Sequelae of Left Ventricular Puncture with Angiocardiography

By VIKING OLOV BJÖRK, M.D., INGEMAR CULLHED, M.D., ADAR HALLÉN, M.D., HERMAN LODIN, M.D., AND ELIS MALERS, M.D.

The left ventricle may be catheterized from the aorta,1-3 from the left atrium by several routes,4-6 or may be directly punctured. Since 1958 we have performed left ventricular puncture in 142 cases for pressure measurements and contrast injection. It is the aim of this paper to report our complications together with a review of those reported by others.

Material and Methods

Our cases were 6 months to 56 years old, most between 30 and 40 years of age. The diagnoses are presented in table 1. The main indications for the procedure were aortic stenosis or mitral insufficiency, and our results with it were recently reported.7-9

The investigation is performed with the patient in the fasting state, under penicillin prophylaxis with blood and necessary equipment for cardiac resuscitation in readiness. In adult patients general anesthesia is not used, only premedication with morphine and sepolamine. The puncture is performed by a thoracic surgeon in the presence of a cardiologist, an anesthesiologist, and a radiologist. We use the intercostal method of Brock et al.10,11 We only wish to stress that the needle used has a blunt end and a sharp mandrin. When the ventricular cavity is reached, the needle is locked by a screw so that it cannot be introduced farther. An electrocardiogram is continuously monitored on a two-beam cathode-ray oscilloscope. The pressure curves from the left ventricle and a peripheral artery are recorded. The ventricular curve must be free and undamped up to the moment of contrast injection and during slight changes in the position of the needle, in order to avoid intramyocardial deposition of contrast medium. With an automatic pressure syringe we then inject 1 to 1.2 ml. per Kg. of body weight of 76 per cent Urografin, with a speed of about 30 ml. per second. The pressures are again checked after the contrast injection. During the injection phase and immediately afterwards compression of both common carotid arteries is performed to diminish the flow of the dye to the brain. In order to avoid alteration in the position of the needle during this time, the patient is ordered to hold his breath. A chest radiogram of the frontal projection in the supine position is taken shortly afterwards; if this is unaltered, the patient is transported to the postoperative ward. For the next 20 hours he is closely supervised with frequent and regular observations of pulse and blood pressure. Then a chest radiogram in frontal and lateral projections in the sitting position and an electrocardiogram are taken and the patient is brought back to the medical ward. As a rule the patient leaves the hospital a few days later.

Results

We have performed 142 left ventricular punctures on 137 patients. In four cases the puncture was unsuccessful. In one of these cases the needle caused very frequent ventricular premature beats. In two other cases the needle entered the right ventricle. No contrast material was injected, and the surgeon deemed it inadvisable to perform more punctures. In the fourth case ventricular fibrillation occurred, which necessitated cardiac resuscitation.

Of the remaining 138 punctures no injection was possible for technical reasons in four cases and in one case because of coagulation in the needle. There remained 133 successful punctures in 131 cases.

In most instances only slight or no pain was experienced during and immediately after the puncture. When the needle passed through the ventricular wall extrasystoles of ventricular origin were seen in practically all cases. When the needle end was free in the ventricular cavity, the pre-existing rhythm was restored as a rule. In one case

From the Department of Thoracic Surgery (Head: V. O., Björk, M.D.), the Department of Medicine (Head: E. Ask-Upmark, M.D.), and the Department of Diagnostic Radiology (Head: F. Knutsson, M.D.), University Hospital, Uppsala, Sweden.
LEFT VENTRICULAR PUNCTURE

The Diagnoses in 137 Cases Submitted to Left Ventricular Puncture

<table>
<thead>
<tr>
<th>Diagnoses</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic stenosis</td>
<td>16</td>
</tr>
<tr>
<td>Aortic insufficiency</td>
<td>6</td>
</tr>
<tr>
<td>Aortic stenosis and aortic insufficiency</td>
<td>13</td>
</tr>
<tr>
<td>Mitral stenosis</td>
<td>3</td>
</tr>
<tr>
<td>Mitral insufficiency</td>
<td>13</td>
</tr>
<tr>
<td>Mitral stenosis and insufficiency</td>
<td>17</td>
</tr>
<tr>
<td>Combined aortic and mitral</td>
<td>63</td>
</tr>
<tr>
<td>Ventricular septal defect</td>
<td>3</td>
</tr>
<tr>
<td>No valvular disease</td>
<td>3</td>
</tr>
</tbody>
</table>

A few of these cases were combined with other disorders, such as tricuspid stenosis and insufficiency, aortic coarctation, atrial septal defect, corrected transposition, and extreme poststenotic aortic dilatation, due to proved cystic medial necrosis in one case.

A short run of supraventricular tachycardia (175 per minute) was registered during the puncture but soon subsided and contrast injection could be performed.

During and immediately after the angiocardiography some events were regularly seen (table 2). During the injection 5 to 10 ventricular extrasystoles occurred, probably released by the contrast jet hitting the opposite endocardium. Preceded in some cases by asystole or bradycardia, a moderate tachycardia followed, accompanied by a blood pressure fall of varying degree. After the angiocardiography some patients complained of headache, which was in no case severe, and a few experienced nausea.

A slight rise in temperature (37.5 to 38 C.) was noted in 74 cases during the first 24 hours. In 15 other cases the temperature exceeded 38 C., generally associated with minor or major complications. Four cases had pleuritic pain localized to the site of puncture for more than 24 hours without proved cause. One of them, however, had a pericardial friction rub.

The complications may be divided into minor and major groups.

Minor Complications

This group (table 3) includes those who experienced no or only slight inconvenience and did not require special therapeutic measures.

1. Hemopericardium. There may always be some leakage of blood into the pericardium. Twenty-seven cases were operated upon within 2 months and in four cases the surgeon noted "enlarged amounts" of blood in the pericardial sac. None of these cases had clinical signs of cardiac tamponade, and the operation was performed 8, 8, 11, and 30 days after the puncture.

2. Pneumothorax was observed in eight cases and caused no subjective discomfort. The diagnosis was established by chest radiogram in seven cases and only by angiocardiogram in one (being substernal). In the other seven cases it was left-sided and in all but one of minimal size. In this last case it was three fingers broad.

In the case diagnosed by angiocardiography and in another a loud extra heart sound with varying position in the heart cycle was heard for several days. In the first patient it was audible only during inspiration and was so loud as to be heard at some distance, and by the patient himself. In the second case it was less loud, present in all phases of respiration and was followed some days later by a typical pericardial friction rub. The electrocardiogram and radiograms were normal. These phe-

<table>
<thead>
<tr>
<th>Phase of investigation</th>
<th>Sinus Rhythm</th>
<th>Atrial Fibrillation</th>
<th>Asystole</th>
<th>Bradycardia</th>
<th>Tachycardia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before injection</td>
<td>79</td>
<td>43</td>
<td>25</td>
<td>—</td>
<td>7</td>
</tr>
<tr>
<td>During injection and x-ray exposure</td>
<td>12</td>
<td>11</td>
<td>99</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>X-ray exposure (continued)</td>
<td>75</td>
<td>35</td>
<td>22</td>
<td>12</td>
<td>22</td>
</tr>
<tr>
<td>After x-ray exposure</td>
<td>79</td>
<td>43</td>
<td>5</td>
<td>—</td>
<td>2</td>
</tr>
</tbody>
</table>

*Findings in 122 cases, in which full information was available.

†VES = (repeated) ventricular extrasystoles.

‡Asystole = cardiac standstill lasting more than 2 seconds.

Table 1

Table 2

Changes in Heart Rhythm and Rate during Left Ventricular Angiocardiography

Circulation, Volume XXIV, August 1961
Punctures

Minor Complications in 142 Left Ventricular Punctures

<table>
<thead>
<tr>
<th>Complication</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemopericardium without tamponade</td>
<td>4*</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>8</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>15</td>
</tr>
<tr>
<td>Parenchymatous pulmonary changes</td>
<td>8</td>
</tr>
<tr>
<td>Delayed onset of arrhythmia</td>
<td>2</td>
</tr>
</tbody>
</table>

*This is a minimum number, representing only those found at surgery.

Some of these phenomena were probably due to the presence of a small amount of air between the pericardium and the pleura, causing a "noisy pneumothorax." For practical purposes the chest radiograms were not performed in expiration, when a small pneumothorax would more often be evident.

1. Pleural effusion was seen in 15 cases, in 12 cases on the left side only, in one on the right side, and in two bilateral. It always appeared to be minimal, although no radiographs were taken with the patient in the lateral recumbent position.

2. Pulmonary complications in the form of small basal, atelectatic streaks were seen on the left side in six cases, and on both sides in two cases. Only one case had fever exceeding 38 C. Two cases showed clinical and radiologic signs of bronchopneumonia 1 or 2 days after the puncture.

In cases with effusion and parenchymatous changes there were no abnormalities in the radiographs immediately after puncture. In contrast, pneumothorax was detectable as often in these as in the radiograms a day later. This observation may explain the lung changes: the immobilization for 12 to 14 hours after puncture plus slight chest pain may cause a superficial ventilation. The observed changes soon disappeared.

5. Late disturbance of heart rhythm. Atrial fibrillation began one and two days after the puncture in two cases with combined mitral and aortic valvular disease. There may have been no relation between the puncture and the fibrillation, although late onset of arrhythmia has been noted often after noncardiac thoracic surgery.13

Major Complications

This group includes ventricular fibrillation, cardiac tamponade, faulty contrast injection, and cerebral complications (table 4). Some of our cases were briefly reported earlier.11

1. Ventricular fibrillation occurred once, in a 32-year-old woman with aortic stenosis, aortic insufficiency, and slight aortic coarctation. It was difficult to reach the ventricular cavity and at the second puncture ventricular fibrillation appeared. Thoracotomy was immediately performed, and after cardiac massage and defibrillation sinus rhythm was rapidly restored. Left ventricular puncture was then made on the exposed heart, but no contrast medium was injected. The patient recovered.

2. Cardiac tamponade occurred in six cases, twice with fatal outcome. The first case was a 55-year-old man with severe calcific aortic stenosis. For technical reasons no contrast medium could be injected. When returned to the ward he developed signs of cardiac tamponade, and thoracotomy was performed when he developed cardiac standstill. In spite of cardiac massage and acute surgical dilatation of the aortic valve, spontaneous cardiac activity was not restored. He had a large hemopericardium and autopsy revealed gross hypertrophy of the left ventricle except at a small region near the apex. Here the wall was only a few millimeters thick, and this was unfortunately the puncture site. Microscopically this area showed interstitial fibrosis.

The second fatal case was a 47-year-old woman with severe mitral insufficiency. She was severely ill with pulmonary hypertension, a heart size of 1,760 ml./M.2 body surface area, and a very low capacity for work. About 2 hours after the puncture with left ventricular angiocardiology, she became hypotensive, and soon afterwards the heart stopped. On thoracotomy cardiac tamponade was found but cardiac massage was without success.

In a third case, a 27-year-old man with a small ventricular septal defect, the puncture was successful but no contrast medium was injected because the tubing ruptured. Beginning from the second day he was febrile. Repeated chest radiographs showed at first only
left pleural effusion; on the sixth day, enlargement of the cardiac silhouette. An electrocardiogram taken this day showed frequent ventricular extrasystoles and S-T elevations indicative of pericarditis. On pericardial puncture on the seventh day only 70 ml. of blood were obtained. On the tenth day he fainted in bed. The area of absolute cardiac dullness was increased and another pericardial puncture on the eleventh day yielded 120 ml. of blood, but the patient became unconscious and thoracotomy was performed. The pericardium was found to contain 1,400 ml. of blood. There was right ventricular hypertrophy with clockwise rotation of the heart. Consequently the descending branch of the left coronary artery lay near the apex and had been injured by the needle. The patient made a good recovery but 3 months later he was hospitalized once more because of chest pain and fever. The heart size had increased and a thoracotomy was performed again, since puncture failed. Besides a pleural exudate a frame-work was found inside the pericardial cavity, containing blood-stained fluid. To prevent constricting pericarditis a pericardectomy was deemed necessary. He finally recovered after a second relapse with fever and signs of myocarditis. We interpreted this case as cardiac tamponade which was atypical, due to the slow oozing of blood from the injured vessel, complicated with a perimyocarditis with doubtful relation to the puncture.

In a fourth case 100 ml. of blood were evacuated by pericardiocentesis a few minutes after the procedure and resulted in improvement. In two other cases only 50 ml. of blood could be evacuated. In at least one of these there were obvious clinical signs of cardiac tamponade that promptly subsided afterwards.

3. Faulty contrast injection caused the death of a 9-month-old boy with atypical tetralogy of Fallot. On suspicion of aortic stenosis the puncture was performed and at the third attempt the needle entered the left ventricle. In spite of a previous free pressure curve, the electrocardiogram showed deep S-deflections and S-T depressions during the contrast injection. The angiocardiogram and a chest radiogram 1½ hours later showed contrast medium in the left myocardium (fig. 1). He did well the first hour but then rapidly deteriorated. Because of cardiac standstill thoracotomy was performed but no contractions of the left ventricle could be evoked. The pathologic examination showed hemorrhage in the posterior wall of the left ventricle, with 3-cm. rupture of the endocardium.

In two cases the angiocardiogram showed that small amounts of contrast medium had been injected into the myocardium. However, no contrast medium was detectable on the radiographs taken some minutes later, and there were no clinical symptoms. In a fourth case a small amount of contrast medium was injected into the pericardial sac. There were no sequelae.

Table 4

<table>
<thead>
<tr>
<th>Major Complications in 142 Left Ventricular Punctures</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal</td>
<td>Nonfatal</td>
</tr>
<tr>
<td>Ventricular fibrillation</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cardiac tamponade</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Faulty contrast injection</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Cerebral complications</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 1

Left ventricular angiocardiogram, frontal projection. The contrast medium is mainly deposited in the myocardium and in the pericardial sac. Early contrast filling of the coronary veins. No contrast medium in the aorta.
In two cases, a 36-year-old woman and a 55-year-old man, both with combined mitral-aortic valvular disease, there was a disorientation for some hours afterwards with amnesia. There were no other neurologic signs and they recovered completely. The probable genesis was a reaction to the contrast medium. In the first case, however, there were some signs of cardiac tamponade, too; and pericardial puncture yielded 50 ml. of blood.

**Discussion**

The reported complications of left ventricular puncture in the literature are listed in table 5. They are divided according to the method of puncture—subxiphoid or intercostal. As is evident from the table, practically all workers with the subxiphoid method have performed left ventricular angiocardiography, whereas our group has employed the intercostal method. The different consecutive reports by one and the same team are listed together, as some of the major but nonfatal complications are not repeated in their latest reports.

**Ventricular fibrillation** that necessitated thoracotomy occurred twice, both with recovery after cardiac massage. In the case of Smith et al., contrast medium was injected slowly and near the origin of the left coronary artery. In our case no contrast medium was injected but repeated punctures were made. The risk of ventricular fibrillation emphasizes the absolute necessity of a continuous electrocardiogram during the procedure. Impending ventricular fibrillation is sometimes heralded by multiple ventricular extrasystoles; if it is established, cardiac resuscitation must be per-

<table>
<thead>
<tr>
<th>Authors</th>
<th>Number Angiogram</th>
<th>No Angiogram</th>
<th>Ventricular fibrillation</th>
<th>Cardiac tamponade</th>
<th>Faulty (= extravascular) contrast injection</th>
<th>Needle diam. mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Subxiphoid method</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Nunez et al., 1951</td>
<td>45</td>
<td></td>
<td>1</td>
<td>1.7</td>
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<tr>
<td>Ponsadomech et al., 1951</td>
<td>56</td>
<td></td>
<td>1</td>
<td>1.5</td>
<td></td>
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<tr>
<td>Smith et al., 1954</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cregg et al., 1955</td>
<td>8</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smith et al., 1956</td>
<td>31</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>McCaughan et al., 1957</td>
<td>31</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lehman et al., 1957</td>
<td>69</td>
<td>8</td>
<td>5 (2)*</td>
<td></td>
<td>1.5</td>
<td></td>
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<tr>
<td>Lehman et al., 1959</td>
<td>230</td>
<td></td>
<td>3</td>
<td>3 (3)</td>
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<td></td>
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<tr>
<td>Lehman, 1959</td>
<td>&gt;300</td>
<td>3</td>
<td>3 (3)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Greenberg et al., 1960</td>
<td>41</td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>459</td>
<td>305</td>
<td>11 (4)</td>
<td>4 (1)</td>
<td>1.55</td>
<td></td>
</tr>
</tbody>
</table>

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*The figure in parentheses designate fatal outcome.
formed without delay. As prophylaxis 100 per cent oxygen breathing and the administration of quinidine or procaine amide might be of value. Premedication with drugs containing atropine may cause tachycardia and ventricular extrasystoles.

Fatal cardiac tamponade seems to occur with either method. Lehman reports three successfully treated cases among more than 300 left ventricular punctures. In a series of 184 intercostal punctures Roe reports two fatal cases, a 61-year-old woman with arteriosclerotic heart disease without aortic stenosis, and a 57-year-old man with aortic stenosis. In both cases the procedure was somewhat protracted due to attempted aortic catheterization. In the first case the needle entered the left ventricle through a 3-mm. thick fibrous part of the myocardium as in our fatal case. In a third case signs of cardiac tamponade appeared suddenly on the fourth day after the puncture but then spontaneously subsided. Morrow et al. observed one case of cardiac tamponade in seven direct left ventricular punctures. Botham et al. reported one case of cardiac tamponade that necessitated thoracotomy. The needle had been left in situ for 15 minutes.

In our two fatal cases cardiac tamponade was at once suspected but unfortunately thoracotomy (or pericardial puncture) was not performed until cardiac arrest suddenly appeared. It is possible that immediate intervention might have prevented the fatal outcome.

It seems probable that the amount of blood in the pericardial cavity can be rather large without causing signs of tamponade. Of the 69 cases reported by Lehman et al. were operated upon 1 to 20 days after the puncture. Eleven cases were found to have 50 to 100 ml. of blood in the pericardium, two cases 100 to 200 ml., and in one case 300 ml. In no case were there clinical signs of cardiac tamponade. Green et al. reported thoracotomy in 18 cases immediately after the puncture and generally found 75 to 100 ml. of blood; in one case, 150 ml. None of these cases showed clinical signs of cardiac tamponade in spite of a rather large hemopericardium. The explanation is probably that the bleeding had been slow. On the other hand, small but rapid bleeding might cause signs of tamponade.

In the available literature no report has been seen of a lacerated coronary vessel as the cause of hemopericardium after left ventricular puncture. This was the mechanism in one of our cases (I.B.) in which thoracotomy was performed. Preoperatively there had been a strong suspicion of a ventricular septal defect.

Hemopericardium with cardiac tamponade should be suspected when a fall in blood pressure reappears some minutes after the procedure. In our experience the electrocardiogram has not been very helpful. Only standard lead II has been used and there have been no diagnostic ST-T alterations. Likewise the chest radiographs taken about 10 minutes after the puncture have been normal in all cases, with unaltered size silhouette. Thus, it is not probable that studying the heart size during the Valsalva maneuver would be helpful for the diagnosis of pericardial effusion. We have not been observant regarding the presence of the pulsus paradoxus, as is described in pericardial effusion.

When cardiac tamponade is suspected, urgent therapy is necessary. Pericardiocentesis should be carried out as rapidly as possible, in the ward or in the cardiac laboratory. If immediate, significant, and lasting rise in blood pressure is not obtained, another puncture is performed. If the patient still is hypotensive, a thoracotomy is performed at once. Bishop et al. have used the electrocardiogram as a safeguard during pericardial puncture. An argument in favor of thoracotomy might be the possibility of finding and properly treating the bleeding site.

The one case of early (extravascular) contrast injection of Ponsdomenech et al. had the contrast deposited in the pericardium with no untoward effects. The case of Smith et al. with ventricular fibrillation, cited above, was due to contrast injection near a coronary artery. The same authors reported that the needle once entered a distended stomach, appa-
ently with no ill effects.\textsuperscript{17} Lehman\textsuperscript{23} lost three cases due to intramyocardial injection, one case not until 6 months later and due to bolus of contrast substance in the septum causing heart block. Seven other cases survived. Greenberg et al.\textsuperscript{24} reported six faulty injections, four into the myocardium, one into the pericardium, and one into both. There were transient electrocardiographic abnormalities but no sequelae. Our fatal case was a 9-month-old boy; in infants this procedure should be avoided. In a 6-month-old girl with mitral insufficiency and ventricular septal defect, however, the puncture with angiocardiography was successful but the contrast medium was injected manually. In no case did we erroneously inject into the right ventricle. This occurred in 12 injections by Lehman et al.\textsuperscript{22}

Certain precautions should be undertaken to prevent this complication.\textsuperscript{17, 21} The needle must be short-beveled, preferably with a blunt end and a sharp mandrin. Side-holes might give better contrast mixing but would be more dangerous because a free pressure curve would not guarantee a completely free position in the cavity. The pressure curve should be free immediately before the injection (as it was, however, in our fatal case). The patient must hold his breath during the 2 to 3 seconds of injection. In agitated patients general anesthesia might be preferred; in infants, it is necessary. The pressure curve must be unchanged and free when the needle is moved in different directions. Lehman et al.\textsuperscript{21} do a gradual withdrawal until the curve becomes damped, then push the needle in about 0.5 cm. A test injection of 1 ml. of contrast solution under electrocardiographic control is used by McCaughan et al.\textsuperscript{29} as a safeguard against extravascular injection. These precautionary measures should be taken immediately before angiocardiography, and in the same phase of respiration used during the contrast injection.

The whole procedure should not take longer than about 5 minutes. The gage of the needle seems to be of some importance, as is seen from table 5. Fleming et al.\textsuperscript{28} experienced three cases with cardiac tamponade when changing from a needle with a 1.25-mm. outer diameter, to one with 1.5 mm., in order to facilitate catheterization of the aorta. In these cases, however, the prolonged time may be the chief cause. On the other hand, a needle with smaller diameter is less suitable for angiocardiology, as the contrast medium will be injected too slowly.

**Summary and Conclusions**

In a series of 142 percutaneous left ventricular punctures we have encountered 11 cases of major complications with three fatalities. About 900 left ventricular punctures are reviewed, with a total of 8 fatal complications, i.e., less than 1 per cent. The fatal cases were to the same extent due equally to cardiac tamponade and intramyocardial deposition of contrast material.

To prevent cardiac tamponade the needle should be as small as practicable, and the needle left in the heart as short a time as possible. Great care should be exercised when ischemic heart disease is suspected. Cardiac tamponade requires prompt diagnosis and immediate treatment.

The risk of faulty contrast deposition may be minimized by ensuring the free position of the needle end in the ventricular cavity immediately before angiocardiography. This risk is larger in small infants with a small ventricle.

The puncture always must be performed with continuous electrocardiographic control. Ventricular fibrillation must be immediately diagnosed and treated, but fortunately it is rare.

The percutaneous puncture can be performed either by the subxiphoid or the intercostal method. The frequency of cardiac tamponade was nearly four times greater with the latter method. On the other hand there is a higher frequency of extravasal contrast injection with the subxiphoid method. The question of which method is safest cannot be answered yet.

In our opinion, percutaneous left ventricular puncture combined with selective left ventricular angiocardiography is a practical method that gives valuable information re-
regarding rheumatic heart disease, especially aortic stenosis and mitral insufficiency. It is, however, associated with a definite morbidity, some of which cannot be avoided. This method should therefore be performed only in the investigation of cases for major heart surgery. At least in cases without tight aortic stenosis retrograde aortic catheterization of the left ventricle is, according to our experience in the last year, a more secure and equally informative method. Retrograde left ventricular angiocardiography may immediately be followed by aortography to evaluate competence of the aortic valve.

References
25. Nuvoli, I.: Cited by Broek et al.89
29. Ross, D. N.: Percutaneous left ventricular puncture.
The Early History of Precision in Medicine

The latter part of the 16th and the first half of the 17th centuries was a germinial period in medicine. It saw advances in anatomy and physiology, which led up to Harvey's splendid discovery. It saw, too, the failure of his thesis to influence medical practice immediately or largely. The same period in Italy beheld the first attempts at precision as regards temperature and the study of the pulse. This was the birth era of instrumental accuracy in medicine, but many a day went by before the infant attained to useful manhood. Most strange it is that the seeds of scientific thought as to the first heat records and the pendulum were cultivated in the garden of medicine. Between 1593 and 1597 Galileo, sometime a student of medicine, invented the crude open thermometer or thermoscope. . . .

The thermometer of Galileo was, as I have drawn it (fig. 2), a tube of glass, open below and ending above in a bulb. This bulb having been warmed the open end of the tube was set in water, so that as the bulb cooled, the water rose in the tube. Then any heat applied to the bulb caused the water to descend, the reverse of that which occurs in the more modern instrument. This coarse thermoscope was obviously a barometer as well as a rude measurer of the change of temperature. A slight change in the weight of the atmosphere might easily neutralize an increase of heat. It was not an accurate instrument, nor does Galileo seem to have rated it highly since he nowhere mentions it in his works. Others thought more of it. The approximate date of this invention is set for us by one Padre Benedetto Castelli, in a letter about the treatment of a wounded man, written to one Cesarini, in 1638. He calls to mind the fact that Galileo had thirty-five years before shown him the air thermometer.—S. WEIR MITCHELL, M.D. The Early History of Instrumental Precision in Medicine, Transactions of the Congress of American Physicians and Surgeons, Second Triennial Session held at Washington, D.C., 1891. New Haven, The Congress, 1892, p. 166.
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