ATRIAL ARRHYTHMIAS occur in about 10 per cent of acute myocardial infarctions and the commonest of these arrhythmias is atrial fibrillation. When atrial fibrillation is sustained after beginning during myocardial infarction, it has been reported to be associated with an 89 per cent mortality. Although there have been a number of studies on the clinical aspects of the association of such rhythm disturbances with myocardial infarction, little is known regarding their pathogenesis.

This is a report of findings from 11 selected cases of patients with myocardial infarction who developed atrial arrhythmias. All were necropsied. Each heart was carefully dissected to determine the manner of blood supply to the atria as well as the ventricles, and special attention was given to the blood supply to the sinus node and AV (atrioventricular) node. Note was made whether occlusions in the main coronary artery were proximal or distal to the origin of the nodal arteries. For histologic study the sinus and AV nodes were cut serially at 2 mm. intervals in all 11 cases.

Because atrial fibrillation both clinically and experimentally is so closely related to other atrial arrhythmias (atrial flutter, atrial tachycardia, etc.), the terms “atrial fibrillation” and “atrial arrhythmias” in general are used interchangeably.

Case Reports

Case 1
R.C., a 53-year-old man, died of subacute bacterial endocarditis with rupture of the aortic valve, and lamellar myocardial infarction of both ventricles. His final illness was associated with multiple atrial arrhythmias (fig. 1). At necropsy there was marked compromise of the lumen of the left circumflex artery by old sclerosis, and this artery crossed the crux to supply the AV node; in addition there was a recent occlusion of the small right coronary artery proximal to the origin of the sinus node artery (fig. 2). Echymoses were present in the epicardium of the sulus terminalis over the sinus node, and these corresponded to infarction of the node seen microscopically (figs. 3 and 4). No pathology was found in the AV node.

Case 2
M.K., a 68-year-old woman, died during an acute anterolateral myocardial infarction with atrial fibrillation. At necropsy most of the left ventricle was infarcted and a fresh thrombus occluded the main left coronary artery; the sinus node artery arose from the left circumflex branch. There was an old occlusion of the right coronary artery just beyond the margo acutus and proximal to the AV node, which it supplied. There was infarction of the sinus node (fig. 5), but no pathology was found in the AV node.

Case 3
J.D.H., a 78-year-old man, died of an acute myocardial infarction of the left ventricular free wall and septum. His final illness included the onset of atrial fibrillation. At necropsy there was a recent occlusion of the main left coronary artery, plus an old occlusion of the right coronary artery proximal to the origins of the arteries supplying both the sinus node and AV node. In the sulcus terminalis there were gross epicardial hemorrhages over the sinus node (fig. 6), which corresponded to a hemorrhagic infarction seen histologically (fig. 7). There was no infarction in the AV node.

Case 4
H.L., a 72-year-old man, died of an acute posterior myocardial infarction. Initially his electrocardiogram showed incomplete AV block but later

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he developed atrial fibrillation (fig. 8). At necropsy there were two recent occlusions, one in the right coronary artery at the margo acutus and the other at the origin of the left anterior descending artery, compromising the lumen of the main left coronary artery also. The sinus node artery arose from the left circumflex branch, adjacent to the main left coronary artery, and was partially involved by the recent occlusion. The right coronary artery crossed the crux of the heart and supplied the AV node. Histologically, old and new infarction involved most of the sinus node exit junctions (fig. 9); in the AV node there was lesser damage.

Case 5

T.S., a 64-year-old man, died of congestive failure due to intractable atrial fibrillation with rapid ventricular response. At necropsy there was old occlusion of the left anterior descending, the left circumflex, and right coronary arteries. The right coronary occlusion was proximal to the origin of both nodal arteries (fig. 10). Except for some small new foci the ventricular infarction in most of the left ventricle was old. In the epicardium of the sulcus terminalis there were ecchymoses over the sinus node (fig. 11), corresponding to infarction present microscopically (figs. 12 and 13). No pathology was found in the AV node.

Case 6

L.V., a 61-year-old man, died of an acute posterolateral myocardial infarction during which he developed atrial fibrillation. At necropsy there was an old occlusion of the right coronary artery at the margo acutus, with that artery supplying an unusually large area of the posterior and lateral left ventricle, as well as the AV node. There was also a recent occlusion of the smaller main left coronary artery proximal to the origin of the sinus node artery, which arose from the even smaller left circumflex artery. There was infarction at the exit junctions of the sinus node, and marked sclerosis of the AV node artery (fig. 14); no other pathology was found in the AV node.

Case 7

C.C.B., a 66-year-old man, died of posterior myocardial infarction during which he developed an atrial tachycardia of 176 per minute. At necropsy there was a recent occlusion of the right coronary artery proximal to the origin of the sinus node artery, the right coronary continuing to supply the posterior wall and AV node. Ecchymoses were present in the epicardium over the sinus node (fig. 15) and infarction was present in the sinus node. No pathology was found in the AV node.

Figure 1

Electrocardiogram of case 1, showing intermittent sinus node activity.
Figure 2
Photograph of the heart, case 1. Right arrow indicates the cut edge of a recent occlusion of the right coronary artery; left arrow indicates the sinus node artery, which arose distal to the occlusion. Ao, is the aorta; Ap, the right atrial appendage; SVC, the superior vena cava; and RV, the right ventricle.

Figure 3
A low-power photomicrograph of the sinus node, case 1. In this and subsequent photomicrographs N refers to the sinus node and A to the right atrium. There is hemorrhage and infarction at the junction of the node and atrium.

Case 8
V.H., a 62-year-old man, died of a large anterolateral myocardial infarction, during which he developed atrial fibrillation. At necropsy there was an old occlusion of the right coronary artery proximal to where it crossed the crux, supplying the AV node. The left circumflex artery was occluded by an old lesion at the origin of the sinus node artery, and the left anterior descending artery was occluded by a fresh thrombus 2 cm. from its origin. Infarction was found in both the sinus node and AV node.

Figure 4
Higher power photomicrograph of the sinus node, case 1, showing hemorrhage and degeneration at the junction of the node and atrium.

Case 9
W.G., a 64-year-old man, died of acute posterior myocardial infarction. In his final illness he had a variety of atrial arrhythmias, including atrial fibrillation. At necropsy there was a recent occlusion of the left circumflex coronary artery near

Figure 5
Two photomicrographs of the sinus node, case 2, showing congestion and hemorrhage at the junction of the node and atrium under low power (top) and high power (bottom).
the margo obtusus, with the circumflex artery continuing to the crux of the heart and posterior left ventricle, supplying the AV node. There was an old occlusion of the relatively small right coronary artery proximal to the origin of the sinus node artery. Gross ecchymoses were present in the epicardium of the sulcus terminalis over the sinus node; these corresponded to an infarction of the sinus node seen microscopically (fig. 16). No pathology was found in the AV node.

Case 10

W.S., a 48-year-old man, had a posterior myocardial infarction 1 year previously and then died during a lateral infarction. During both of these he had intermittent cessation of sinus node activity (fig. 17). At necropsy there was infarction of most of the left ventricle, with old occlusions of both the left anterior descending artery and the left circumflex artery. The latter vessel supplied the AV node and the entire left ventricle except the anteroseptal portion, the right coronary artery being diminutive. There was a fresh occlusion in the first centimeter of the left circumflex artery, the sinus node artery arising distal to this, at a point of old occlusion near the margo obtusus. Infarction was present in both the sinus node and AV node.

Case 11

T.L.D., a 66-year-old man, died of myocardial insufficiency during intractable atrial flutter and fibrillation with a rapid ventricular response; he also had hemochromatosis. At necropsy there was old occlusion of the left anterior descending artery and of the right coronary artery proximal to the origin of the sinus node artery; the right coronary continued to the crux of the heart to supply the posterior wall and AV node. Ventricular infarction was streaky and both old and new. There were edema and hemorrhage at the exit junctions of the sinus node. Degenerative changes were present in the AV node about iron deposits (fig. 18); despite careful searching, no iron could be demonstrated in the sinus node.

Comment on the Eleven Cases

In all 11 cases a coronary occlusion was present proximal to the origins of both the sinus node artery and AV node artery. In six of the hearts gross ecchymoses were found in the sulcus terminalis directly over the sinus node. Data relating the nodal histopathology to the arrhythmias are presented in table 1.

Microscopically, infarction of the sinus node was found in all 11 cases. Lesser changes were apparent in the AV node in five cases. These changes were acute and consisted primarily of hemorrhage and edema; however, collagen deposition and fatty infiltration were present in scattered foci of all the sinus nodes, suggesting that previous focal damage had occurred.

The sites of damage in the sinus node were characteristic in every case, occurring at the junctions of the node with the right atrium and sinus intercava rum. Hemorrhages at these locations involved Purkinje tracts leaving the node and may be presumed to be asso-
Figure 8

Two electrocardiograms from case 4 showing incomplete AV block (P-R time 0.26 second) at the onset of acute posterior myocardial infarction (top), and atrial fibrillation 2 days later (bottom).
Assessed with impairment of normal transmission of the sinus impulse to the rest of the heart. Pathologic changes were less often seen in the central portion of the node or in the more distal atrial muscle, suggesting that the exit junctions of the node may be peculiarly vulnerable to acute hypoxia.

Histopathology of the AV node was less consistent and less striking. Presence of an occlusion in the main coronary artery proximal to the origin of the AV node artery in all 11 cases certainly suggests that those AV nodes must have been rendered hypoxic. The possible contribution of this AV nodal hypoxia to the pathogenesis of atrial arrhythmias is discussed later; however, at present this remains a speculative probability.

Discussion

Although it has long been thought that atrial arrhythmias in acute myocardial infarction probably represent concomitant

Figure 9
Low-power (top) and high-power (bottom) photomicrographs of the sinus node, case 4, showing fibrosis, fatty replacement, and recent hemorrhage at the junction of the sinus node and atrium.

Figure 10
Photograph of the heart of case 5, demonstrating the sinus node artery (left arrow) arising from the right coronary artery (right arrow); in the knuckle of right coronary artery indicated by the curved arrow there was a complete occlusion. Ao, the aorta; Ap, the right atrial appendage; SVC, the superior vena cava. The sinus node artery courses into the sinus node at the junction of the atrial appendage and vena cava.

Figure 11
Another view of the heart in figure 10 (case 5), demonstrating the ecchymoses in the sulcus terminalis over the sinus node, being the area between the two pin heads. SVC, the superior vena cava; and RA, the right atrium.
atrial damage, evidence to support this clinical impression has been meager. A notable exception was the demonstration by Cushing et al. that the commonest clinically recognizable manifestation of atrial infarction was the presence of an atrial arrhythmia, but they did not specifically relate these observations to the pacemaker of the heart. Atrial infarction in experimental animals is not, however, associated with regular production of atrial

Figure 12A
Low-power photomicrograph of the sinus node from case 5. Hemorrhagic infarction is present between the body of the node and the atrium.

Figure 12B
Low-power photomicrograph through the tail of the node, 10 mm. from figure 12A. Hemorrhage and old fibrosis have virtually replaced the node.

Figure 13
Medium-power (top) and high-power (bottom) photomicrographs of the hemorrhagic infarction at the junction of the node and atrium (case 5).

Figure 14
Photomicrograph of the two branches of the AV node artery, both sclerosed for more than 75 per cent of their lumina and surrounded by morphologically normal AV node (case 6).
arrhythmias,\textsuperscript{13, 14} and ligation of the primary blood supply to the sinus node of the dog only rarely disturbs the sinus rhythm.\textsuperscript{15} It must be concluded that atrial arrhythmias occurring during acute myocardial infarction have a more complex pathogenesis.

There are few studies on the pathology of the sinus node, exceptions being the recent reports of Lev\textsuperscript{16, 17} and Hudson.\textsuperscript{18} Lev observed that increasing fibrosis in the sinus node is a normal consequence of aging, making evaluation of old focal lesions there difficult. Hudson has noted that various pathologic changes in the sinus node are by no means uncommon.

Based on a study of the 11 cases reported here, and a review of the published observations on this subject, the following factors may be considered as influencing the onset of atrial fibrillation (or other atrial arrhythmias) during acute myocardial infarction:

1. Depressed sinus node "dominance."
2. Impaired sinus impulse transmission.
3. Vagal and vagomimetic reflexes.
4. AV node injury.
5. Extranodal atrial injury.

Figure 16
Photomicrograph of the sinus node of case 9. There is hemorrhage at the junction of the node and atrium, with degeneration of the node.

6. Atrial distention.
8. Increased circulating catecholamines.

Usually more than one of these factors is present in any given case, but each is discussed separately.

Depressed Sinus Node "Dominance"

Since the cardiac pacemaker is naturally so located that its regular stimulation of the heart is distributed with maximal efficiency, any condition producing sustained replacement of sinus rhythm by some other rhythm must either destroy or weaken the sinus impulse, block this impulse, or be of such strong potential itself as to supersede this impulse. Experimental application of aconitine to canine atria is an example of the latter, but it is significant that atrial fibrillation so induced is self limiting, and aconitine must be reapplied if the arrhythmia is to be sustained; as the extranodal impulse weakens, the undamaged sinus node resumes dominance.

Whether transmission of the sinus impulse from the node to the atria can be suppressed without damage to the sinus node and atrium is problematical. That the impulse can be blocked in its passage from the atria to the ventricles without damaging the AV node is well substantiated both experimentally and clinically, and the role of such block is discussed later.
The present observations suggest that ischemia or injury of the human sinus node influences the onset of atrial fibrillation in myocardial infarction. That this alone is inadequate to produce such arrhythmia was long ago suggested by the persistence of regular rhythm following destruction of the region of the sinus node, and further suggested by the persistence of sinus rhythm following ligation of the sinus node artery of the dog. It must nevertheless be presumed that ischemia or injury of the sinus node, by weakening normal sinus node dominance of the heart, is an important factor in this problem, and particularly a factor in prolongation or sustaining of such arrhythmias.

Another important factor depressing sinus node "dominance" is vagotonia. That some vagotonia occurs in most acute myocardial infarctions can little be doubted. It has even been stated that increased vagal tone is the universal mechanism of sudden death in myocardial infarction. The effect on the sinus node of increasing vagal tone (especially the right vagus) is well known and consists of increasing bradycardia to ultimate cessation of all sinus node activity. When this occurs in a patient with other factors favoring the onset of atrial fibrillation, it must be presumed to contribute to the onset of the arrhythmia. In addition, there are other effects of vagal stimulation that favor the onset of fibrillation, such as increasing the normal disparity of repolarization speed in atrial fibers.

Sinus arrest observed during acute myocardial infarction may be the result of either vagotonia or sinus node ischemia or both, and the clinical differentiation of the two factors may be difficult. Atropine counteracts vagotonia, but its effect on sinus bradycardia or sinus arrest due to ischemic weakening of sinus impulse formation is unknown. In man, vagotonia encountered clinically is unlikely to be unilateral, and bilateral vagotonia should result not only in sinus bradycardia but also prolongation of AV conduction time; in myocardial infarction, however, not only is there likely to be bilateral vagotonia, but both sinus and AV nodes may be rendered ischemic at the same time by a coronary occlusion proximal to both their nutrient arteries. In every case in this study the main coronary arteries were occluded proximal to the origin of the blood supply of both nodes.
Impaired Sinus Impulse Transmission

In all 11 of the cases, infarction occurred at the junctions of the sinus node with the right atrium and sinus intercavarum, regions through which the normal sinus impulse must pass to the heart. Although hemorrhages at these points were impressive, in none of the hearts were all the junctions damaged, so that potential points of exit still existed.

Since potential points of exit still were present, and since in experimental animals virtually all the connections to the sinus node can be severed without the occurrence of atrial fibrillation, it must be concluded that impaired sinus impulse transmission, like suppressed sinus node "dominance," may be a contributing factor to the onset of atrial fibrillation during myocardial infarction, but that it is rarely capable of producing this effect by itself.

Other factors that may impair sinus impulse transmission during acute myocardial infarction are atrial distention and cellular anoxia. In the presence of congestive heart failure atrial pressure rises and the atrium distends as the ventricle fails to empty; in addition to the reflex effects of atrial distention, the stretching of the atrial fibers lengthens the distance the normal impulse must travel, as well as probably further increasing the normal disparity of atrial fiber repolarization. Hypoxia of the atrial fibers during acute myocardial infarction also contributes to atrial dilatation, impaired atrial conduction, and increase in normal disparity of atrial fiber repolarization.

Vagal and Vagomimetic Reflexes

The effects of these very important reflexes that contribute to the onset of atrial fibrillation during acute myocardial infarction are discussed in detail under the other headings. Both the origin and specific pathways of these reflexes in acute myocardial infarction are poorly understood. For possible mechanisms and routes, considering the pathophysiology of acute myocardial infarction, one may consult the comprehensive reviews of cardiovascular reflexes.

AV Node Injury

The AV node is an efficient alternate cardiac pacemaker. Persistence of an efficient regular cardiac rhythm in experiments in which the sinus node is destroyed is most likely due to assumption of pacemaking by the AV node or juxtanodal centers. It seems most reasonable, therefore, to believe that main coronary artery occlusions that compromise the blood supply to both the sinus node and AV node are more likely to evoke a disorganized rhythm than occlusions that compromise the blood supply of only the sinus node. This proved to be the case in the present study.

Since the right coronary artery supplies the AV node in about 90 per cent of human hearts, and the sinus node in about 55 per cent, it is occlusion proximal to the

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**Table 1**

Summary of the Arrhythmias and Nodal Pathology in 11 Cases of Myocardial Infarction

<table>
<thead>
<tr>
<th>Case</th>
<th>Sinus node</th>
<th>AV node</th>
<th>Atrial arrhythmias</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Infarcted</td>
<td>No pathology found</td>
<td>Multiple atrial arrhythmias</td>
</tr>
<tr>
<td>2</td>
<td>Infarcted</td>
<td>No pathology found</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>3</td>
<td>Infarcted</td>
<td>No pathology found</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>4</td>
<td>Infarcted</td>
<td>Infarcted</td>
<td>Incomplete AV block, then atrial fibrillation</td>
</tr>
<tr>
<td>5</td>
<td>Infarcted</td>
<td>No pathology found</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>6</td>
<td>Infarcted</td>
<td>Sclerotic AV node artery</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>7</td>
<td>Infarcted</td>
<td>No pathology found</td>
<td>Atrial tachycardia (176/minute)</td>
</tr>
<tr>
<td>8</td>
<td>Infarcted</td>
<td>Infarcted</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>9</td>
<td>Infarcted</td>
<td>No pathology found</td>
<td>Multiple atrial arrhythmias</td>
</tr>
<tr>
<td>10</td>
<td>Infarcted</td>
<td>Infarcted</td>
<td>Intermittent sinus arrest</td>
</tr>
<tr>
<td>11</td>
<td>Infarcted</td>
<td>Degeneration</td>
<td>Atrial flutter then fibrillation</td>
</tr>
</tbody>
</table>
origin of the sinus node artery in the right coronary artery that is most likely to be associated with atrial fibrillation.

Klainer and Altschule\textsuperscript{31, 32} observed that patients who developed atrial arrhythmias during myocardial infarction often had prolongation of the P-R interval in their electrocardiograms prior to the onset of the arrhythmia, and further that this AV block could be reduced by the administration of atropine. Although this is strong evidence that a vagomimetic influence on the AV node was present in their cases, the possibility that the AV block was due to ischemia or damage to the AV node rather than to vagotonia was not discussed, and the histology of the node was not reported.

Injury to the AV node may impair AV conduction sufficiently to reduce cardiac output and coronary flow. The importance of reduced coronary flow in the pathogenesis of arrhythmias during acute myocardial infarction has recently been stressed by Corday and others.\textsuperscript{33, 34}

**Extranodal Atrial Injury**

Cushing et al.\textsuperscript{12} emphasized the clinical importance of atrial arrhythmias in atrial infarction. Although damage to the sinus node is probably the most important atrial injury, damage to the “working” muscle of the atria may also contribute to the onset of atrial arrhythmias during acute myocardial infarction. For example, irritable atrial muscle at the periphery of such injury may establish a competing ectopic pacemaker, eager to take over if the sinus node should fail. Such a pacemaker may remain regular, but would more likely deteriorate to fibrillation, especially under the influence of other factors.

Additionally extranodal atrial injury may impair normal sinus impulse transmission, a factor already discussed, and increase further the normal disparity of repolarization speed in atrial fibers.\textsuperscript{24} A weakened area of atrial muscle may also contribute to atrial dilatation from any other cause.

Since the sinus node artery is the largest and most constant atrial artery in man,\textsuperscript{90} one might expect an occlusion proximal to its origin to produce a large atrial infarct. This did not prove to be the case in the 11 cases studied, only four of the 11 having a grossly recognizable atrial infarct, and the largest of these was less than 1 cm.\textsuperscript{2} in size; all four were in the right atrium. Thus extranodal atrial injury does not seem to be a regular accompaniment of sinus node infarction, but is an associated factor contributing to the onset of atrial arrhythmias in less than half of the cases.

**Atrial Distention**

Although listed separately as a contributing factor to atrial arrhythmias during myocardial infarction, which it is, atrial distention’s specific effects and causes have been discussed under other headings.

**Hypercalcemia and Increased Circulating Catecholamines**

Both these factors influence the onset of atrial fibrillation during acute myocardial infarction through their effect on repolarization speed and are discussed together, although their pathogenesis differs. They further increase the normal disparity of repolarization speed in atrial fibers,\textsuperscript{22-24} thus favoring both onset and perpetuation of fibrillation. They may also enhance any potential ectopic pacemaker.

Kleitman has shown that in man hypercalcemia normally occurs within a very short time after assuming the supine position.\textsuperscript{25} Furthermore, this increase in circulating calcium was in the ionizable, or biologically active, form. Although it is well known that prolonged inactivity, as in poliomyelitis, is associated with increased calcium mobilization,\textsuperscript{36} it is unlikely that these observations are applicable to patients placed at bed rest because of acute myocardial infarction. Kleitman’s observations, however, are certainly pertinent and need to be studied further.

An increase in circulating catecholamines during acute myocardial infarction has been observed.\textsuperscript{37} When of sufficient quantity these would not only have a chronotropic effect, but might raise the arterial blood pressure and
SINUS NODE ARTERY LIGATION

+ EPINEPHRINE

CALCIUM or

or DISTENTION

NOREPINEPHRINE

RT. ATRIUM

VAGAL STIMULATION

↓ ATRIAL FIBRILLATION

Figure 19

A summary of some experimental observations on atrial arrhythmias in myocardial infarction.

Iatrogenic Factors

A number of therapeutic measures commonly employed in patients with acute myocardial infarction may contribute to the onset of atrial arrhythmias. Prominent among these is quinidine. Because it suppresses all myocardial excitability, quinidine may suppress an already weakened sinus node or AV node still further and thereby facilitate atrial arrhythmias. Although this possibility is not a strong contraindication to the use of quinidine otherwise indicated, its effect on the nodal centers should be kept in mind.

The effects of digitalis on the sinus node and AV node depend on the dosage administered. In therapeutic levels it mildly suppresses AV conduction, while in toxic doses it completely blocks it. In therapeutic doses its effect on the sinus node is not clinically significant, but in toxic doses it sometimes produces sinus arrest. In addition to nodal effects, digitalis accelerates repolarization of atrial myocardium, thus increasing the normal disparity of repolarization speed in atrial fibers and favoring the onset of atrial fibrillation. As with quinidine, digitalis should still be employed when indicated in myocardial infarction, but in determining its indication it is well to remember its effects on the conduction centers.

Pressor amines are being employed with increasing frequency in the therapy of acute myocardial infarction with hypotension, and have undoubtedly been responsible for the saving of many lives. However, they too may contribute to the onset of atrial arrhythmias. The two ways in which this may occur are by a chronotropic effect on myocardium (already discussed) and by overshooting the therapeutic mark and producing acute hypertension. A remarkable example of the latter problem was recently reported by Smith and Logue, and their emphasis on the vagomimetic reflexes brought into play by their therapy is most important.

Other therapeutic measures may also play a role in iatrogenic facilitation of the onset of atrial arrhythmias, but the ones presented serve to orient thought to these factors.

General Comment

In a recent experimental study on the pathogenesis of atrial arrhythmias in myocardial infarction the validity of most of these clinical considerations was confirmed in the laboratory, and a schematic summary is presented in figure 19. Not one of the factors listed was capable alone of producing atrial fibrillation except in rare circumstances; additionally, any two of the factors also usually failed to induce atrial fibrillation. When the sinus node was made ischemic, and calcium, catecholamines, or atrial distention was added, then vagal stimulation regularly produced atrial fibrillation. It was concluded that this complex combination, employing only factors that are known to occur in the course of
A combination of acute posterior myocardial infarction and atrial fibrillation indicates an occlusion of the first 2 cm. of the right coronary artery.

The consistent demonstration of morphologic changes in the sinus node at necropsy of patients dying of acute myocardial infarction with atrial arrhythmias requires special study of the region that is somewhat more detailed than technics conventionally employed in the routine necropsy. Numerous descriptions of the anatomy of the sinus node are available. To determine whether a main coronary occlusion is proximal to the origin of the sinus node artery only requires knowledge of the anatomy of the latter vessel, which may arise from the proximal portion of either the right or left circumflex coronary artery.

The frequency of serial sectioning in the region of the sinus node need not be every 5 micra. Sections obtained approximately 2 mm. apart are satisfactory to assure incorporation of significant focal lesions of the node. For the average node this produces about 10 slides, a number that one can conveniently study carefully. Hudson has recently reported a similar experience in "serial" sectioning of the sinus node.

Using the normal anatomy of the coronary arteries in conjunction with the behavior of the ischemic sinus node and AV node, one can determine in vivo the exact location of some acute coronary occlusions. Just as a neurologist is able to determine the location of a cerebral artery occlusion by the abnormal neurologic manifestations, a cardiologist can determine the location of some coronary occlusions from the abnormal behavior of the cardiac conduction centers.

It is well known that most myocardial infarctions occur in hearts with pathology in more than one coronary artery, but some infarctions occur by the occlusion of a single artery. If the atrial arrhythmias of an acute myocardial infarct are due to recent occlusion of one artery with blood supply to the sinus node originating beyond an old occlusion in another artery, finding of infarction in the sinus node (as in every case of this study) suggests that collateral circulation to the node was dependent on patency of the recently occluded artery. Thus atrial arrhythmias during myocardial infarction imply ischemia of the sinus node plus coronary occlusion proximal to the origin of its blood supply, but the occlusion may be either recent or remote. In this regard such reasoning tells neither more nor less than coronary angiography.

The complex problem of multiple coronary occlusions may be more rationally approached if we understand the behavior of myocardial
infarction that follows a single coronary occlusion. The concept of this type of analysis may be introduced by considering right coronary artery occlusion. Since the right coronary supplies the AV node in 90 per cent of human hearts, a patient with acute myocardial infarction who develops any degree of heart block almost certainly has a right coronary occlusion.\(^{47-49}\) Vagotonia associated with acute infarction may contribute to this block, but this factor is usually more transient.

Determination that the right coronary is occluded still leaves a long segment of vessel in which to localize the occlusion. Of some help is the fact that most clinically recognizable myocardial infarctions are associated with an occlusion in the first 4 or 5 cm. of the artery. Of much greater localizing value, however, is the onset of atrial arrhythmias. This can be detected on clinical auscultation, and confirmed electrocardiographically in all except the most transient cases.

If an atrial arrhythmia occurs in a patient with a posterior myocardial infarction, the coronary occlusion is most likely to be proximal to the origin of the sinus node artery. Since true posterior infarctions are in 90 per cent of cases due to right coronary occlusion, and since the sinus node artery from the right (55 per cent of humans) arises most frequently within 2 or 3 cm. from the aorta, the coronary occlusion in a posterior myocardial infarction with an atrial arrhythmia is most likely in the first 2 or 3 cm. of the right coronary artery (fig. 20).

In the 10 per cent of patients who supply the crux of the heart from the left circumflex artery, a clinically recognizable myocardial infarction is most likely to follow occlusion in the proximal left circumflex artery, which produces not only a true posterior but also a high lateral ventricular infarction. In such a case the electrocardiographic evidence of infarction is not limited to leads III, aV\(_F\), and V\(_8\), but is also seen in aV\(_L_5\), lead I, and high leads HV\(_3\) to HV\(_6\). Thus posterior infarction when due to left circumflex occlusion may be diagnosed with the use of conventional supplementary electrocardiographic leads. In such cases the added occurrence of atrial arrhythmias serves to localize the occlusion to the very first centimeter of the left circumflex artery, for the sinus node artery from the left (45 per cent of humans) only rarely arises any greater distance from the bifurcation than this (fig. 21). Proximity of such occlusions to the main left coronary artery, and the increased likelihood of eventual occlusion of this main trunk, serves to explain why such a high mortality rate has been described in lateral myocardial infarctions associated with atrial fibrillation,\(^{50}\) an observation which has previously been unexplained.

From these two basic considerations of occlusions of the right and left circumflex coronary arteries, it is simple to extend the same reasoning to other combinations in the heart. Since the sinus node artery virtually always arises from either the right or left side, not from both, location of an occlusion proximal to this vessel becomes a very useful tool.

It is unusual (less than 10 per cent) for the right coronary artery not to reach the crux of the heart and AV node, and conversely it is unusual for the left circumflex to reach this point; the lengths of these two arteries are reciprocal.\(^{51}\) Lateral infarctions not associated with atrial arrhythmias suggest that the sinus node artery arose proximal to the point of occlusion in the left circumflex artery, or that the sinus node artery in that case arose from the right side; the latter explanation is the usual one in clinically recognizable infarctions. On the right side, a posterior infarction not associated with atrial arrhythmias suggests that the sinus node artery either arose proximal to the point of occlusion in the right coronary artery or arose from the left side; either of these is equally possible, since the right coronary is usually longer than the left circumflex. It is apparent that the absence of atrial arrhythmias is much less helpful than their presence in localizing a coronary occlusion.

Anteroseptal myocardial infarctions, which in single coronary occlusions are almost invariably due to left anterior descending coronary occlusion, are rarely associated with either atrial arrhythmias or heart block. If

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AV block occurs, it is usually due to a vagomimetic reflex rather than damage of the AV node. If an atrial arrhythmia occurs there is virtually always an associated second coronary occlusion (old or new) involving the left circumflex or right coronary artery.

Finally, comment is offered regarding the significant differences in canine and human coronary anatomy relative to interpretation of changes in cardiac rhythm in canine experiments on myocardial infarction. The sinus node artery of the dog is nearly always a terminal branch of the right coronary artery, whereas the sinus node artery in man arises with about equal frequency from the right and left sides, and from the anterior third rather than the distal third. The arterial supply of the AV node in the dog is more complex than in man and cannot be so simply analyzed as determining which artery crosses the crux. The left coronary artery of the dog supplies almost the entire left ventricle and interventricular septum, whereas the posterior wall of the left ventricle in man is most often supplied by the right coronary artery. It is unnecessary to go into more detail regarding these differences here. The careful planner of canine experiments on myocardial infarction should be more familiar with them than is commonly the case, however.

Summary
In each of 11 necropsied patients with myocardial infarction and atrial arrhythmias, a coronary occlusion was found proximal to the origin of the sinus node artery and there was infarction of the sinus node.

The multiple factors influencing the onset of atrial arrhythmias during acute myocardial infarction are discussed. Infarction of the sinus node is only one of these factors. Other important ones are ischemia of the AV node, vagal and vagomimetic reflexes, atrial distention, and circulating chronotropic substances.

By combination of a knowledge of the anatomy and pathology of the human coronary arteries with the observation of atrial arrhythmias during acute myocardial infarction, an accurate diagnosis of the point of coronary occlusion can often be made.

References

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