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Vascular Supply of Interventricular Septum of Human Heart

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Despite the numerous investigations into the blood supply of the ventricles of the human heart, little attention has been paid to the finer details of the vascular pattern of the arteries of the interventricular septum. In view of the importance of the effects of any deficiency in the blood supply to the septum, a comparison was made of the normal and diseased vascular patterns seen in the interventricular septum and in the free walls of the left and right ventricles.

The present paper reports the results of an investigation in which hearts were examined by postmortem injection and microradiographic and histological techniques.

Material and Method

Examinations were made of 76 hearts obtained at necropsy of 12 infants and children ranging in age from stillbirths to 9 years, and 64 adults from 31 to 85 years. All were male except for 9 children and 4 adults.

All 12 hearts from children and 18 from the adults were considered "normal", and 46 adult hearts showed diffuse or localized lesions of either the left or right ventricles.

The vasculature was studied by injecting a radiopaque medium (Colorpaque,* Pilot Chemical Co. Ltd.) into the coronary arteries (Farrer-Brown 1967, 1968a). After fixation, the hearts were sectioned on a bacon slicer from apex to base into uniform 5 mm. thick slices. When necessary the myocardial slices were recut on the bacon slicer or on a Sartorius freezing microtome with a thermomodule stage.

The general pattern of the large vascular supply of the myocardium was visualized by *x*-raying these slices onto fine grain *x*-ray film, initially using a G.E.C. *x*-ray unit and Superay Ansco film, but for the last 24 hearts using a water-cooled, low voltage Machlett *x*-ray tube and Microtex (Kodak) *x*-ray film.

In order to demonstrate the finest vessels, selected slices were *x*-rayed onto Kodak maximum resolution plates using the Machlett *x*-ray tube; 25 kV and 10–20 mA exposures were used for 15–35 minutes according to the thickness of the slice.

Portions of the interventricular septum and the ventricles of the first 52 hearts, and whole transverse ventricular slices of the last 24 hearts were also examined by conventional histological techniques.

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* Formerly Chromopaque, Damancy and Co.

Results

The interventricular septum was found to be supplied by large branches from the anterior and posterior descending coronary arteries which entered the septum at right angles to the pericardial surface and ran towards each other. The largest arteries lay in the middle, or a little to the right of the middle of the septum and ran parallel to the endocardial surfaces. At the apex, the source of the blood supply depended on the position of the anastomoses of the anterior and posterior descending coronary arteries. The major portion of the rest of the interventricular septum was supplied by branches of the anterior descending artery, and in half the hearts studied two-thirds of the septum was supplied from these branches.

The large septal arteries gave off secondary branches, often almost at right angles, which supplied the right and left sides of the septum. In adult hearts, the pattern on each side of the septum closely resembled the respective patterns described for the right and left free ventricular walls (Fig. 1) (Farrer-Brown, 1968b, c).

On both sides of the septum the main septal arteries gave off "branching" and "straight" type arteries. The left side showed regular spacing of the "branching" arteries which divided in a cascading tree-like pattern and gave off small branches of gradually diminishing calibre, the terminal branches supplying the subendocardial zone in a similar manner to that seen in the free wall of the left ventricle. A similarity was also seen between the "straight" type arteries supplying the trabeculae

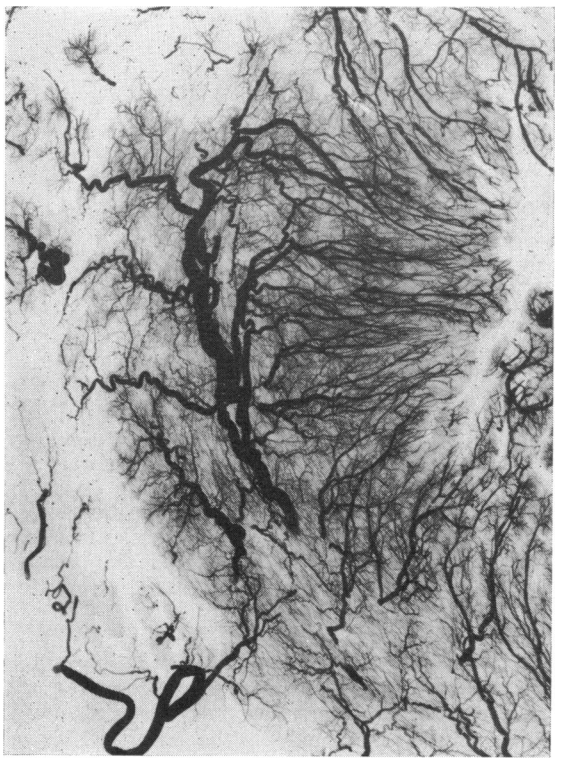

FIG. 1.—A microradiograph of the interventricular septum of a 5 mm. thick ventricular slice from the heart of an adult to show the contrast of the vascular pattern of the arteries supplying the left and right sides of the septum. This was the most striking contrast seen. (×3·3.)

carneae along the left side of the interventricular septum and the "straight" arteries in the left ventricular free wall. These arteries gave off only a few branches and maintained their calibre until their final termination.

The secondary branches on the right ventricular side of the septum did not show the conspicuous tree-like pattern of branching seen on the left side, though the larger branches going to the trabeculae carneae were prominent and passed into the middle of these muscle bundles and then gave branches to their periphery.

When the vasculature down to the small arteries had been injected, the blood supply of the right side of the interventricular septum appeared to be less than the left, but in those hearts in which either arterioles (Fig. 2) or capillaries had been filled the radiographic density of these vessels on each side of the septum was similar.

The contrast in the small arterial pattern of the two sides of the septum was also seen in the hearts of two children of 5 and 9 years of age (Fig. 3). No

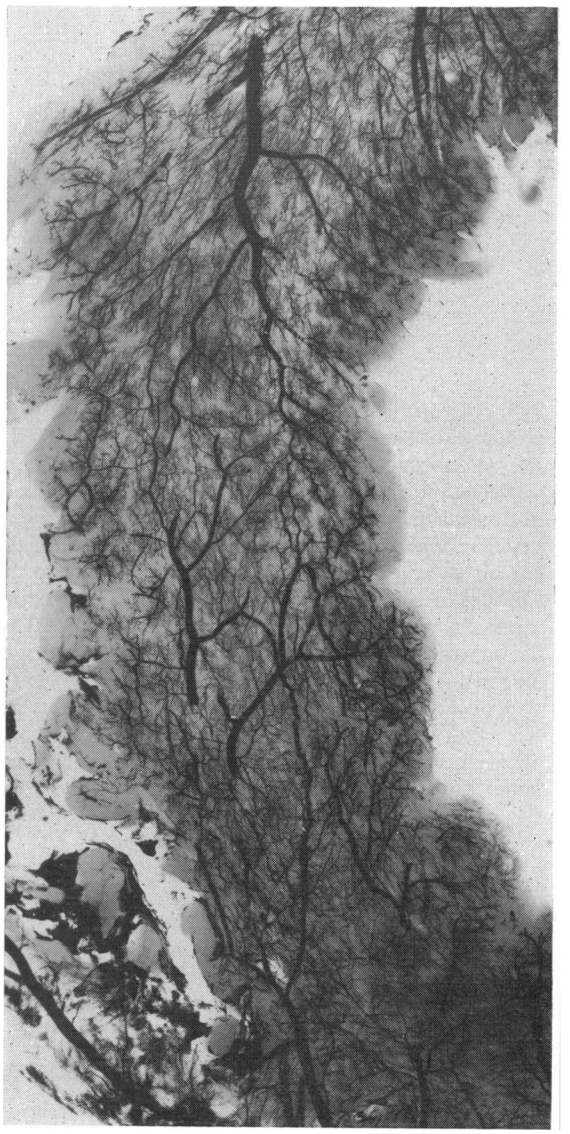

FIG. 2.—The radiographic density of the blood vessels on the left and right sides of the interventricular septum appears similar when medium has filled arterioles. (×2·5.)

such difference in pattern was seen in the hearts from stillbirths or infants (Fig. 4), but at this age there was no obvious difference in the pattern of the blood supply of the right and left free ventricular walls.

In hearts in which the only abnormality was hypertrophy of the myocardium of the free wall of the left ventricle, there was a tendency for the main septal branches of the anterior and posterior descending arteries to run slightly more to the right

FIG. 3.—A microradiograph of the interventricular septum of a 5 mm. thick mid-ventricular slice from the heart of a 5-year-old child, to show the contrast in arterial pattern of the right and left sides. (×3·5.)

FIG. 4.—No significant difference in the pattern of the arteries on the two sides of the interventricular septum is seen in this microradiograph of a 5 mm. ventricular slice from an infant. (×11.)

of the septum than in apparently normal hearts. Consequently, a slightly greater portion of the septum showed a vascular pattern similar to that of the left ventricular free wall.

Some degree of "waviness" of the main septal arteries was seen in the majority of the hearts. The appearance of these vessels was quite different from the extreme tortuosity of anastomotic arteries present between the anterior and posterior septal arteries. Fig. 5 illustrates the almost corkscrew appearance of these vessels which were more numerous and larger (up to 440 μ) in hearts showing severe coronary artery disease. The majority of these vessels ran in the centre of the septum rather than at the sides. Small tortuous vessels up to 50 μ were also seen in the hearts of stillbirths and infants. These were usually scanty, but one heart of an infant, who died within 2 hours of birth with respiratory distress syndrome, showed a consider-

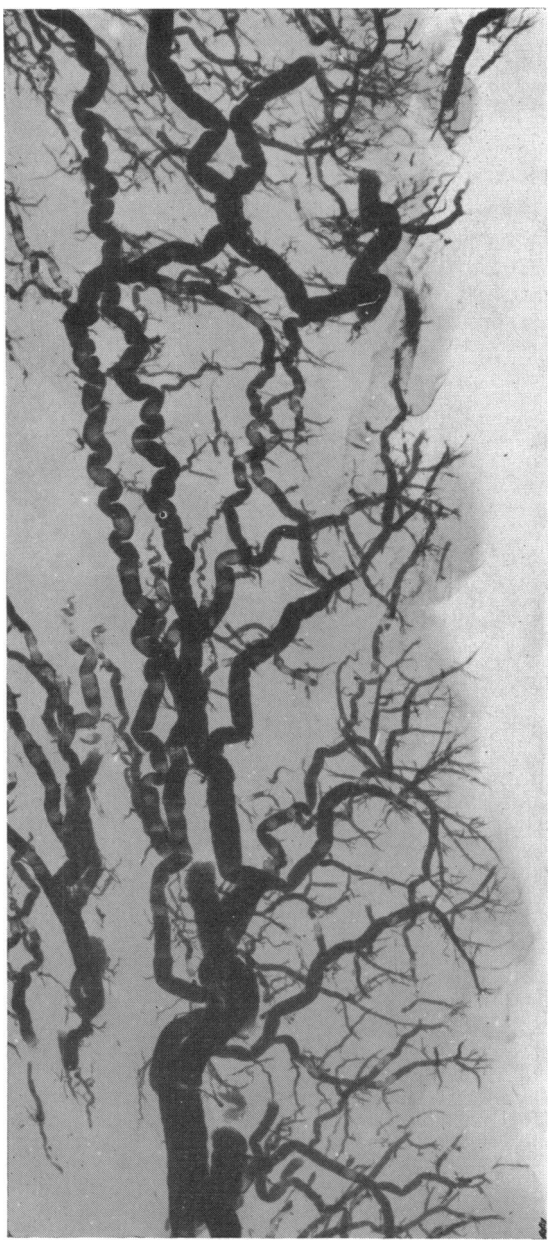

FIG. 5.—Typical tortuous anastomotic vessels, the largest about 350 μ in diameter, between the terminal septal branches of the anterior and posterior descending arteries in a heart from an adult with severe coronary artery disease. (×7.)

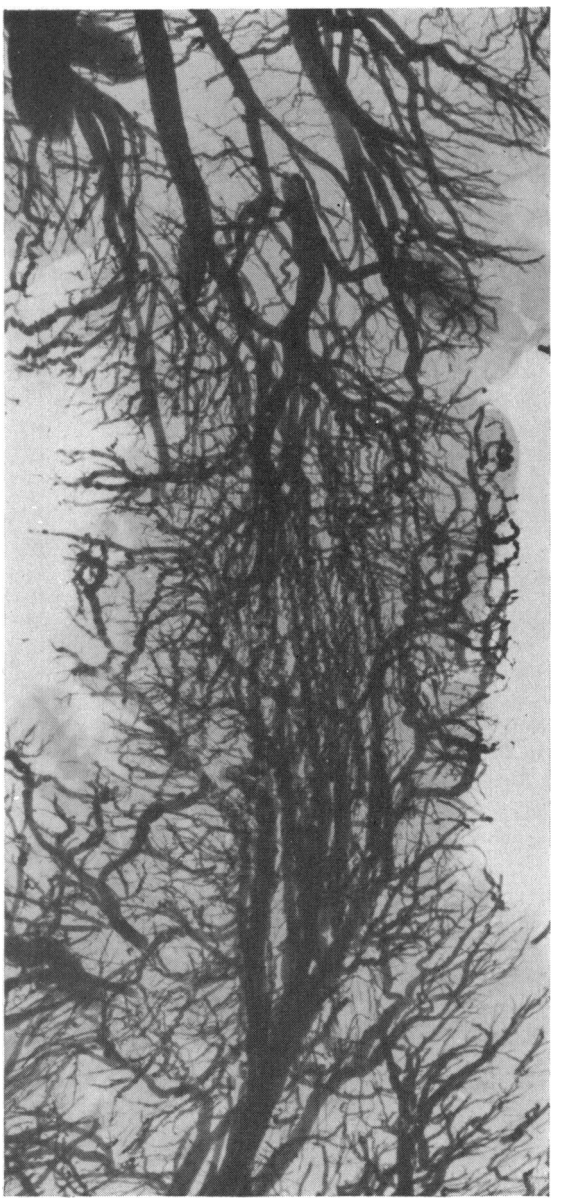

FIG. 6.—A 5 mm. thick slice of the interventricular septum from an infant who died within 2 hours of birth shows tortuous anastomotic arteries about 50 μ in diameter running mainly in the central third of the septum with few of these vessels at the sides. (×11·8.)

FIG. 7.—Loss of normal arterial pattern and replacement by an increased number of large arteries is seen in an area of fibrosis on the left side of the interventricular septum of a heart from a patient with severe coronary artery disease. (×5·5.)

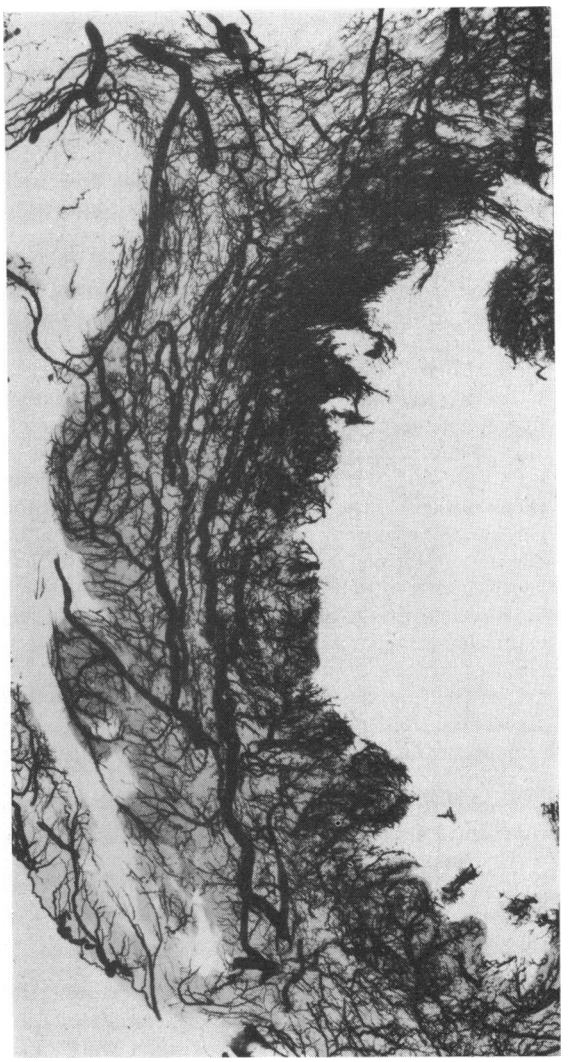

FIG. 8.—A "plexus" is shown on the left side of the posterior half of the interventricular septum from a heart from a 43-year-old man, who had had a myocardial infarction 7 months before death. (×2·3.)

able number of these vessels, the majority of which ran in the central portion of the septum with few at the sides (Fig. 6).

Fibrosis in the Interventricular Septum. The changes in the vascular pattern seen in fibrosis of the interventricular septum were, in many ways, similar to those seen in fibrosis of the left ventricular free wall (Farrer-Brown, 1968d) and also showed a relation with the extent and density of the fibrous tissue.

Small areas of fibrosis, which were best visualized when capillary filling had been achieved, showed an absence of main arteries in the area and few capillary vessels.

In larger areas of scarring, the pattern of the large septal arteries was abnormal, with loss of the normal pattern of "branching" and "straight" type arteries. An increased number of large arteries was seen and instead of being mainly in the centre of the septum they were also present running circumferentially at the sides in a disorderly manner. The changes were usually more pronounced on the left side of the septum (Fig. 7).

A localized increase in small vessel density, previously referred to as a "plexus" (Farrer-Brown, 1968d), was seen on the left side of the interventricular septum in 4 hearts from patients with severe coronary artery disease (Fig. 8). In each instance the appearances were similar to "plexuses" which were also present in the left ventricular free wall. The interventricular plexus consisted of a circumferential component of dilated small arteries, arterioles, and capillary-like vessels and a more radially running component of dilated larger arteries. In contrast to the "plexuses" seen in the free wall of left ventricles, a number of dilated large arteries were also running in a circumferential direction.

In two of these hearts, histology showed that fibrosis of the myocardium was confined to the left side of the septum and was related to the area of each "plexus". The fibrosis was most dense along the *inner* half of the left side of the septum and the extent of these areas of fibrosis was similar to the degree of fibrosis seen in "plexuses" in the left ventricular free walls.

In one heart showing a recent infarct of the left ventricle, superimposed on areas of fibrosis, a band of fibrous tissue was present in the anterior half of the interventricular septum which extended across the left two-thirds of the septum. The remaining third of septum appeared normal histologically.

The distribution of main septal arteries from the right and left coronary arteries in these three hearts was normal, and the right and left sides of the septum were supplied by the same large septal arteries.

Discussion

This study has confirmed the presence of the main septal branches of the anterior and posterior descending arteries described by such workers as Gross (1921), Campbell (1929), James (1961), Fulton (1965), and Mitchell and Schwartz (1965).

In addition, the present findings are in agreement with their descriptions that the major part of the interventricular septum of all hearts is supplied by branches of the anterior descending artery. This dominance of the left coronary artery is obviously of importance when considering the extent of a myocardial infarction of the left ventricle which involves the septum.

The microradiographs of the transverse slices have emphasized that in normal hearts the large septal arteries lie near the middle, or to the right of the middle of the septum, as originally observed by Spalteholz (1924). However, the manner in which these arteries give off secondary branches, and the findings that the *pattern* of branches to the left side of the septum resembles that of the left ventricular free wall, while those of the right side resemble the right ventricular free wall, do not appear to have been previously described.

It is of interest that the contrast in arterial pattern on the two sides of the septum is not seen in the hearts of infants or stillbirths.

Gross and Kugel (1933), commenting on the *x*-ray appearances of the arteries of the heart from an 11-day-old infant, stated that "even at this early age period the part of the septum which belongs to the right ventricle receives larger blood vessels and more of them than does the corresponding part of the left ventricle". This was not confirmed in the present study, in that no obvious difference in the vascularity of the two sides of the septum was seen in the hearts from stillbirths and infants aged up to 2 weeks.

While only a few hearts of the 6-month to 5-year age-group have been studied so far, the available evidence indicates that the contrast in the patterns develops as the muscle mass of the left ventricle increases compared to the right. Gross and Kugel (1933) described a change in the "richness" of the vascular supply of the two sides of the interventricular septum occurring with increasing age, but it should be pointed out that though there is an apparent variation in the density of small arteries on the two sides, a uniform vascular density is seen when filling of capillaries is present. This observation is of importance when considering the blood supply not only of the individual muscle fibres but also of the neural conducting tissue in the interventricular septum. However, the technique used in this investigation was not adaptable to make a detailed study of this latter tissue. The differentiation of conducting cells from the muscle fibres in transverse ventricular histological sections is difficult, and, as Hudson (1965) points out, it is necessary to show that the former tissue originates from the bundle of His before positive identification can be made.

In methods of dividing the heart into right and left sides, the allocation of the septal weight has proved difficult. A division of the septum in proportion to the weight of the right and left ventricular free walls was used by Müller (1883). Lewis (1914) sliced the septum to include a portion with both free walls, leaving a small central strip of septum. Herrmann and Wilson (1922) divided down an arbitrary line, while Fulton, Hutchinson, and Jones (1952) cut off the free right ventricular wall and weighed the free left ventricle and interventricular septum as one part. While this present study has not been concerned with a comparison of the weights of the left and right ventricle, the contrast of small

artery pattern on the two sides of the interventricular septum suggests that the line of the main septal arteries may allow a more accurate functional division of the interventricular septum.

In hearts with hypertrophy of the myocardium the large septal branches coursing through the interventricular septum tended to lie slightly more to the right compared with normal. This is of interest in view of the finding by Fulton *et al.* (1952) that septal hypertrophy is more common and more pronounced in left than in right ventricular hypertrophy, and may be additional evidence for the suggestion that functionally the interventricular septum may be divided into right and left sides. Another factor in favour of this suggestion is the localization of the "plexus" formation and of fibrosis to the inner half of the left side of the interventricular septum in two hearts from patients with severe coronary artery disease. The appearances of these areas were identical to the degree of fibrosis seen in the areas of "plexus" formation in the free wall of the left ventricle. It is generally accepted that these changes in the left ventricle are the result of ischaemia following a deficiency in the blood supply, and consequently it suggests that though the main supplying septal artery is the same for both sides of the septum, the blood supply to the damaged area on the left side becomes deficient. This may be due to a number of factors. It is possible that the right side of the septum maintains its blood supply via a collateral network; that in man a gradient of pressure exists across the septum similar to the gradient across the free wall of the left ventricle in cats (Johnson and Di Palma, 1939). In addition, less flow of blood may occur in this area during diastole.

The extent of muscle damage across the septum will obviously vary from heart to heart, as illustrated by the heart with a recent infarct superimposed on an old infarcted area having a band of fibrous tissue extending from the left side for two-thirds of the septum. The degree of coronary atheroma in the main coronary arteries and the rapidity of any occlusion or thrombosis in these vessels may be additional factors in determining the extent of any fibrosis.

The tortuosity of the anastomotic arteries between the terminal septal branches of the left anterior descending and right posterior descending arteries has been noticed in adult hearts by a number of workers. By injecting medium down one coronary artery, Laurie and Woods (1958) have shown the presence of anastomotic vessels in three newborn infants, but they did not illustrate these vessels. Baroldi, Mantero, and Scomazzoni (1956), using a corrosion method following injection of latex down the coronary arteries, described the corkscrew appearance of intercoronary anastomotic vessels in the interventricular septum in hearts both from infants and adults. They stated that these vessels were often in bundles and that 20–30 were usually observed. The youngest patient whose heart they illustrated was, however, a 16-year-old.

This present study shows that these anastomotic vessels are present at birth, and in particular the heart from an infant, who died two hours after birth with a respiratory distress syndrome, showed that they ran mainly in the central third of the septum, thus having a similar distribution to the tortuous anastomotic vessels seen in the adult. The functional significance of these vessels at this early age is difficult to assess, but presumably their possible enlargement in adult life explains the finding of frequent anastomotic vessels about 40 μ in diameter in hearts from patients with severe coronary artery disease.

Summary

The vascular pattern of the interventricular septum in a series of 76 human hearts has been studied at necropsy by injecting a radiopaque medium, and taking microradiographs of transverse myocardial slices.

The arrangement of the large septal arteries, arising from the anterior and posterior descending coronary arteries, and their division into "secondary" branches with the pattern of each side of the septum closely resembling the respective patterns in the right and left free ventricular walls, are described.

The changes in pattern seen in fibrosis of the interventricular septum are also described. The presence of tortuous anastomotic arteries in the interventricular septum of infants is illustrated, and the possibility that functionally the interventricular septum may be divided into right and left halves by the line of the main septal arteries is discussed.

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