Variations in Serum Glutamic Oxaloacetic Transaminase Activity in Experimental and Clinical Coronary Insufficiency, Pericarditis, and Pulmonary Infarction

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Previous studies have demonstrated consistent rises in serum activity of the enzyme, glutamic oxaloacetic transaminase (SGO-T), following myocardial necrosis of various etiologies. The present study demonstrates markedly different findings in experimental and clinical coronary insufficiency, pericarditis, and pulmonary infarction unless concomitant myocardial necrosis was present. This seems to be a valuable means of differentiating clinical problems in which the presence of myocardial injury is suspected as the basis of the patient's chest pain.

The serum activity of the enzyme, glutamic oxaloacetic transaminase (SGO-T), increases following experimental or clinical myocardial necrosis.1-4 When acute myocardial necrosis is produced by ligation1 or embolization3 of the coronary vessels of a dog, the SGO-T activity begins to rise within 4 hours after the heart muscle damage, reaches a peak within 12 to 24 hours, and remains elevated for 2 to 7 days. The intravenous injection of papain in rabbits causes myocardial necrosis and significant rises of SGO-T. Such elevations have been seen in all animals developing myocardial necrosis of different types, and the degree of rise is roughly proportional to the amount of damaged muscle.3-4 It has been possible to detect necrosis of less than 1 Gm. of dog myocardium from a study of the serial changes in the SGO-T level. Characteristic curves have been observed following heart muscle necrosis in man due to myocardial infarction and in some patients with the carditis of rheumatic fever.5 Preliminary observations in animal experiments and in man suggested that myocardial ischemia without necrosis was not followed by elevation of SGO-T even when associated with marked electrocardiographic abnormalities of the ST and T waves.2-4 The accuracy of the variations in SGO-T activity in detecting myocardial necrosis is shown in table 1.

The SGO-T level has not been found to be elevated in a large group of patients with infectious, neoplastic, allergic and degenerative disease states unless evidence of acute damage to the liver,6 heart, or skeletal muscle was present.

The patient with prolonged chest pain and fluctuating electrocardiographic abnormalities of the ST and T segments is frequently a difficult diagnostic problem. The decisions whether such pain is of cardiac origin and, if so, whether necrosis of the myocardium has occurred, are of the utmost importance, and confusion in diagnosis is common. Minor abnormalities in the white blood cell count, erythrocyte sedimentation rate, C-reactive protein, and temperature are often difficult to evaluate and may even be misleading.

The observation that the SGO-T failed to rise following myocardial ischemia due to temporary occlusion of a dog's coronary artery or following prolonged coronary insufficiency in man despite marked but reversible ST and T wave evidence of myocardial injury2,4 encouraged us to study the changes in SGO-T activity following experimental and clinical myocardial ischemia, pericarditis, and pulmonary infarction.

Assay of Enzyme

The SGO-T levels were analyzed spectrophotometrically.
Aspartate +
α-Ketoglutarate → Glutamate +
Transaminase
Oxaloacetate

**TABLE 1.—Maximum SGO-T Concentration Following Myocardial Ischemia in Dogs with Electrocardiographic Abnormalities of Varying Duration**

<table>
<thead>
<tr>
<th>Dog No.</th>
<th>Duration occlusion (min.)</th>
<th>Duration EKG abnormality (min.)</th>
<th>Maximum SGO-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-67</td>
<td>3½</td>
<td>9</td>
<td>79</td>
</tr>
<tr>
<td>X-71</td>
<td>4</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>X-63</td>
<td>2½</td>
<td>4½</td>
<td>28</td>
</tr>
<tr>
<td>164</td>
<td>1½</td>
<td>4</td>
<td>44</td>
</tr>
<tr>
<td>X-158</td>
<td>1</td>
<td>45</td>
<td>33</td>
</tr>
<tr>
<td>163</td>
<td>7½</td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td>185</td>
<td>3/4</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>196</td>
<td>3</td>
<td>5</td>
<td>96*</td>
</tr>
<tr>
<td>X-26</td>
<td>1½</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>X-84†</td>
<td>Artery Permanently Occluded</td>
<td>150</td>
<td>36</td>
</tr>
<tr>
<td>X-333</td>
<td>1</td>
<td>45</td>
<td>44</td>
</tr>
</tbody>
</table>

* Control = 80, hence a rise of only 16 SGO-T units.
† Premedication with atropine and aminophylline.

**Oxaloacetate +**

DPNH + Malate + DPN

Malic Dehydrogenase

One unit of transaminase was designated as a change in optical density of .001 per ml. per minute. The normal range as determined in 44 presumably normal dogs was 7 to 45 units per ml. per minute (mean 26; S.D. 9.5). The normal range as determined in 150 healthy adults was 8 to 40 units per ml. per minute (mean, 22.1; S.D., 7.1). All analyses were done at room temperature of approximately 23 C.

**EXPERIMENTAL CORONARY INSUFFICIENCY**

**Method**

Dogs were anesthetized with intravenous sodium pentobarbital and intubated and their respiration was sustained by intermittent positive pressure with compressed air or oxygen. The duration of anesthesia did not exceed 3 hours. A left lateral chest incision was made and the pleural space was entered through the fourth interspace without rib resection. The main branch of the left anterior descending coronary artery was then dissected free and a thick braided silk tie threaded beneath it in a sling-like fashion. The ends of the sling were brought to the body surface through stab wounds in the chest and buried subcutaneously (fig. 1). The effects of temporary coronary occlusion could then be studied 10 to 14 days later.

![Fig. 1. Technic for the production of temporary myocardial ischemia in the dog. In A the sling is seen threaded beneath the isolated coronary artery. B and C show the coronary vessels in cross section before and after traction upon the string. D shows the ends of the tie brought through the closed chest wall in readiness for the application of traction in order to compress the coronary vessel.](https://circ.ahajournals.org/doi/abs/10.1161/01.cir.16.4.325)
days after the operation when the consistent SGO-T rise following transection of the chest musculature had subsided. At that time 30 mg. of morphine sulfate were given subcutaneously, and 20 minutes later traction was applied to the ends of the suture for 30 seconds to 71/2 minutes to compress the lumen of the coronary artery. Continuous electrocardiographic observations were made during this period.

Serial venous blood samples and electrocardiograms were obtained during a minimum period of 5 days. During the first 36 hours blood was drawn approximately every 8 hours. Subsequently all animals were autopsied and appropriate microscopic sections of the myocardium obtained. If no myocardial lesions were visible grossly, multiple sections were obtained from the area supplied by the artery that had been temporarily occluded.

Homogenates of infarcted and normal areas of dog heart were prepared in an ice-water bath as soon after death of the animal as possible. When tissues were not homogenized at once, they were frozen and stored in dry ice. Homogenization of saline suspensions of minced muscle was complete except for very small amounts of residual collagen. Calculations of glutamic oxaloacetic transaminase (GO-T) content were based on the wet weight of the fresh heart muscle. The spectrophotometric analysis was performed in the standard fashion with at least 10 minutes allowed for the blank reaction before the addition of α-ketoglutarate.

**Results**

Seventeen dogs were operated upon, 2 dying postoperatively. In all the remaining 15 dogs temporary occlusion of the coronary artery (fig. 1) produced marked electrocardiographic abnormalities. The usual rise in the serum transaminase following thoracotomy was seen in all 15 animals. A second rise in SGO-T was seen in 5 of the 15 dogs following temporary coronary artery occlusion and equivocal changes in a sixth (dog X-333).

Four of these animals had definite myocardial infarction at autopsy, which varied in size from less than 1 Gm. to more than 6 Gm., and are therefore excluded from table 1. Dog X-333 showed minute foci of subendocardial necrosis and equivocal changes in the SGO-T, possibly the only animal in this and in the previous series in which myocardial necrosis, although exceedingly small in amount, did not produce diagnostic SGO-T changes; he is included in table 1. The sixth animal, X-67, showed no gross areas of myocardial infarction at autopsy, but the SGO-T rose to 79 units. Unfortunately, the microscopic sections of the myocardium of this animal were not examined and it cannot be stated whether minute areas of myocardial necrosis were actually present. This dog is therefore listed as a probably false positive SGO-T. No myocardial necrosis and no rise in SGO-T were observed in the other 9 dogs.

Table 2 shows the incidence of increased SGO-T activity following acute transmural myocardial infarction in man and following myocardial infarction in dog. The marked differences in the incidence of these elevations following reversible myocardial ischemia and after myocardial infarction may be seen by a comparison of tables 1, 2, and 3.

Figures 2 and 3 show the results of a typical experiment (dog 164). Gradual peaking of the T waves and elevation of the ST segments followed temporary coronary artery occlusion. After the release of the traction upon the ends of the ties, the ST segments gradually returned to the baseline and the peaked T waves then resumed their control form. The duration of

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**Table 2.—Incidence of Elevated SGO-T Activity Following Acute Myocardial Infarction in the Dog and in Man**

<table>
<thead>
<tr>
<th></th>
<th>Number of patients</th>
<th>Number elevated SGO-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Dog</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>297</td>
</tr>
</tbody>
</table>

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**Table 3.—Clinical and Laboratory Findings in Fifty Patients with Coronary Insufficiency and Status Aginosus**

<table>
<thead>
<tr>
<th>Clinical findings</th>
<th>Number Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESR &gt; 20 mm./min.</td>
<td>7</td>
</tr>
<tr>
<td>Normal ESR</td>
<td>2</td>
</tr>
<tr>
<td>WBC &gt; 10,000/mm.³</td>
<td>5</td>
</tr>
<tr>
<td>Normal WBC</td>
<td>8</td>
</tr>
<tr>
<td>Temperature &gt; 99.8°F</td>
<td>7</td>
</tr>
<tr>
<td>Normal temperature</td>
<td>9</td>
</tr>
<tr>
<td>Congestive failure</td>
<td>3</td>
</tr>
<tr>
<td>No congestive failure</td>
<td>11</td>
</tr>
<tr>
<td>Shock</td>
<td>2</td>
</tr>
<tr>
<td>No shock</td>
<td>13</td>
</tr>
</tbody>
</table>
Fig. 2. The typical electrocardiographic changes in lead V4 following temporary myocardial ischemia in dog 164 are shown. Peaked T waves 6 seconds after coronary occlusion were followed by gradually increasing amplitude of the T waves and elevation of the ST segment. The electrocardiogram reverted to normal within 4 minutes after release of the coronary artery occlusion.

Fig. 3. The SGO-T activity following temporary myocardial ischemia was unchanged in dog 164, whose electrocardiograms are shown in figure 3. Only a minimal postoperative rise occurred.

marked electrocardiographic abnormality was 2 minutes, with return to normal in 4 minutes. No significant elevation of the SGO-T was seen following this experiment.

All except 1 animal in this series and in the previous study of myocardial infarction showed a similar sequence of electrocardiographic changes following occlusion of the coronary circulation, namely peaking of the T waves followed by ST segment elevation and return to normal if restitution of the circulation was prompt. In the 1 exception, ST segment depression and T wave inversion were produced. In addition, during the period of temporary ischemia, many types of cardiac arrhythmias developed in these animals including atrial

and ventricular premature contractions, 1 instance of coupled rhythm due to ventricular premature contractions, and 1 instance of ventricular tachycardia that ceased abruptly upon release of the coronary occlusion long before actual myocardial necrosis could have been produced. There was no correlation between changes in SGO-T activity and the arrhythmias in these animals.

GO-T Content in Normal and Previously Ischemic Heart Muscle. Table 4 lists the assay of GO-T in the heart muscle of 5 animals in whom coronary insufficiency was produced successfully. (Dog X-333 is listed although microscopic areas of myocardial necrosis were present.) There is no significant difference in GO-T content in the area of myocardium supplied by the artery that had been temporarily occluded and that taken from an area supplied by the other main coronary artery. The SGO-T activity had remained relatively unchanged following the production of "coronary insufficiency" in these animals.

Clinical Coronary Insufficiency

Material and Criteria

Fifty patients hospitalized with coronary insufficiency were studied at the New York Hospital, the Memorial Center for Cancer and Allied Diseases, the Second (Cornell) Medical Division of Bellevue Hospital, or the State University of New York Medical Center at Syracuse. No patient was included unless at least 3 separate serum transaminase determinations and serial electrocardiograms were obtained during the initial acute phase of his illness.

The criteria for the diagnosis of coronary insufficiency were: 1. Status anginosus or constant precordial or substernal chest pain of 30 minutes' duration or greater. Patients with obvious non-cardiac causes of chest pain such as pneumonia and

<table>
<thead>
<tr>
<th>Dog number</th>
<th>Normal muscle</th>
<th>Previously ischemic muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-333</td>
<td>201,000</td>
<td>219,290</td>
</tr>
<tr>
<td>185</td>
<td>300,720</td>
<td>411,570</td>
</tr>
<tr>
<td>X-158</td>
<td>348,320</td>
<td>362,130</td>
</tr>
<tr>
<td>163</td>
<td>373,220</td>
<td>374,930</td>
</tr>
<tr>
<td>164</td>
<td>307,550</td>
<td>298,800</td>
</tr>
</tbody>
</table>
hiatus hernia were excluded. 2. Definite T-wave abnormalities on the electrocardiogram. These patients frequently showed associated ST segment abnormalities. All patients were excluded whose electrocardiograms showed the evolution of recent transmural myocardial infarction as proved by the development of significant Q waves. Thirteen had electrocardiograms showing evidence of old transmural infarction but developed marked T-wave variations during the present attack of chest pain without any change in the Q waves.

Results

The pertinent clinical and laboratory data for 50 patients with coronary insufficiency are listed in table 3. Valid serial determinations of the erythrocyte sedimentation rate, white blood cell count, and temperature were not available in all patients. In addition, these determinations were ignored when influenced by extracardiac factors such as pneumonia, thrombophlebitis, etc. Sixteen of these 50 patients demonstrated elevations of SGO-T activity at some time during the acute phase of their disease. A significant number of patients with normal levels showed abnormalities of the erythrocyte sedimentation rate, white blood cell count, or temperature. In addition, the SGO-T remained normal in 5 of the patients with congestive heart failure and in 2 who were in moderate shock when admitted to the hospital. Those patients with elevated SGO-T activity revealed a somewhat higher percentage of laboratory and clinical abnormalities except for alterations in the white blood count. The white blood count was elevated in 5 of 13 patients with abnormal SGO-T levels and 14 of 25 with normal SGO-T activity. However, a significant number of patients who had normal white blood cell counts, erythrocyte sedimentation rates, and temperature developed elevation of the SGO-T.

![Graph](image)

**Fig. 4.** The average course of the SGO-T in 50 patients with acute transmural myocardial infarction (solid black circles) and 50 patients with coronary insufficiency or status angnosus (solid black triangles). Each open circle represents the day and the height of the maximum SGO-T activity of each of these 50 patients with coronary insufficiency. Only 16 patients had elevated SGO-T; 8 elevations were first seen after the fourth day of illness.

Table 5 lists those patients in whom valid serial determinations were obtained of at least 2 of the 3 tests (WBC, ESR, and temperature) most often utilized in following the course of patients of this type. Six of 12 patients with an elevated SGO-T and 8 of 27 with normal SGO-T activity revealed abnormalities in at least 2 of these 3 tests. It is apparent that the SGO-T activity did not consistently parallel changes in temperature, white blood cell count, or erythrocyte sedimentation rate. In 8 patients the SGO-T did not rise until after the fourth day of observation. Figure 5 illustrates this phenomenon and contrasts the curves of SGO-T activity following coronary insufficiency with those noted following transmural myocardial infarction in 50 patients. Each open circle represents the maximum SGO-T value for each individual patient with coronary insufficiency. The solid triangles represent the average daily levels in the patients with coronary insufficiency. The solid circles represent the average daily SGO-T activity following

### Table 5.—Relationship of SGO-T to Abnormalities in White Blood Cell Count, Temperature, and Erythrocyte Sedimentation Rate

<table>
<thead>
<tr>
<th>Number patients abnormal SGO-T</th>
<th>Number patients with abnormalities in at least 5% WBC, ESR, temperature</th>
<th>Number patients normal SGO-T</th>
<th>Number patients with abnormalities in at least 5% WBC, ESR, temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>6 (50%)</td>
<td>27</td>
<td>8 (29%)</td>
</tr>
</tbody>
</table>
acute transmural myocardial infarction. The marked difference in the course of SGO-T activity in the 2 conditions is readily apparent. The open circles beyond the fourth day of the present illness in the abnormal range of SGO-T represent the 8 patients with delayed elevations of the SGO-T. The preponderance of patients with normal serum enzyme activity is also obvious.

Dicumarol was administered to 17 patients in this series. The SGO-T was abnormal in 4 patients before therapeutic levels were reached. In 4 other patients slight elevation of SGO-T activity was seen after anticoagulation had reached a satisfactory level. No information is available regarding the course of the SGO-T after anticoagulation was discontinued.

The behavior of the enzyme and its use as a diagnostic aid in patients with coronary insufficiency can best be illustrated by the following representative cases.

Case Reports

Case 1 (Fig. 5.) R.H., a 49-year-old man, suffered severe squeezing retrosternal pain 3 weeks prior to admission to New York Hospital. This pain recurred frequently until the evening prior to admission, when it became more frequent and severe in intensity and radiated into the arms. Physical examination was negative. The temperature on admission was 100.4 F. and it fell to normal in 24 hours. The blood pressure was 135/80 and remained unchanged during hospitalization. The maximum white blood cell count was 12,400 per mm.\(^3\) and the maximum sedimentation rate (Wintrobe) 27 mm./hour.

Case 2 (Fig. 6.) R.A.H., a 53-year-old male executive was admitted to Memorial Hospital after 3 days of progressively frequent and severe substernal pain, worse on reclining, often lasting more than 15 minutes despite the frequent use of nitroglycerin. Except for an apical systolic murmur of grade II intensity, the physical examination was essentially negative. The blood pressure on admission was 160/110 and it fell to 130/90 during the first hospital day. The temperature remained normal. The maximum white blood cell count was 8,000 per mm.\(^2\) and the maximum erythrocyte sedimentation rate (Wintrobe) 16 mm./hour.

The T-wave abnormalities were similar in both patients, but completely reverted to normal in case 2 after 3 months. Since Q waves did not develop in either patient, the only diagnosis that could be supported electrocardiographically was that of myocardial ischemia. The increase of SGO-T activity to 56 units in case 1 suggested that a small amount of myocardial necrosis had taken place. Although the temperature, erythrocyte sedimentation rate, and the white blood cell count were increased in this patient, these abnormalities have been found in other similar patients without a concomitant rise of the transaminase.

**Experimental Pericarditis**

**Method**

Pericarditis was produced experimentally in dogs by a modification of the 2-stage procedure used in producing coronary insufficiency. A length of polyethylene tubing was sutured into the pericardial cavity, brought to the exterior, and buried subcutaneously after closure of the chest. Ten to 14 days later, approximately 5 Gm. of ordinary talcum powder (magnesium silicate) were suspended in saline and injected through the tubing into the pericardial cavity. Serial determinations of the serum transaminase were obtained postoperatively and after injection of the talcum. Electrocardiograms

![Fig. 5.](image1)

![Fig. 6.](image2)
were recorded periodically. All of the animals were autopsied and the organs examined microscopically.

Results

The course of the SGO-T after the production of pericarditis was studied in 7 dogs and was elevated in 4 of these animals. In these 4 animals moderate to extensive subepicardial myocardial necrosis was demonstrated microscopically. In the other 3 animals no myo-

![Graph](image)

**Fig. 7.** Minimal elevations of the SGO-T activity in case 3 of severe pericarditis complicating infectious mononucleosis.

Cardial necrosis was demonstrated in 2 and was quite minimal in the third. A foreign-body granulomatous inflammatory process was present in the pericardium and epicardium of all animals.

Clinical Pericarditis

Material and Criteria

The SGO-T activity of 11 patients with pericarditis was measured daily for 3 to 30 days. The diagnosis of pericarditis was established by the presence of a typical friction rub in 10 patients. The eleventh patient, S.E., is described in detail below (case 3, figs. 7 and 8). The etiology of the pericarditis was idiopathic in 3 instances and secondary to the following diseases in the remainder: uremia, 3; Hodgkin's disease, 2; myelogenous leukemia, 1; lupus erythematosus, 1; and infectious mononucleosis, 1.

Results

Of the 11 patients studied in whom unequivocal evidence of pericarditis was present 2 showed minor serum transaminase eleva

![Graph](image)

**Fig. 8.** Electrocardiographic changes of pericarditis in case 3. Note ST elevation on 1/25/55, the inverted T waves on 1/27/55, and the return of the electrocardiogram to normal on 3/23/55 after the patient's recovery.
tions. In 1 of these patients, S.E., (case 3) definite liver function abnormalities were also present, although of minor degree. The other patient had advanced myelogenous leukemia with marked hepatomegaly and splenomegaly. Liver dysfunction or actual invasion of the myocardium by leukemic cells may have contributed to the increased SGO-T activity present in this patient. The remaining 9 patients showed no alterations in SGO-T activity during the acute phases of their diseases.

Case Reports

Case 3. Pericarditis Due to Infectious Mononucleosis. (figs. 7 and 8.) S.E., a 26-year-old man, was awakened at 3 a.m., by crushing substernal pain radiating down the inner aspect of the left arm to the elbow. The pain lessened during the next 8 hours but he was admitted to the New York Hospital because of an abnormal electrocardiogram (fig. 8). After close questioning he recalled that he had been somewhat fatigued and suffered vague myalgia 1 week prior to admission and felt somewhat chilly with the onset of this chest pain. The patient's father, uncle, and 4 grandparents all died following myocardial infarction.

Examination revealed a temperature of 100.4 F., a blood pressure of 110/80, and a pulse of 90 per minute. The physical examination was completely negative including that of the heart. No pericardial friction rub was heard at any time during the hospitalization. On the fourth hospital day, generalized lymphadenopathy and a slightly injected pharynx appeared but otherwise the general physical examination remained within normal limits.

The laboratory examination was normal on admission but on the third hospital day 70 per cent of the white blood cells were noted to be lymphocytes, 75 per cent of which were of the Downey type. These cells were considered to be compatible with infectious mononucleosis and persisted for at least the following month. The heterophile agglutination titer rose to a peak of 1:3,584 during the second hospital week. Differential absorption of the heterophile agglutination was diagnostic of infectious mononucleosis. There were minor abnormalities of the liver function tests.

The minor elevations in SGO-T are shown in figure 7. The electrocardiograms are shown in figure 8. The evolution of the electrocardiogram is considered to be diagnostic of pericarditis.

Despite the marked current of injury pattern on the electrocardiogram, there were only minor abnormalities of the serum transaminase. It is possible that the minor increase in transaminase activity was the result of liver damage commonly seen during the course of infectious mononucleosis. A markedly elevated SGO-T would have been expected if sufficient myocardial necrosis were present to cause such extensive electrocardiographic abnormalities. That the relatively normal SGO-T on admission ruled out significant myocardial necrosis was confirmed by the clinical course of the patient.

Experimental Pulmonary Infarction

No studies on experimental pulmonary infarction were performed in our laboratory but Agress and associates\textsuperscript{10} have reported that only minor transaminase variations are noted following experimental pulmonary infarction in dogs.

Clinical Pulmonary Infarction

Material and Method

Seven patients with pulmonary infarction were studied. The criteria utilized in establishing the diagnosis were, (1) chest pain, hemoptysis, or sudden respiratory distress in a patient with evidence of peripheral phlebitis or atrial fibrillation, (2) x-ray shadows compatible with this diagnosis, (3) rapidly fluctuating electrocardiographic signs of prominent S\textsubscript{1}, Q\textsubscript{2}, and diphasic or inverted T\textsubscript{V}1, 2, 3. Only 2 patients showed these electrocardiographic changes.

Results

In the 7 patients with pulmonary infarction, the highest transaminase recorded was 50 units although large areas of pulmonary infarction were present in 3 of these patients.

Discussion

Acute myocardial ischemia of 1 to 150 minutes produced by compression of the coronary artery of the dog was followed by the prompt appearance of characteristic ST segment and T-wave changes that usually disappeared within 5 minutes after restoration of coronary blood flow in the animals that did not exhibit postmortem evidence of myocardial necrosis. The SGO-T, however, did not rise significantly unless concomitant heart muscle cell necrosis was found at autopsy (table 2). The GO-T content of the area of heart muscle rendered ischemic was the same as that of the
nonischemic areas (table 4). In previous experiments a progressive diminution in GO-T concentration was found in infarcted myocardium associated with rises in serum activity of the enzyme.

These experimental data support the interpretation of the significance of the SGO-T alterations during and following prolonged coronary insufficiency in man. The fact that 34 of 50 patients with coronary insufficiency had normal levels of SGO-T, despite prolonged substernal chest pain associated with ST segment and T-wave changes, is strong presumptive evidence that irreversible muscle damage did not occur or was of small degree and probably of questionable clinical significance. The occurrence of elevations of the white blood count and erythrocyte sedimentation rate in 14 of these patients and of temperature elevation in 5, of congestive failure in 5, and of shock in 2 patients, casts some doubt upon the reliability of these extracardiac findings so commonly used to substantiate the presence of acute myocardial infarction. A more consistent relationship between SGO-T elevations and temperature, white blood cell count, and sedimentation rate was noted if 2 of the latter 3 determinations were also abnormal. Furthermore, the finding of persistently normal SGO-T levels in patients with status anginosus exhibiting equivocal electrocardiographic changes permitted much earlier ambulation and shortened their hospitalization. The use of anticoagulants was not uncommonly followed by significantly less angina. Some of the 16 patients with comparable clinical findings but elevated SGO-T activity were treated as having sustained an acute myocardial infarction.

The delayed rise of SGO-T activity in 8 of the 16 patients, first appearing on the fourth to twenty-first day of hospitalization, is of considerable interest and lends support to the concept of a preinfarction clinical syndrome, although there was nothing in the clinical picture of these patients to distinguish them from the other patients with coronary insufficiency. We have made it our policy to administer anticoagulants to all patients with persistent and frequently recurring coronary insufficiency.

The number of patients studied is too small to permit any positive statements, but it is strongly suggested that the SGO-T activity may be a useful method in detecting the presence of myocardial infarction in the patient with angina pectoris or coronary insufficiency and equivocal electrocardiographic changes. This laboratory test is similarly helpful when left bundle-branch block, pericarditis, or pulmonary infarction make definitive electrocardiographic interpretation difficult.

In all except 1 of over 20 experiments in which a major coronary vessel was either permanently or temporarily occluded through an intact chest wall, a characteristic sequence of electrocardiographic changes was seen, both in the precordial leads and an appropriate bipolar limb lead. Peaking of the T wave followed by increased amplitude of the T wave was first noted, followed by gradual elevation of the ST segment often resulting in a monophasic configuration of the QRS-T complex unless the coronary circulation was re-established. Upon restoration of the coronary circulation, the ST segment and T waves usually returned to the baseline form promptly if irreversible myocardial damage had not been produced. It was only after a longer period of coronary occlusion sufficient to cause irreversible myocardial damage that the pattern of an elevated ST segment and an inverted T wave was seen.

These electrocardiographic changes, presumably the result of partial loss of the normal polarizing effect of the myocardial cell membrane with transudation of electrolytes into the extracellular space, were not associated with a simultaneous elevation of the serum concentration of transaminase. This observation supports the concept that more severe and prolonged cellular injury is necessary to elevate the SGO-T than is sufficient to cause reversible electrocardiographic changes. Whether the larger molecular size of the enzyme is a determining factor in this dissociation between electrocardiographic changes
and changes in serum concentration of transaminase is a matter of speculation at present.

Experimental pulmonary infarction failed to cause consistent or marked deviations of SGO-T activity.\(^{10}\) Six of 7 patients with clearcut evidence of pulmonary infarction had SGO-T levels well within normal limits and in the seventh the peak value was only 50 units. These data suggest that acute myocardial infarction can be differentiated from pulmonary infarction by means of serial SGO-T determinations. More patients need to be studied to substantiate this impression.

Extensive pericarditis resulting from the instillation of talcum into the pericardial sac was followed by SGO-T elevation only when microscopic evidence of subepicardial damage was present. The SGO-T activity in clinical pericarditis of varied etiology in 11 patients was normal throughout the study in 9 instances and only slightly elevated in 2 patients. These data indicate that acute myocardial infarction can usually be distinguished from pericarditis, since in the former the SGO-T activity usually rises to higher levels and the characteristic rise and fall within 3 to 7 days is completely unlike the low peak and intermittent elevations of the SGO-T activity seen in 2 patients during the course of acute pericarditis.

The importance of accurate technic, measurement of enzyme activity at 23 C., and analysis within 4 days of drawing the blood cannot be overemphasized. Serum should be promptly separated from the red blood cells and stored at refrigerator temperatures. When the SGO-T activity is being used to diagnose or exclude acute myocardial infarction blood must be drawn within 3 days following infarction if the SGO-T activity is to be relied upon as a diagnostic aid.

**Summary**

The serum activity of the enzyme, glutamic-oxaloacetic transaminase, was not increased following experimental myocardial ischemia in dogs unless myocardial necrosis was found at autopsy. The SGO-T activity remained within normal limits in 34 of 50 patients with status anginosus or severe coronary insufficiency accompanied by ST segment and T-wave abnormalities. The SGO-T activity appears to be useful in establishing the presence or absence of myocardial necrosis in patients with severe recurrent substernal pain.

The SGO-T activity was within normal limits in experimental pericarditis unless subepicardial necrosis was found at autopsy and the SGO-T activity remained within normal limits in 9 of 11 patients with acute pericarditis of various etiologies. In 2 patients brief and insignificant elevations (maximum 56 units) occurred.

In 6 of 7 patients with pulmonary infarction no alterations in transaminase levels were found. An insignificant rise was seen in the seventh patient.

The SGO-T activity appears to be useful in determining the presence or absence of acute myocardial damage following acute myocardial infarction, coronary insufficiency and pericarditis. It can be a valuable aid in the differential diagnosis of chest pain.

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**Summary in Interlingua**

Le activitate seral del enzyma 'transaminase glutamic-oxaloacetic' non esseva augmentate in canes con experimental ischemia myocardial excepte in le casos in que le autopsia revelava le presentia de necrosis myocardial. Le activitate seral de transaminase glutamic-oxaloacetic remaneva intra limites normal in 34 ex 50 patientes con stato anginoso o sever insuffientia coronari accompaniante per anormalitates del segmento ST e del unda T. Le activitate del enzyma pareva utile in establir le presentia o absentia de necrosis myocardial in patientes con sever e recurrente dolores substernal.

Le activitate del enzyma esseva intra limites
normal in pericarditis experimental, except in casos in que le autopsia revela le presentia de necrosis subepicardial.

Le activitate del enzyma remaneva intra limites normal in 9 ex 11 pacientes con pericarditis acute de varie etiologias. In 2 pacientes, breve e non-significative elevationes (56 unitates como maximo) eseva notate.

In 6 ex 7 pacientes con infarcimento pulmonar nulle alterationes in el nivel del transaminase eseva constatate. Un elevation non-significative occurrve in le septime paciente de iste serie.

Le activitate del enzyma es apparentemente utile pro determinar le presentia o absentia de acute lesiones myocardial post acute infarcimento myocardial, insufficientia coronari, e pericarditis. Illo pote esser un adjuta precioso in le diagnose differential de dolores del thorace.

REFERENCES

Helmholtz, for instance, the great German physicist, speaking in 1891 at a banquet on his seventieth birthday, described the way in which his most important new thoughts had come to him. He said that after previous investigation of the problem "in all directions... happy ideas come unexpectedly without effort, like an inspiration. So far as I am concerned, they have never come to me when my mind was fatigued, or when I was at my working table. They came particularly readily during the slow ascent of wooded hills on a sunny day."

Helmholtz here gives us three stages in the formation of a new thought. The first in time I shall call Preparation, the stage during which the problem was "investigated... in all directions"; the second is the stage during which he was not consciously thinking about the problem, which I shall call Incubation; the third, consisting of the appearance of the "happy idea" together with the psychologic events which immediately preceded and accompanied that appearance, I shall call Illumination. And I shall add a fourth stage, of Verification, which Helmholtz does not here mention.—Graham Wallas, 1858–1932.
Variations in Serum Glutamic Oxaloacetic Transaminase Activity in Experimental and Clinical Coronary Insufficiency, Pericarditis, and Pulmonary Infarction

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