Myocardial Necrosis in Experimental Occlusion of the Portal Vein

By Raúl H. Mejía, M.D.

The predominant role of the myocardium in the development of circulatory failure in experimental hypovolemic shock, already suggested by the contributions of Erlanger, Janeway, and others, was clearly established by Wiggers and Sarnoff on the evidence of their hemodynamic studies.

The characteristic electrocardiographic abnormalities observed in patients following hemorrhage of the digestive tract were ascribed by Master to a diffuse subendocardial ischemia, due to acute coronary insufficiency. A similar pattern was found by Izquieta in experimental hemorrhagic shock, but although these abnormalities are the electrocardiographic expression of a diminished coronary flow, they cannot be held as criteria of myocardial damage responsible for the hemodynamic changes described by Wiggers and Sarnoff.

However, subendocardial hemorrhages and miliary necroses were observed by Mylon, Melcher, and Hackel in experimental shock, and by Sheehan, Horn, and others in patients with hemorrhagic shock. The present study was undertaken in an attempt to obtain humoral and histopathologic evidence of myocardial necrosis.

Methods

Fourteen mongrel dogs, weighing from 8.2 to 24.6 Kg., were used. A 45-minute temporary occlusion of the portal vein, as described elsewhere, was performed on 9 of the animals, followed by daily injections of penicillin (200,000 units) for 3 days. The control group included 5 dogs on which a mid-line incision was performed under sodium pentobarbital anesthesia. A mercury manometer was used for the reading of arterial pressure, and electrocardiograms were taken daily. Einthoven, Goldberger, and Wilson leads were used in this study.

Table 1

<table>
<thead>
<tr>
<th>Dog no.</th>
<th>Weight in Kg.</th>
<th>ECG.</th>
<th>GOT</th>
<th>Plasma levels U./mls.</th>
<th>Days sacrificed</th>
<th>Hist.</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>13.6</td>
<td>SEI/TMN</td>
<td>TMN</td>
<td>53</td>
<td>123</td>
<td>MMN</td>
</tr>
<tr>
<td>41</td>
<td>14.2</td>
<td>SEI/TMN</td>
<td>SEI/TMN</td>
<td>47.5</td>
<td>220</td>
<td>Normal</td>
</tr>
<tr>
<td>44</td>
<td>8.2</td>
<td>SEI/TMN</td>
<td>TMN</td>
<td>74</td>
<td>145</td>
<td>MMN</td>
</tr>
<tr>
<td>45</td>
<td>10.0</td>
<td>TMN</td>
<td>TMN</td>
<td>73</td>
<td>301</td>
<td>MMN</td>
</tr>
<tr>
<td>49</td>
<td>10.5</td>
<td>SEI/TMN</td>
<td>TMN</td>
<td>70</td>
<td>198</td>
<td>MMN</td>
</tr>
<tr>
<td>42</td>
<td>11.6</td>
<td>SEI</td>
<td>Normal</td>
<td>46</td>
<td>48</td>
<td>Normal</td>
</tr>
<tr>
<td>46</td>
<td>23.3</td>
<td>SEI</td>
<td>Normal</td>
<td>81</td>
<td>98</td>
<td>Normal</td>
</tr>
<tr>
<td>47</td>
<td>23.2</td>
<td>SEI</td>
<td>Normal</td>
<td>72</td>
<td>168</td>
<td>Normal</td>
</tr>
<tr>
<td>48</td>
<td>24.6</td>
<td>SEI</td>
<td>Normal</td>
<td>89</td>
<td>102</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Occl.: During occlusive period.
Post.: Following occlusive period.
SEI: Subendocardial ischemia.
TMN: Transmural necrosis.
MMN: Miliary myocardial necrosis.
AO: Abscess in omentum.

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Figure 1

Dog 46: Transitory occlusion of the portal vein.

Serum glutamic oxalacetic transaminase (GOT) activity was measured as reported in a previous paper. The anterolateral and posterior walls of the left ventricles were sectioned for microscopic examination. Histological sections were also made of the liver, spleen, and lungs, and routinely stained with hematoxylineosin or with Mallory's stain.

Results

All dogs with a temporary occlusion of the portal vein recovered from the ensuing hypovolemic shock. In all the cases, electrocardiographic abnormalities suggestive of Master's subendocardial ischemia were observed with-
MYOCARDIAL NECROSIS

30 min. after the occlusion

after releasing the occlusion

24 hours later

72 hours later

96 hours later
sacrificed the ninth day

Figure 2

Dog 44: Transitory occlusion of the portal vein.

in 30 minutes of the beginning of the hypotensive phase (table 1; figs. 1, 2). These changes reverted to normal in 4 dogs once the portal occlusion was released (fig. 1) and the other dogs manifested a pattern of high lateral myocardial infarction (fig. 2).

Serum GOT plasma level paralleled the electrocardiographic changes rising to significantly high levels whenever the electrocardiographic signs of myocardial infarction were present, and remained within normal limits in the other instances (table 1). One dog had a high serum GOT titer, which was not corroborated by the electrocardiogram; postmortem examination revealed a large abscess of the liver.

Histopathologic studies of the myocardium revealed necrotic areas extending from the endocardium to the epicardium. There was a slight predominance of necrotic tissue over
healthy tissue in the lateral and anterior walls of the left ventricle (fig. 3). Liver, lungs, and spleen were normal.

No significant deviations from the normal, as shown by the electrocardiogram or the GOT test, were found in the control group.

**Discussion**

A marked reduction in blood volume, following the temporary occlusion of the portal vein, has been reported by Mallet-Guy,\(^{22}\) by Johnstone,\(^{23}\) and has been confirmed by our investigations.\(^{24}\) Upon the release of ligature, the blood accumulated in the splanchnic bed regains access to the systemic circulation and normovolemia is restored.

The electrocardiographic changes described by Izquieta\(^{9}\) in experimental shock and observed by Master\(^{8}\) in clinical cases, although characteristic of diffuse subendocardial ischemia, cannot be considered as signs of myocardial necrosis. On the other hand, electrocardiographic evidence of necrosis of the myocardium in hypovolemic experimental shock has been presented by us in earlier papers. The characteristic electrocardiographic pattern was a fairly constant finding in our previous series of shocked dogs.\(^{19,20}\)

Since the original work of LaDue,\(^{25}\) much data has been gathered on serum GOT activity in experimental and clinical myocardial...
necrosis, as compared to hepatic and pulmonary necrosis. High elevated titers of serum GOT activity are regarded as confirmatory evidence of myocardial infarction. A quantitative relationship has even been established between the number of enzymatic units and the size of the necrotic zone provided that the absence of necrosis in other organs has been ascertained.

Structural changes in the myocardium of our dogs did not resemble the histopathologic picture of myocardial infarction following acute coronary ligation, but conformed to a pattern of scattered mililiary necrosis. A greater density of necrotic foci in a given area with the resulting predominance of dead over normal tissue is possibly responsible for the electrocardiographic pattern of epicardial or transmural necrosis of the high lateral wall of the left ventricle. The hemodynamic changes described by Wiggers, and Sarnoff, and the circulatory failure found in the normovolemic phase of shock may also be traced back to the reported mililiary necrosis.

It is suggested that metabolic changes taking place during the hypovolemic phase of shock are the outcome of anoxia. There is an impairment of cellular function and finally cellular death, as shown, by the electrocardiographic, humoral and histopathologic evidence. It is our contention that the myocardial necrosis reported herein plays a fundamental role in the development of cardiac insufficiency in hypovolemic experimental work, and perhaps also in its irreversibility.

Summary

Fourteen dogs were subjected to temporary occlusion of the portal vein. Electrocardiographic changes suggestive of epicardial or transmural necrosis of the high lateral region of the left ventricle and of subendocardial ischemia, were found in 55 per cent of the dogs. These electrocardiographic changes were accompanied by a significant rise of plasma GOT. Myocardial sections showed areas of multifocal necrosis, extending from endocardium to epicardium, with predominance in the lateral and anterior wall and pillars of the left ventricle and interventricular septum.

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Summario in Interlingua

Dece-quatro canes esseva subjicito a occlusion transiente del vena portal. Esseva trovate in 55 pro cento del casos alterationes electrocardiographic de typos indicative de necrosis epicardial o transmural del region supero-lateral del ventrieulo sinistre e de ischemia subendocardial. Iste alterationes del electrocardiogramma esseva accompaniate de un aumento significative de transaminase glutamic-oxaloaeetic del plasma. Sectiones myocardial revelava areas de necrosis multifocal, ab le endocardio usque al epicardio, cos predominantia in le pariete lateral e anterior e le pilares del ventrieulo sinistre e le septo interventricular.

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