an external diameter of 1.5 to 2 mm.

McAlpine (1975) pointed out that the *ADSA* enters the IVS behind the pulmonary valve. In our findings, the main stem had an average length of 16 mm and bifurcated into a superior and an inferior branch; occasionally there was a third left (deep) branch. The superior branch was found to divide into several twigs supplying the myocardium of the middle superior section of the IVS.

The inferior branch supplied the myocardium of the middle inferior section and released the moderator band artery.

It is notable that the course followed by the *ADSA* and its branches, and that of some branches of the *RSSA*, correspond to the course of the right part of the conducting system (Reig et al., 2001). Therefore, we assume that the branches of the *ADSA* also supply parts of the conducting system, in particular the second and third divisions of the right bundle. Reig et al. (2002) stressed that there are a few cases where superior branches of the *ADSA* supply parts of the first division, and even the His bundle.

We found a stemless *ADSA* in 6 cases; here, two or three stout branches arose from the AIA at the same site. These cases can be interpreted as an "early" division of the *ADSA* or as a duplication or triplication of the ADSA. In the subaortic region, terminal twigs of the upper branch of the *ADSA* may cross terminal branches of the *RSSA*.

Terminal twigs of the lower branch of the *ADSA* may cross a few distal branches of the AIA.

These crossing manoeuvres show that the branches of the *RSSA* and *ADSA* course in a myocardial layer that is related to the right ventricle, while the branches of other anterior septal arteries course in a layer that is related to the left ventricle. Intraseptal arterial crossing manoeuvres have been shown angiographically by Vlodaver et al. (1976).

The moderator band artery

A superficial twig of the inferior branch of the *ADSA* reaches the myocardium of the moderator band (trabecula septomarginalis). Haupt et al. (1983), and Reig et al. (2000, 2001) designated this vessel the *artery of the moderator band*.

Other small twigs of the inferior branch of the *ADSA* also supplied the anterior papillary muscle of the right ventricle; however, it was apparent from our specimens that this artery is not always the exclusive means of supply to the papillary muscle. There were six cases in which two or three dissectable arteries supplying the moderator band derived from sources other than the *ADSA*. These other sources were the stem of the AIA, the fourth or fifth branch of the AIA, and the *RSSA*. To our knowledge, such results have not been reported previously.

Right superior septal artery (RSSA)

Both the origin and the significance of the *RSSA* vary. It may arise from the proximal part of the RCA or derive from the sinuatrial artery, the conal artery, the ostial area of the RCA, or even "early" from the right aortic sinus (von Lüdinghausen and Ohmachi, 2001).

The *RSSA* supplies the subvalvular myocardium, the myocardium in the area of the crista supraventricularis, and the dorsal wall of the conus arteriosus (Bream et al., 1979; Taylor, 1980; Reig-Vilallonga et al., 1983; Rath et al., 1986).

A dissectable, intramurally-coursing *RSSA* was found in between 12% and 77% of cases, with a diameter ranging from 0.3 to 1.6 mm and a length from 11 to 16 mm, in the various studies (Campbell, 1929, Urwitz, 1937, Rodriguez et al., 1961, McAlpine, 1975, and von Lüdinghausen and Ohmachi, 2001). Bream et al. (1979) visualized the RSSA as present in 3% of the living population. Rath et al. (1986) documented the *RSSA* angiographically in 0.29% of their patients suffering from severe obstructive coronary heart disease. When originating directly from the right aortic sinus, the *RSSA* was found by von Lüdinghausen and Ohmachi (2001) to provide collateral circulation to branches of obstructed right and left coronary arteries and was designated by them as an equivalent of the *LSSA*.

The *RSSA* is not mentioned in the Terminologia Anatomica (1998). It is designated under different names that are used as synonyms (von Lüdinghausen, 1997): septal perforator coronary artery (Rath et al., 1986), right superior septal perforator artery (Bream et al., 1979), ramus superior septi interventricularis (McAlpine, 1975), ramus cristae supraventricularis (Campbell, 1929; Smith, 1962), the artery of the crista supraventricularis (McAlpine, 1975), descending septal branch (Smith, 1962), and descending septal artery (Rodriguez et al., 1961; Taylor, 1980).

In two of the cases examined in the present study there was a long and strong "dominant" *RSSA* of substantial appearance arising from the stem of the RCA. The dissectable lengths were 35 and 36 mm, and calibres 1.5 and 1.6 mm respectively. The vessel entered and nourished the superior third of the IVS.

Allwork (1979) and Anderson (1982) presented a cast of the coronary arteries exhibiting a further dominant long and strong *RSSA*, which entered the middle superior section of the IVS, traversed the middle inferior section in an oblique anterior direction, and gave off numerous septal branches. After its long intraseptal course, it appeared again on the surface of the heart in the inferior part of the anterior interventricular sulcus. This *RSSA* replaced the terminal AIA and its septal branches.

Topaz et al. (1999) reported one case in which a stout *RSSA* arose from the right aortic sinus, traversed between the aorta and pulmonary artery, and followed an intraseptal course to the anterior interventricular sulcus. Here it supplied most of the anterior myocardial wall of the left ventricle. In so doing, this large artery replaced an almost hypoplastic AIA.

Posterior inferior septal arteries (PISAs)

In the present study, the posterior inferior section of the IVS was found to be supplied by septal branches of the terminal PIA: the *PISAs*.

In 12 cases there was an ectopic origin of a *PISA* from the right marginal artery or the RCA itself. This branch coursed epimurally over, or intramurally in, the diaphragmatic wall of the right ventricle towards the posterior interventricular sulcus. Here it contributed to the supply of the posterio-inferior section of the IVS. Such an ectopically arising and coursing branch has never been described before; however, it is seen in McAlpine's Atlas in one specimen but is not mentioned or highlighted as a remarkable occurrence.

Developmental anatomy of septal arteries

Regarding the vascular supply of the IVS is concerned, a few observations should be made about aspects of the development of the IVS itself. The main apical (inferior) muscular part of the IVS begins development on the 27th day of the existence of a 6 mm long embryo (Langman, 1977; Moore, 1988). The basal (superior) membraneous part of the IVS is formed by material from the right and left conal bulges and conal septum respectively and the posterior atrioventricular endocardial cushion. The development of the IVS is complete in an embryo at Carnegie stage 20 of 20 mm length (O'Rahilly, 1971; Hirakow, 1983; Hutchins et al., 1988; Williams et al., 1989).

Recording to the findings of Grant (1926), Hill (1936), Chase and De Garis (1939), Voboril and Schiebler (1970), Hackensellner (1955), Licata (1956) and Frick (1956, 1960), it is certain that the coronary arteries appear as endothelial sprouts or solid angioblastic buds in the walls of the base of the aorta.

Superficial coronary arteries-Anlagen have been found at the earliest in human embryos at Carnegie stages 18-19, exhibiting a length of 12 to 19 mm in the 6th to 7th week (Licata, 1956; Conte and Pellegrini, 1984; Hutchins et al., 1988; Christ, 1990).

The arteries course at first to the bulbus cordis and then spread over the rest of the heart, joining up with the capillary network formed by the veins and intertrabecular spaces in the developing myocardium.

More than two endothelial outgrowths at the aortic bulb may constitute remnants of the number of coronary arteries that sometimes develop at the roots of the aorta and the pulmonary artery during early developmental stages in mammals. However, except for the two coronary arteries, in most human hearts these frequent vascular Anlagen disappear.

To date, the morphogenesis of intraseptal arteries has not been determined.

Comparative anatomy of septal arteries

Intraseptal anastomoses

In the heart specimens of many mammals (except humans) numerous potential sites have been found for intraseptal anastomoses between the cranial and caudal descending arteries (Christensen, 1962) corresponding to the AIA and PIA of the human heart. Numerous intraseptal anastomoses have been described by Moore (1930).

Left superior septal arteries (LSSA) and *posterior superior septal arteries (PSSA)*

In pigs there is a rather small first branch of the AIA which may be designated an equivalent to the *LSSA*: it supplies the anterior superior section of the IVS. Moreover there is an equivalent to the PSSA that supplies the posterior superior section (Fehn et al., 1968).

In dogs there is a small artery which may be addressed as an equivalent of the *PSSA*, but not of the *LSSA* (Fehn et al., 1968).

Anterior descending septal artery (ADSA) or *main septal artery*

An equivalent of the *ADSA* has been found in many instances of the IVS in the horse, cow, sheep, pig and dog (Moore, 1930; Kazzaz and Shanklin, 1950; Donald and Essex, 1954; Wolfe, 1959; Christensen and Campeti, 1959; Blair, 1961; Christensen, 1962; Bertho and Gagnon, 1964; Fehn et al., 1968). Fehn et al. (1968) named this equivalent the *ADSA;* Moore (1930), Donald and Essex (1954), Blair (1961) and Christensen (1962) simply designated it a *septal artery*.

In the dog, this *septal artery* has been found to bifurcate or even trifurcate and release many branches to the superior and inferior middle parts of the IVS, supplying almost 75% of the septal myocardium (Moore, 1930; Pianetto, 1939; Ohmachi, 2000).

In the sheep, the *septal artery* has been found to exhibit a variable length and in most cases to be of relatively little significance. When it was a long vessel it extended across the width of the septum; however, it was sometimes absent (Christensen, 1962).

In the ox, two *septal arteries* have been found, arising 1 cm apart and extending between one half and all of the way through the IVS. Unlike in the human heart, the penetrating branches of the caudal descending artery (equivalent to the PIA) contribute significantly to the arterial supply of the IVS. In the pig, the *septal artery* may be absent (Christensen, 1962).

Right superior septal artery (RSSA)

An equivalent to the *RSSA* is well established in the heart of some mammals; in the heart of the rat it originates from the proximal stem of the RCA and courses to a depth and to the right between the aorta and pulmonary conus to reach the cephalic portion of the IVS on the right side (Halpern, 1957). It supplies the upper third or even the upper two thirds of the IVS. Halpern (1957) designated this branch of the RCA simply the “septal artery”.

A similar artery was noted in 66% of porcine and bovine hearts (Rodriguez et al., 1961), where it reportedly supplied more than 50% of the septal myocardium (Urwitz, 1937; Rodriguez et al., 1961). In equine hearts, a dissectable equivalent to the *RSSA* existed in about 32% of the cases studied by Rodriguez et al. (1961).

In the Syrian hamster, the vessel equivalent to the *RSSA* originated from the proximal portion of the right coronary artery in 28.2% and from the right aortic bulb with a separate ostium in 4.5% of cases examined by Sans-Coma et al. (1993). One or two arteries corresponding to the RSSA have been described, but not named, in the heart of the Asian elephant by Hill (1936) and Cave (1936). In *Macaca fuscata*, such an artery was found in 60% of the cases examined by Urwitz (1937).

In their studies of the hearts of higher primates, Abramson and Eisenberg (1935), Chase (1938), Chase and De Garis (1939), and Frick (1970) make no mention of an artery resembling the RSSA.

The *RSSA* has also not been identified in the hearts of reptiles (Spalteholz, 1908; Grant, 1926; Grant and Regnier, 1926), cats (Pianetto, 1939; Urwitz, 1937; Rodriguez et al., 1961), or dogs (Moore, 1930; Pianetto, 1939; Donald and Essex, 1954; Christensen and Campeti, 1959; Fehn et al., 1968).

The clinical anatomy of septal arteries

Peculiarities of the arterial supply of the IVS

The frequent and rather long branches of the AIA supply the anterior two thirds or even three quarters of the bulky myocardium of the IVS of the human heart. The rather small branches of the PIA, among them the *AVNA*, supply the posterior third or quarter of the IVS. These findings confirm the results of morphologists such as McAlpine (1975), Paulsen and Vetner (1973), von Lüdinghausen (2003), and many clinicians, for example Isner and Roberts (1978), Haupt et al. (1983), and Cabin et al. (1987).

The PIA (as above “the rather small branches of the PIA, among them the *AVNA*”) which supplies the posterior third or quarter of the IVS was found to originate from the RCA in 90% or from the circumflex branch of the LCA in 10% of the cases examined by Schoenmakers (1963), von Lüdinghausen (1975) and von Lüdinghausen and Ohmachi (2001).

In exceptionally rare cases, the *ADSA* exhibits a conspiciously long transseptal course and even replaces the PIA, thus supplying more than half of the IVS (Allwork, 1979; Anderson and Becker, 1982).

The proximal branches of the RCA, among them the *RSSA*, have been rather neglected as regards their role as suppliers of the superior sections of the IVS. In a few cases the *RSSA* has been found to be the dominant septal artery when it supplies more than half of the IVS and replaces the AIA or even the entire LCA (Topaz et al., 1999; Nerantzis and Koutsaftis, 1998).

Intraseptal collateral routes

Septal arteries are known as routes of inter- and intracoronary collateralization. The sources for such collateralisation are (among others) epimural arteries that are situated between a narrowed or even obstructed AIA and the PIA and course from a location proximal to any stenosis (Gross, 1921; Baroldi et al., 1956, Helfant and Gorlin, 1972; Paulsen and Vetner, 1973; McAlpine, 1975; Vlodaver et al., 1976, Isner and Roberts, 1978; Haupt et al., 1983; Rath et al., 1986; Turner and Navaratnam, 1996; Reig et al., 2000).

Among the transseptal collateral arteries, the *ADSA* is of the most importance when it arises from the proximal AIA and in a proximal position to a severe narrowing, and when the *RSSA* originates close to, or in, the ostial area of the RCA in the right aortic sinus itself (von Lüdinghausen and Ohmachi, 2001). Angiographically, Paulsen and Vetner (1973) and Vlodaver et al. (1976) demonstrated the *RSSA* to be present twice as often in hearts that exhibited occlusion than in those without. These authors emphasized the significance of *RSSAs* and other septal branches as potential bypass circuits.

In cases of acute proximal right coronary artery occlusion there is an intensive collateral flow from the AIA and its main branches (the *ADSA* and the moderator band artery); such a collateral flow may prevent infarction of the right ventricle (Haupt et al., 1983; Allwork, 1987; Reig et al., 2000).

Septal arteries and the arterial supply of the conduction system

According to James and Burch (1958), McAlpine (1975), and our findings, the course of the *RSSA*, of the superior and inferior branches of the *ADSA*, and of the moderator band artery corresponds to the course followed by the second and third divisions of the right bundle branch in the moderator band. The posterior septal branches (which run from the initial part of the PIA) may also provide branches to the first division and even to the His bundle (Campbell, 1929; James and Burch, 1958).

Septal arteries and septal infarction

According to Hermanek (1954), Bakst et al. (1973), Bakst et al. (1974), and our findings, the risk of a septal infarction, septal perforation, rupture of a papillary muscle and severe disturbance of the conducting system increases when the following morphological phenomena coincide: (1) a strong and long *ADSA* and an occlusion of the proximal AIA, and (2) a strong and long *RSSA* and an occlusion of the proximal RCA.

Preponderance of septal arteries

In most of the cases examined by McAlpine (1975) and in 93% of our cases there was a left septal preponderance because the AIA releases frequent and strong septal branches, among them the *ADSA*, for the arterial supply of the IVS.

However, in 4% of our cases there was a balanced type of arterial septal supply because the *ADSA* and *RSSA* were of equal length and diameter and supplied an approximately equally-sized part of the IVS.

In the remaining 3% of our cases there was a right septal preponderance because the *RSSA* was strong and long (more so than the *ADSA*) and supplied the middle superior and middle inferior sections of the IVS and also the moderator band and the anterior papillary muscle of the right ventricle.

A really dominant *ADSA* exhibiting a long transseptal course and replacing the distal part of the PIA was reported by Allwork (1979) and Anderson and Becker (1982).

A case of extreme right septal preponderance exhibiting a dominant *RSSA* was shown by Topaz et al. (1999), who described a *RSSA* that followed a long transseptal course towards the anterior interventricular sulcus. Here the terminal *RSSA* replaced the distal two thirds of the AIA.

A similar case was reported by Nerantzis and Koutsaftis (1998): a stout *RSSA* exhibited a long transeptal course towards the inferior part of the anterior interventricular sulcus and there entirely replaced the LCA and all its branches.

According to our findings, septal arterial preponderance bears no relation to the arterial preponderance of the coronary arteries on the surface of the heart.

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