The Coronary Arteries in Coarctation of the Aorta

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SUMMARY
The histological changes found in the coronary arteries in 15 patients with coarctation of the aorta have been described. Qualitative and quantitative studies were performed and the results compared with the findings of a matched control group of patients without heart disease.

Severe changes in the intima during early life and even the severe atheroma which appears in young persons are considered to be a reaction to coronary hypertension. The striking thickening of the media in the coronary arteries is also thought to be a reaction to the altered hemodynamic forces.

In coarctation of the aorta the coronary arteries are of greater than normal capacity, and it is suggested that this histological feature parallels the increased metabolic requirements of the left ventricle.

Additional Indexing Words: Coronary sclerosis Hypertension Arteriosclerosis Congenital heart disease

No histological study of the coronary arteries in coarctation of the aorta has, to the best of our knowledge, been published.

Coronary artery changes in supravalvular aortic stenosis, with hypoplasia of the ascending aorta which produces coronary hypertension, have been reported in a 2-year-old boy. Vessels, other than coronary arteries, from patients with coarctation have been studied and have shown thickening of the vessel wall, as well as narrowing of the lumen, in the arterioles of the arm and the leg, the thyroid, pancreas, kidney, and periadrenal tissue.

In this investigation, the histological changes in the coronary arteries in 15 cases of coarctation of the aorta have been studied and correlated with the hemodynamics of this malformation.

Methods
The histological specimens were obtained from 15 hearts of patients in whom coarctation of the aorta was the sole anomaly. All patients were males; 10 were aged between 2 and 10 years and five, between 10 and 30 years.

The cases chosen for study were those in which the obstructive anomaly was situated near or at the junction of the aortic arch and the descending aorta. Transverse sections were taken from the left and right coronary arteries 1 cm from their ostia and from the anterior descending branch of the left coronary artery, 1 cm below its origin.

For the qualitative study, histological sections were stained with hematoxylin-eosin and elastica-van Gieson stains. For the quantitative study, the viso-planimetric method previously described was employed.

Results
Histology
Marked intimal changes were present. In addition to degenerative and proliferative changes of the elastic fibers of the intima, there was excess collagen tissue (fig. 1), when compared with normal hearts, matched for age and sex. In young men with this malformation, atherosclerotic lesions were also conspicuous (fig. 2).

The musculo-elastic layer was fairly well developed at all ages but was relatively less...
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Figure 1

Left coronary artery from a 10-year-old boy with coarctation of the aorta complicated by terminal bacterial endocarditis with aortic incompetence. Blood pressure: 220/90. The intima shows excess of collagen tissue, in addition to degenerative and proliferative changes of the elastic fibers. The muscle fibers of the media show marked thickening. Elastic tissue stain counterstained with van Gieson's connective tissue stain, × 200.

apparent than in normal subjects. The media was markedly thickened, with rich elastic fibers interspersed between muscle bundles (fig. 3). The media often constituted the most prominent of the layers, in contrast to normal subjects for this age group. Hyaline changes were often found in the media. This prominent thickening of the media was also present in the intramural coronary arteries and even in the arterioles which accompany the main coronary arteries (fig. 4).

Quantitative Study

In histological measurements of coronary arteries in a group of 10 persons with coarctation of the aorta, ranging from 2 to 10 years, the combined area of the intima and the musculo-elastic layer together was found to be 17% of the total cross-sectional area of the artery (fig. 5).

In a control group without heart disease, matched for age and sex, the area of the intima and the musculo-elastic layer was 14% of the total. In coarctation of the aorta the media was found to be 42% of the total cross-sectional area of the artery, whereas in the control group it was 35%. Quantitative index for the coronary arterial changes related to age and sex in 15 cases of coarctation of the aorta is shown in table 1.

The mean total area of the media in the coarctation group was found to be 0.70 mm², as compared with 0.37 mm² in the control group (fig. 6). The medial thickness, obtained by linear measurements of the artery

Figure 2

Anterior descending coronary artery from a 20-year-old male with coarctation of the aorta. Blood pressure: 180/120. Note marked proliferation of intima in form of a plaque similar to the one seen in atherosclerosis. Elastic tissue stain counterstained with van Gieson's connective tissue stain, × 100.
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Figure 3

Right coronary artery from a 6-year-old boy with coarctation of the aorta. The muscle fibers of the media show marked thickening with elastic fibers richly interspersed between the muscle bundles. Elastic tissue stain counterstained with van Gieson's connective tissue stain, × 200.

Projected on the visopan screen, was found to be 0.2 mm in the coarctation group and 0.1 mm in the control group (fig. 6).

The mean total area as well as the mean lumen area of the coronary arteries was larger in the coarctation group than in the control group. No significant differences were found in the total area to lumen ratio between the coarctation and the control group (fig. 7).

Discussion

Many authors have stressed the role of hemodynamic forces in the differentiation of the normal arterial layers and their subsequent development.\textsuperscript{12, 13} Coronary artery blood flow is interrupted by myocardial contraction during systole\textsuperscript{14–16} and thus is greater during diastole.

Clinical, hemodynamic and experimental studies in coarctation of the aorta have shown the left ventricular pressure to be elevated and equal to the pressure in the proximal aorta.\textsuperscript{1–5} Hypertension in the aorta distal to the coarctation is not solely due to increased resistance, but an important role is played by the limited capacity and distensibility of the proximal aorta and by the physiological reactions of the left ventricle. Since the coronary arteries originate proximal to the aortic obstruction, elevated pressure in the aorta proximal to the coarctation increases the central coronary perfusing pressure.

Development of coronary hypertension in patients with coarctation may explain the severe changes in the intima in early life and the severe atheroma found in young adults. One of our cases of coarctation (fig. 8) was
Table 1

Quantitative Index for the Coronary Arterial Changes Related to Age and Sex in Fifteen Cases with Coarctation of the Aorta

<table>
<thead>
<tr>
<th>Case</th>
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<th>(I + Me)/Tot. area</th>
<th>Media/Tot. area</th>
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</table>

* (I + Me)/Tot. area = Relation between the intima and musculo-elastic layer to the total area of the coronary artery expressed in percent.

Media/Tot. area = Relation between the media and the total area of the coronary arteries (%).

†Not available for quantitative studies.

of special interest because the lesions of atheroma were found in a 30-year-old Yemenite immigrant, who is from an ethnic group with a low incidence of coronary heart disease.16, 17
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Figure 7
Mean total area and mean lumen area of coronary arteries in coarctation of aorta.

Figure 8
Left coronary artery from a 30-year-old male, a Yemenite with coarctation of the aorta. Note the prominent atherosclerotic plaque occluding partially the vessel lumen.

These considerations and the development of hyaline changes and marked elastosis in the media form the basis for the prevailing opinion that operation is best performed during childhood, prior to the development of progressive sclerotic and hyaline changes in the arteries, which undoubtedly increase the surgical risk.18

The striking thickening of the media of the coronary arteries in cases of coarctation is demonstrable not only by histological examination but also by the precise measurements of the surface area of the individual different layers by the visopan-planimetric method, when compared with a group of patients without heart disease in which the age and sex were the same. The absolute area of the media and the mean thickness of the media in cases of coarctation are almost twice those of the normal. Similar changes were previously described in a 2-year-old boy with supravalvular aortic stenosis and uniform narrowing of the entire ascending aorta.1 The media of the coronary arteries was thickened and elastic changes were evident. These changes were attributed to hypertension in the coronary vessels. Prominent thickening of the media is also present in cases of essential hypertension,19 but not to the same extent as in coarctation.

The added load on the left ventricle increases the work and metabolic requirements of the ventricle6 which, in turn, increases the coronary flow, possibly responding to coronary dilatation produced by local relative anoxia.

In coarctation the cardiac output is normal or slightly increased at rest.20 This can be explained in part by a compensatory increase in flow through different branches of the aorta, including the coronary system.5 This is made possible, (1) by the mechanism of coronary dilatation which increases the coronary flow, and (2) by the anatomic fact, that the coronary artery capacity is larger than normal, which is confirmed by the measurements of the external diameter, the total area, and the lumen area, which are larger than in the control group.

Acknowledgment

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References


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