Arteriosclerosis in the Intramural and Extramural Portions of Coronary Arteries in the Human Heart

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Fifteen instances of intramural coronary arteries were observed in the dissection of 276 human hearts at consecutive unselected autopsies. All but 2 of these 15 had severe atheromata and narrowing of the lumen. It was thought important to determine whether or not the covering of the artery by cardiac muscle for a major part of its course protected the artery from atherosclerosis. From our data, one may assume that those portions surrounded by heart muscle were not protected from atherosclerotic process which occurred there as well as in extramural portions of the same arteries and in other entirely extramural coronary arteries.

The coronary arteries of the heart have been the subject of many thorough anatomic and physiologic studies. Numerous variations in the course of these vessels have been described. The coronary arteries usually course above the surface of the myocardium through the epicardial fat. Only at or near their termination do they dip into the muscle itself. In some patients, however, some of these arteries pass through the myocardium superficially and may be entirely surrounded by myocardial fibers soon after their origin; they may run in the muscle for the rest or main part of their course. Some arteries may dip beneath the myocardium for 1 to 3 cm. only to reappear on the surface for the remainder of their courses. Geiringer¹ could find little mention of this variation in the literature; he found no mention of its frequency nor a description of the state of the intima in such instances.

Geiringer studied the anterior descending branch of the left coronary artery because the straight course offered ease of measurement, and because atherosclerotic lesions appear early and are clinically important in this segment. The dipping into the myocardium is not necessarily confined to this vessel. He classified as mural those arteries in a narrow interventricular groove that had become folded over the artery with only a thin septum of connective tissue linking the periarterial space with the epicardium. He suggested that the artery, from a strictly anatomic sense, is epicardial, but, from a physiologic standpoint, intramural. He classified such arteries as mural in his report. Others were often completely surrounded by myocardium.

In 100 unselected autopsies at the Royal Infirmary, Edinburgh, the macroscopic incidence of mural type of left anterior descending coronary artery was 23. The distance the vessel was buried measured 5 mm. or more, at any part of its course. Microscopically, he found the covering fibers to be at right angles to the course of the vessel, the vortex fibers. He noted also that when full allowance was made for variation in age, sex, vessel size, heart weight, and especially the influence of hypertension, the mural portions of the left anterior descending branch tend to have a considerably narrower intima than the epicardial portions. "In other words, at the same age and sex, in hearts of the same weight, an epicardial left anterior descending artery of the same lumen as a corresponding mural branch, tends to have a considerably thicker intima." This fact was brought out by a study of microscopic slides in which a mural and an epicardial coronary co-existed. Geiringer states that it is quite

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### Table 1.—Location and Degree of Arteriosclerosis of Intramural and Extramural Segments

<table>
<thead>
<tr>
<th>Autopsy No.</th>
<th>Artery</th>
<th>Location of Involvement</th>
<th>Degrees of Involvement</th>
<th>Location of Intramural Segment</th>
<th>Length of Intramural Segment</th>
<th>Depth in Myocardium of Intramural Segment</th>
<th>Occclusion and Infarction</th>
</tr>
</thead>
<tbody>
<tr>
<td>14967</td>
<td>LAD</td>
<td>2.5 cm. from origin of LAD</td>
<td>IV Calcified</td>
<td>Prox.</td>
<td>0.5 cm.</td>
<td>0.6 cm.</td>
<td>Thrombus occluded LAD 1 cm. from orifice</td>
</tr>
<tr>
<td>14920</td>
<td>Rt. (predominant)</td>
<td>5 cm. from dist.</td>
<td>II</td>
<td>I</td>
<td>2.0 cm.</td>
<td>0.3 cm.</td>
<td>None</td>
</tr>
<tr>
<td>14795</td>
<td>LAD</td>
<td>5 cm. from origin</td>
<td>IV Sclerotic</td>
<td>IV</td>
<td>Mid.</td>
<td>5.0 cm.</td>
<td>At intramural-extramural segment</td>
</tr>
<tr>
<td>14908</td>
<td>LAD</td>
<td>1.3 cm. from aortic origin</td>
<td>IV Sclerotic</td>
<td>Entire</td>
<td>10.1 cm.</td>
<td>0.6 cm.</td>
<td>Recent thrombus distal portion of LAD. Intramural shows less arterioscl., but apex lt. ventricle shows areas of white fibrous tissue as does post. septum supplied by rt. coronary.</td>
</tr>
<tr>
<td>14852</td>
<td>LAD</td>
<td>1.3 cm. from origin</td>
<td>II</td>
<td>Proximal</td>
<td>3.8 cm.</td>
<td>0.15 cm.</td>
<td>None</td>
</tr>
<tr>
<td>14850</td>
<td>Branch of LAD between LAD-Circumflex</td>
<td>2.5 cm. from origin</td>
<td>I</td>
<td>I</td>
<td>6.0 cm.</td>
<td>0.5 cm.</td>
<td>None</td>
</tr>
<tr>
<td>15438</td>
<td>LAD</td>
<td>1.3 cm. from origin</td>
<td>IV Calcified Sclerotic</td>
<td>III</td>
<td>2.0 cm.</td>
<td>0.3 cm.</td>
<td>No occlusion but healed infarct post. wall lt. ventr. Recent infarct. ant. septum and ant. wall lt. ventr. with mural thrombus</td>
</tr>
<tr>
<td>15261</td>
<td>LAD</td>
<td>2.5 cm. from origin</td>
<td>III</td>
<td>I</td>
<td>1.3 cm.</td>
<td>0.15 cm.</td>
<td>None</td>
</tr>
<tr>
<td>Study No.</td>
<td>Location</td>
<td>Description</td>
<td>Luminal Position</td>
<td>Length (cm)</td>
<td>Width (cm)</td>
<td>Comment</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
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<td></td>
</tr>
<tr>
<td>15088</td>
<td>LAD</td>
<td>1st branch 0.5 cm. from ostium, branches 2 cm. from origin of 1st br.</td>
<td>I three fourths</td>
<td>IV</td>
<td>IV</td>
<td>Mid. 1.3 cm.</td>
<td>0.3 cm.</td>
</tr>
<tr>
<td>15862</td>
<td>LAD</td>
<td>2 cm. from ostium</td>
<td>Prox. 2 cm.</td>
<td>III</td>
<td>I</td>
<td>Mid. and dist. 7.5 cm.</td>
<td>0.6 cm.</td>
</tr>
<tr>
<td>15844</td>
<td>LAD</td>
<td>3 cm. from ostium</td>
<td>Thrombus at junction of circumflex</td>
<td>IV Calc. with extensive atheromatosis in all intramural and beyond thrombus</td>
<td>IV</td>
<td>All dist. to 0.3 cm. from ostium 7.5 cm.</td>
<td>0.3 cm.</td>
</tr>
<tr>
<td>15817</td>
<td>Circumflex</td>
<td>4.5 cm. from ostium</td>
<td>Prox. Calcified</td>
<td>IV</td>
<td>I</td>
<td>Dist. half</td>
<td>All of dist half of artery 0.5 cm. Prox. intramural part completely occluded by old thrombus</td>
</tr>
<tr>
<td>15565</td>
<td>LAD</td>
<td>2.5 cm. from ostium</td>
<td>Prox.</td>
<td>II</td>
<td>I</td>
<td>Mid. and dist. 4.0 cm.</td>
<td>0.6 cm.</td>
</tr>
<tr>
<td>15677</td>
<td>LAD</td>
<td>3.5 cm. from ostium</td>
<td>Prox. half</td>
<td>I</td>
<td>I</td>
<td>Dist. half 4.0 cm.</td>
<td>0.3 cm.</td>
</tr>
<tr>
<td>15618</td>
<td>LAD</td>
<td>2.5 cm. from ostium</td>
<td>Prox.</td>
<td>II</td>
<td>II</td>
<td>Mid. and dist. 5.0 cm.</td>
<td>0.3 cm.</td>
</tr>
<tr>
<td>15607</td>
<td>LAD</td>
<td>2.5 cm. from ostium</td>
<td>Prox.</td>
<td>II</td>
<td>II</td>
<td>Mid. and dist. 5.0 cm.</td>
<td>0.3 cm.</td>
</tr>
</tbody>
</table>

clear that mural stretches of the left anterior descending coronary branch are only rarely affected by atherosclerosis, in contradistinction to comparable epicardial segments where this is a common finding. He concluded that these mural vessels have a much thinner intima than corresponding epicardial branches, the extremes of medial hypertrophy and atrophy are found less frequently in them, and that atheroma occurs only rarely in these mural
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stretches. He reasoned that a media-like protective action of the surrounding myocardium occurred.

**Methods and Results**

It was because of our interest in such factors and the possible relation of local factors in the pathogenesis of atheromata and arteriosclerosis, that we investigated the subject. We carefully inspected a total of 276 hearts from unselected autopsies in the Barnes Hospital and St. Louis City Hospital. Arteries that merely dipped deep into myocardium at their terminal branches were not included. Three of the specimens had to be decalcified before sections could be made. There were 15 patients with intramural coronary arteries among 276 consecutive hearts examined post mortem, an incidence of 5.4 per cent. There were 13 left anterior descending coronary arteries, one right coronary artery, and one left circumflex coronary artery which were surrounded by myocardium for variable distances. In one instance, the right coronary artery had a main branch that ran intramurally. All other 14 intramural coronary arteries in the consecutive autopsies, and one (case 16) not in the consecutive group were major coronary arteries (table 1). Case 16 showed an intramural right coronary artery but it was found after examination of the consecutive group of 276 hearts and was not included for purposes of incidence.*

From the data in table 1 it is apparent that in the 16 hearts with intramural coronary arteries, there was appreciable thickness of the myocardium covering the artery, and not merely an invagination of epicardium or epicardium folded over the vessel. All but two of the intramural coronary arteries exhibited severe atheromata and narrowing of the lumen. The other extramural coronary arteries in these hearts showed atherosclerotic involvement also. Eight of the intramural coronary arteries had marked atherosclerotic involvement, six moderate, and two had slight changes.

The other extramural coronary arteries in each of the 16 hearts showed some atherosclerotic involvement also (table 2). None of the extramural arteries had complete absence of atherosclerotic changes. Eight of them had marked atherosclerotic narrowing and four of these had thrombi occluding a portion of the vessel. Six of these extramural coronary arteries showed moderate, and two had slight atherosclerotic changes. Hypertension was present in only two of the patients.

The sections of the extramural coronary arteries were examined with hematoxylin and eosin stain, with microincineration and elastic tissue stains. From our studies we conclude that the covering of a coronary artery by myocardium does not protect it from degenerative change. The same degenerative atherosclerotic changes are found in the intramural portions of the major coronary arteries as are found in the extramural portions, and in other entirely extramural coronary arteries in the same, or in other hearts. There must be more than mechanical pressure exerted by systolic contractions of the myocardium, or the so-

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* At the request of the Editor the individual case reports are being omitted. These will be furnished on request.

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**Fig. 1.** A proximal segment of a major coronary artery in the epicardium showing slight intimal arteriosclerosis. All illustrations are from serial blocks of the same artery (X 35, hematoxylin-eosin stain). Figures 1, 2, 3 and 4 are all from case 13261, Barnes Hospital, St. Louis, Mo.
Fig. 2. An intramural segment within 4 mm. from the section in figure 1, showing the artery completely surrounded by myocardium and involved by advanced arteriosclerosis (× 35, hematoxylin-eosin stain).

Fig. 3. A section from the adjacent block of the same intramural segment with only minimal evidence of arteriosclerosis. (× 35, hematoxylin-eosin stain).

Fig. 4. The distal segment of the artery after its return to an epicardial position. The vessel has branched and each branch is slightly arteriosclerotic (× 35, hematoxylin-eosin stain).

called protection from overdistention by the intravascular blood pressure involved in the process of atherosclerosis. That a single section of a coronary artery is not necessarily representative of the degree of arteriosclerosis in that artery or in other coronary arteries was illustrated in some of our sections (figs. 1, 2, 3 and 4) all of B. H., autopsy no. 15261. These specimens showed little arteriosclerosis, while sections 2 and 3 of the same short mural segment showed advanced changes. Sections (SE 795) of case 13 illustrate the importance of inspecting the coronary arteries thoroughly; a few sagittal cuts of a block of tissue taken at random when doing an autopsy are not sufficient. Certain areas of focal narrowing due to atherosclerosis would escape notice unless longitudinal cuts are made in the gross inspection, since it is not feasible to do serial sections microscopically. At least careful multiple sagittal cuts could be made, if preferred.

Microscopic Pathology. Hematoxylin and eosin stained sections of the principal coronary arteries of case 13, no. 14795 all show advanced arteriosclerosis with variable narrowing of the
lumina. There is a recent thrombus occluding the lumen of one of the sections of the right coronary. All sections of the principal coronary arteries show the vessels to be completely surrounded by epicardial fat. Special sections are taken of a smaller branch of one of the coronary arteries. There are three sections. One section shows the vessel in the epicardial fat; this section shows advanced arteriosclerosis. A second section shows one vessel to be partially but not completely surrounded by myocardium, and another vessel entirely in the epicardial fat. There is very little arteriosclerosis present in the vessel partially surrounded by myocardium, while the other vessel shows arteriosclerosis of an advanced degree with the lumen eccentrically narrowed by a plaque. A third section shows two small vessels of approximately the same size, both within the myocardium. One shows a large intimal plaque with an eccentrically narrowed lumen, while the other shows very little intimal proliferation. This last section, with the difference in degree of change in the two small vessels, is another illustration that intimal proliferation in arteriosclerosis is a focal lesion in many cases.

**Summary**

In a study of 276 human hearts to determine the incidence of intramural coronary arteries, with all or a major portion of a coronary artery covered entirely by myocardium, we found 15 such intramural arteries; an incidence of approximately 1 intramural coronary artery among every 23 examined. One additional heart with an intramural coronary artery was found but was not in the consecutive group of autopsies. In no instance was there more than one coronary artery intramural in any heart. All but two of the intramural coronary arteries exhibited severe atheromatia and narrowing of the lumina. The other extramural coronary arteries in these hearts showed atherosclerotic involvement also. Eight of the intramural coronary arteries had marked atherosclerosis, six had moderate and two had slight atherosclerosis.

From the above findings one may assume that the covering of a coronary artery in the human heart by myocardium during a part of its major course fails to protect it from the atherosclerotic process which occurs there in much the same type and incidence as it does in the extramural portions of the same arteries and in other entirely extramural coronary arteries.

**Acknowledgment**

We are grateful to Dr. David M. Smith, Department of Pathology, Washington University School of Medicine (now at the University of Virginia) for his help in selecting the histologic sections used in making the figures.

We also wish to acknowledge the cooperation of R. A. Moore, M.D., formerly Professor of Pathology, Washington University Medical School, now Vice-Chancellor of the Schools of Health Professions, University of Pittsburgh, John Saxton, M.D., Pathologist at St. Louis City Hospital and wish to thank Ernest Booth, M.D., for supplying us with autopsy material for our investigation.

**Summary in Interlingua**

Esseva executate un studio de 276 cordes human con le objectivo de determinar le frequentia de arterias coronari intramural que es completamente o in major portiones coperite de myocardio. Dece-cinque tal arterias intramural esseva trovate. Isto es un frequentia de 1 arteria coronari intramural pro omne 23 casos examinate. Nulle del cordes eximinate exhibiva plus que un intramural arteria coronari. Omne le arterias coronari intramural, con duo exceptiones, monstrava sever atheromas e reduction del passage. In iste cordes etiam le arterias coronari extramural monstrava un affection atherosclerotic. Octo del arterias coronari intramural exhibiva atherosclerosis a grado marecate, 6 a grado moderate, e 2 a grado leve.

Le supra-presentate constatationes permitte le conclusion que arterias coronari del corde human que es coperite in un portion major de lor curso per le myocardio non es protegite per ille copertura contra le processo atherosclerotic. Le processo atherosclerotic occurre sub le copertura in plus o minus le mesmo manera e con le mesmo frequentia que in le portiones extramural del mesme arterias o que in altere arterias coronari cuje curso es integemente extramural.

**Reference**

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