The Complications of Coronary Arteriography

By Douglass F. Adams, M.D., David B. Fraser, M.D., and Herbert L. Abrams, M.D.

SUMMARY
A nationwide survey was undertaken to determine the rate of complications due to coronary arteriography during 1970-71. The responses from 173 hospitals—including a total of 46,904 coronary arteriograms—were analyzed in relationship to the technique employed and to the number of examinations performed at each hospital during the two-year period. The overall mortality rate was 0.45% (brachial 0.13%, femoral 0.78%). The mortality rate in institutions performing fewer than 200 examinations per two years was eight times higher than in institutions performing more than 800 examinations per two years. Similarly, the incidence of myocardial infarction and cerebral embolism was significantly higher when a smaller number of examinations was performed. The incidence of major complications—including death, myocardial infarction, and cerebral embolism—was higher in examinations using the femoral approach than the brachial approach. The incidence of arterial thrombosis and contrast agent reactions was higher for the brachial approach. Factors which may help to explain these differences are considered and discussed.

Additional Indexing Words:
Myocardial infarction Thrombosis Embolism Contrast agent reactions Hemorrhage Pseudoaneurysm Ventricular fibrillation

THE COMPLICATION RATES of coronary arteriography reported in the literature vary widely.1-18 Yet it is essential that accurate data be available if an intelligent and informed appraisal of risk vs yield is to be made prior to arteriography. For this reason, a nationwide survey was undertaken to gather information on arteriographic complications from hospitals of varying size and with varying frequencies of arteriographic examinations.

Materials and Methods
A questionnaire (fig. 1) was mailed to the director of the coronary arteriography laboratory at each of the 373 institutions with an open heart surgery team listed in the AMA Directory of Medical Schools and Affiliated Hospitals. There were 173 responses. The data were tabulated for each question according to the technique (brachial, femoral, and total) and to the number of cases performed in each institution. Written statements elaborating on the responses clarified the precise nature of many of the complications.

Results
During 1970 and 1971, 46,904 patients were examined in the responding institutions. A few institutions reported data covering less than a two-year period.

Twenty-eight institutions used only the femoral approach and 26 only the brachial approach; 119 institutions reported some cases by each method. There was almost an equal number of patients studied by the femoral as by the brachial technique (table 1). The small group of patients who may have been studied by both was not indicated.

Table 2 shows the number and percentage of complications relative to the number of cases performed during the two-year period at all hospitals. The cases are grouped according to technique (femoral and brachial).

Death
The overall mortality rate was 0.45% (brachial 0.13%; femoral 0.78%; \( P < 0.001 \)). Mortality with the femoral approach was far higher in those institutions doing fewer than 200 cases per two years (1.3%) than in those performing 800 or more (0.16%) \( (P < 0.001) \). Similarly, the brachial approach was accompanied by a higher mortality (0.38%) when fewer than 200 procedures were done.
Complications of Coronary Angiography
From 1 Jan 1970 to 1 Jan 1972

<table>
<thead>
<tr>
<th></th>
<th>Brachial</th>
<th>Femoral</th>
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<tbody>
<tr>
<td>1. Number of patients studied:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Number of deaths related to the procedure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Number of myocardial infarctions related to the procedure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Number of episodes of ventricular fibrillation or prolonged arrhythmia:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Arterial complications requiring surgical treatment:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Thrombosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Hemorrhage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Pseudoaneurysm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Other complications requiring prolongation of hospitalization. (e.g. cerebral emboli, reaction to contrast agent, etc.) Please Specify:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1
This questionnaire was sent to 373 institutions. There were 173 responses. The time period included in the responses was January 1970 through December 1971 in most cases.

Ventricular Fibrillation and Prolonged Arrhythmia
Ventricular fibrillation or prolonged arrhythmia occurred in 1.28% of patients (brachial 1.15%, femoral 1.41%). The incidence was higher in institutions performing a smaller number of examinations (table 2).

Table 1
Complications Reported From January 1, 1970 to January 1, 1972

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Total</th>
<th>Percent</th>
<th>Number</th>
<th>Brachial</th>
<th>Percent</th>
<th>Number</th>
<th>Femoral</th>
<th>Percent</th>
<th>P-Value†</th>
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<tbody>
<tr>
<td>Responses</td>
<td>173</td>
<td>145</td>
<td>0.13</td>
<td>147</td>
<td>0.78</td>
<td>&lt;0.001</td>
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<tr>
<td>Patients</td>
<td>46,904</td>
<td>24,124</td>
<td>0.13</td>
<td>22,780</td>
<td>0.10</td>
<td>&lt;0.001</td>
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<tr>
<td>Deaths</td>
<td>209</td>
<td>31</td>
<td>0.13</td>
<td>178</td>
<td>0.78</td>
<td>&lt;0.001</td>
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<td>Myocardial infarction</td>
<td>284</td>
<td>54</td>
<td>0.22</td>
<td>230</td>
<td>1.01</td>
<td>&lt;0.001</td>
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<td>Ventricular fibrillation</td>
<td>600</td>
<td>278</td>
<td>1.15</td>
<td>322</td>
<td>1.41</td>
<td>&lt;0.01</td>
<td></td>
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<tr>
<td>Thrombosis</td>
<td>675</td>
<td>404</td>
<td>1.67</td>
<td>271</td>
<td>1.19</td>
<td>&lt;0.001</td>
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<tr>
<td>Hemorrhage</td>
<td>54</td>
<td>17</td>
<td>0.07</td>
<td>37</td>
<td>0.16</td>
<td>&lt;0.01</td>
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<td>28</td>
<td>14</td>
<td>0.06</td>
<td>14</td>
<td>0.06</td>
<td>NS</td>
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<td>Other*</td>
<td>269</td>
<td>118</td>
<td>0.49</td>
<td>151</td>
<td>0.66</td>
<td>&lt;0.01</td>
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<td>C. emboli</td>
<td>106</td>
<td>7</td>
<td>0.03</td>
<td>99</td>
<td>0.43</td>
<td>&lt;0.001</td>
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<tr>
<td>Contrast reaction</td>
<td>66</td>
<td>54</td>
<td>0.22</td>
<td>12</td>
<td>0.05</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
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<tr>
<td>Other</td>
<td>97</td>
<td>57</td>
<td>0.24</td>
<td>40</td>
<td>0.18</td>
<td>&lt;0.1</td>
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</table>

*Breakdown of this category is our own extraction from specified responses to question 6 on the questionnaire.
†Significance of difference between brachial and femoral data.

Myocardial Infarction
Coronary arteriography was associated with the development of myocardial infarction in 0.61% of all patients (brachial 0.22%, femoral 1.01%; P < 0.001). The incidence of myocardial infarction was higher when fewer cases were examined. The incidence using the femoral approach was 1.9% in institutions doing fewer than 200 cases per 2 years as compared to 0.19% in those doing over 800 cases per 2 years (P < 0.001). With the brachial approach, the figures were 0.42% (fewer than 200 cases), and 0.10% (more than 800 cases) (P < 0.001).
Arterial Thrombosis Requiring Surgical Treatment

Arterial thrombosis resulted from coronary arteriography in 1.44% of cases. It was more frequent with the brachial than with the femoral approach (1.67% and 1.19% respectively; \( P < 0.001 \)) and had a lower incidence with increasing numbers of examinations (table 2).

Hemorrhage Requiring Surgical Treatment

Hemorrhage occurred at the site of catheter entry in 0.12% of cases (brachial 0.07%, femoral 0.16%; \( P < 0.01 \)). One case of death from hemorrhage following transfemoral catheterization was recorded.

Pseudoaneurysm

Pseudoaneurysm was a rare complication of coronary arteriography. Only 28 cases were reported (0.06%), and they were equally distributed between the brachial and femoral groups (0.06% and 0.06% respectively).

Other Complications Requiring Prolonged Hospitalization

A variety of other complications was recorded (0.57% of all patients; 0.49% in the brachial group; 0.66% in the femoral group). Those that occurred as isolated events were splenic infarct, congestive heart failure, intramyocardial and intrapericardial injections, dissection or perforation of the aorta or its branches, “coronary insufficiency,” embolus of the radial artery, infection, retinal artery occlusion, prolonged hypotension, acute renal failure, sepsis, a variety of neurological syndromes, headache, fever, and shortness of breath.

There was a higher incidence of contrast agent reactions with the brachial approach (0.22% vs 0.05%; \( P < 0.001 \)). The incidence of cerebral emboli was much higher with the femoral approach (0.43% vs 0.03%; \( P < 0.001 \)). In institutions doing fewer than 200 cases per 2 years, the incidence of cerebral emboli was 0.4% (brachial 0.1%; femoral 0.6%); with over 800 cases the incidence was reduced to 0.02% (brachial 0.0%; femoral 0.05%) (\( P < 0.001 \)) (table 2).
Table 2
Complications Grouped According to Number of Examination per Years

| Number of examinations performed per 2 years | 0-49 | 50-99 | 100-149 | 150-199 | 200-249 | 250-299 | 300-349 | 350-399 | 400-449 | 500-499 | 600-649 | 700-749 | 800-849 | 850-899 | 900-949 | 950-999 | 1400-1449 | 1800-1850 |
|--------------------------------------------|------|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----------|-----------|
| Institutions                               | 11   | 2     | 1       | 1       | 0       | 0       | 0       | 0       | 0       | 0       | 0       | 0       | 0       | 0       | 0       | 0       | 0         | 0         | 0         |
| Patients                                  | 1189 | 1046  | 1835    | 1279    | 1829    | 988     | 756     | 827     | 1552    | 1422    | 286     | 100     | 900     | 953     | 1437    | 1831    | 1         |           |           |
| Deaths                                    | 4    | 5     | 6       | 0       | 0       | 1       | 0       | 1       | 3       | 2       | 0       | 0       | 2       | 1       | 0       | 1       | 1         | 0         | 0         |
| Myocardial Infarction                     | 62%  | 13%   | 3%      | .05%    | .05%    | .05%    | .05%    | .05%    | .05%    | .05%    | .05%    | .05%    | .05%    | .05%    | .05%    | .05%    | .05%      | .05%      | .05%      |
| Ventricular Fibrillation                  | 23   | 16    | 3       | 3       | 4       | 7       | 3       | 3       | 7       | 4       | 1       | 2       | 1       | 0       | 0       | 0       | 1         | 1         | 1         |
| Thrombosis                                | 74   | 19    | 16      | 24      | 30      | 63      | 17      | 6       | 28      | 41      | 30      | 24      | 0       | 9       | 1       | 22       | 0         | 0         |
| Hemorrhage                                | 2    | 0     | 3       | 2       | 2       | 0       | 0       | 0       | 4       | 1       | 1       | 0       | 0       | 0       | 3       | 0       | 0         |           |           |
| Pseudoaneurysm                            | 0    | 1     | 3       | 2       | 2       | 0       | 0       | 1       | 1       | 1       | 0       | 1       | 0       | 0       | 2       | 0       | 0         |           |           |
| Other                                     | 0    | 1     | 2       | 3       | 2       | 0       | 0       | 1       | 0       | 1       | 1       | 0       | 1       | 0       | 0       | 0       | 2         |           |           |
| Cerebral                                  | 9    | 4     | 8       | 15      | 15      | 4       | 3       | 1       | 41      | 0       | 5       | 1       | 0       | 0       | 4       | 0       | 0         | 3         | 1         |
| Embolism                                  | 20%  | .08%  | .19%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%      | .10%      | .10%      |
| Contrast                                  | 0    | 0     | 0       | 6       | 13      | 0       | 2       | 0       | 29      | 0       | 2       | 0       | 0       | 0       | 0       | 0       | 0         |           |           |
| Reaction                                  | .32% | .10%  | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%      | .10%      | .10%      |
| Other                                     | .73% | .25%  | .57%    | .38%    | .38%    | .38%    | .38%    | .38%    | .38%    | .38%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%    | .10%      | .10%      | .10%      |
Thus, cerebral emboli were 40 times as common when small groups of patients were studied and significantly higher when the femoral approach was employed.

Incidence of Death, Myocardial Infarction or Cerebral Embolus

At least one of the most severe complications—death, myocardial infarction, or cerebral embolus—occurred in 1.3% of all patients in this series. Grouping these complications demonstrates a striking difference between institutions with a relatively high case load and those with smaller numbers of procedures (fig. 3). The combined complication rate was 2.6% in institutions performing fewer than 200 arteriograms per 2 years but was only 0.23% in those institutions with over 800 cases per 2 years ($P < 0.001$). When the brachial group alone is considered, the combined complication rate in institutions performing fewer than 200 cases per 2 years was 0.95% but dropped to 0.16% when more than 800 cases per 2 years were performed ($P < 0.001$). In the femoral group a similar drop in incidence of complications was observed. With fewer than 200 cases per 2 years, the combined rate of complication was 3.9% whereas with over 800 cases per 2 years it dropped to 0.42% ($P < 0.001$).

Discussion

Death, Myocardial Infarction, Cerebral Embolism, and Arterial Thrombosis

Death and morbidity are associated with coronary arteriography even in the most competent hands. Risk figures from the literature indicate an average death rate of 0.4% associated with selective coronary arteriography.\textsuperscript{19} The range reported in prior studies varied from 0%\textsuperscript{3} to 8%.\textsuperscript{13} A cooperative study on cardiac catheterization,\textsuperscript{5} which reviewed the complications in 3,312 selective coronary arteriograms, listed a lethal complication rate of 0.1%, but 81% of these cases were studied in one laboratory. A more realistic figure of 0.6% was recently reported on the basis of a European experience.\textsuperscript{18, 20} This approximates the figure of 0.45% in the present survey. Takaro et al. have reported a mortality rate of 0.6% with the transbrachial and 2.4% with the transfemoral method.\textsuperscript{21}

Myocardial infarction may be due to embolization from a thrombus at the catheter tip or dislodged atheromatous material, prolonged catheter obstruction of a stenotic lesion, dissection of a coronary vessel,\textsuperscript{22} or possibly even spasm secondary to catheter manipulation. The incidence of myocar-
dial infarction varies from 0% to 2.5% in the literature,19 compared with 0.61% in this survey.

Cerebral emboli are usually the result of thrombus forming on the wall of the catheter although atherosclerotic emboli may at times be dislodged by the catheter. Thrombus material may also be dislodged from the left ventricle during catheter manipulation.

Data on the incidence of cerebral emboli are not easily derived from the literature. Forsberg et al.21 reported one case of cerebral embolism in 492 nonselective examinations, and Takaro et al.15 reported one case in 535 selective examinations. Our own figures suggest a minimum incidence of 0.23% with a significantly higher occurrence using the transfemoral method.

Thrombosis and embolism are the most important arterial problems at the site of catheter introduction. This complication has been reported to be as high as 8%24 or as low as 0.2%.25 Occasionally the catheter will dissect into a subintimal position and occlusion of the peripheral vessel will result.

When occlusion occurs in the femoral artery, an immediate surgical approach is most likely to prevent subsequent limb ischemia. With brachial artery occlusion, patients are sometimes observed for the development of ischemia before an operative approach is recommended. The incidence of thrombosis of 1.44% in our survey is greater and probably more realistic than the 0.5% previously quoted in the cooperative study;5 however, it is well below the figure suggested by Sones and Shirey26 of 6-7% segmental occlusion at the site of brachial arteriotomy. The higher incidence of thrombus with the brachial method is probably related to the relatively smaller size of the brachial artery and the need for routine cutdown. Because brachial artery thrombosis may be serious and may occur relatively frequently, meticulous attention to the radial pulse and the hand circulation is essential during and following brachial artery catheterization.

Figure 3

Relationship of the combined incidence of death, myocardial infarction and cerebral embolism to the number of arteriograms performed per 2-year period.
The Relationship of Technical Factors to Complications

The common methods of coronary arteriography are nonselective, brachial selective, and femoral selective. All carry with them an inherent risk. The less commonly applied transaxillary approach is also associated with significant complications. The risk of nonselective procedures is probably less than the risk of selective ones. Dissections of the coronary arteries are less likely to occur, and thrombi or atheromatous emboli which are generated at the catheter tip may reach a less critical area of the circulation, if they are deposited in the aortic root rather than in the coronary artery. Furthermore, the potential for obstructing an already compromised coronary artery lumen is minimal with the nonselective technique.

The present survey indicates that the incidence of death, myocardial infarction and cerebral emboli is higher when utilizing the femoral approach. Although this higher incidence is relatively less apparent in institutions doing more than 200 cases per year, its explanation must nevertheless be sought. The transfemoral approach is a simple method of studying the visceral circulations and can be easily applied to arteriography of the coronary arteries. When preshaped catheters for transfemoral percutaneous coronary arteriography were first introduced in 1961, their use was limited to a small group who were able to acquire a good deal of experience with catheterization and its limitations. The preshaped catheters now in use have better memory and torque control and therefore require less manipulative skill. Hence, individuals with little experience in transfemoral catheterization techniques and in dealing with cardiac complications of catheterization procedures may do coronary arteriography without the intensive training which preceded such examinations in the past. Furthermore, the procedures may be done sporadically without the opportunity to obtain a continuing exposure to all the problems encountered and to develop appropriate plans for dealing with them expeditiously. By contrast the brachial approach is more difficult to learn, requires a cutdown, and is most successfully used by those who have had more training in cardiac catheterization procedures and their complications.

Deposition of thrombus on the wall of catheters was observed in more than 50% of 93 diagnostic catheterizations, and the incidence increased to 100% if the catheter was left in more than one day. If a thrombus forms on the catheter, it may also form on the metallic leader. The brachial cutdown method requires no metallic leader; the percutaneous femoral method depends on it. If clot forms on the surface of the leader, the catheter tip may gather the thrombus as the catheter is passed over the leader into the abdominal aorta.

Another aspect of the transfemoral approach is that it usually relies on two or more catheters. In the removal of the first catheter, any thrombus on its surface may be stripped from it at the puncture site and may then adhere to the metallic leader. With the insertion of the second catheter, the doughnut-shaped clot attaches itself to the tip of the catheter. Thrombus on the guidewire may also be stripped off by the catheter tip. As long as the catheter moves retrograde in the aorta—against the aortic stream—the clot is forced back around the catheter tip. Even if it breaks off, it may fragment in the large aortic branches and do relatively little harm on most occasions. Once the catheter enters the coronary artery, however, the direction of blood flow around the catheter tip is reversed, the position of the clot may change, and it may separate from the catheter to become an embolus. This possibility further supports the need for nonthrombogenic guidewires and catheters. Because thrombus formation may be related to platelets adhering to the catheter, agents which disrupt platelet adhesiveness (such as aspirin) may prevent the thrombotic complications.

Nejad et al. have suggested that heparin used at the beginning of the catheterization decreases thrombus formation. Several responses to the present survey supported this concept strongly, and it seems clear that randomized prospective studies may provide more objective evidence corroborating the usefulness of heparin. Others have shown decreased complications with the use of low-molecular-weight dextran or with the application of nonthrombogenic substances to the catheters.

Halpern has suggested that the entrance site is the important area of thrombus formation, but it is generally thought that the thrombus forms around the wall of the catheter and is removed as the catheter is withdrawn. Increase in the diameter and length of the catheter as well as prolongation of the procedure increased the chances of thromboembolism.

The Influence of a Large Patient Care Load

The data from this survey support the contention! of Selzer, Anderson and March that the risk may be
higher when a relatively small number of examinations is performed per year. They reported that the incidence of complications in institutions doing more than 200 coronary arteriograms per year was considerably lower than in institutions in which fewer examinations were performed. In the present study the incidence of all complications was strikingly increased in institutions in which relatively few examinations were done per year. With both the femoral and brachial methods, there was a sharp decrease in complications with increasing numbers of procedures—an apparent reflection of the skill that comes with experience. Thus, it seems likely that although the training of the arteriographer may be a factor in complications, the maintenance of skills associated with a large continuing experience is unquestionably a major element in the incidence of complications no matter what technique is employed.

The Length and Complexity of the Procedure

The Cooperative Study indicated that an increased duration of the procedure was associated with an increased risk to the patient. Similarly Formaneck, Frech and Amplatz have shown that the prolongation of the procedure increases the risk of thrombotic complications. Because of this increased risk, it is essential that the primary coronary arteriographic, ventriculographic, and hemodynamic data be obtained as expeditiously as possible. The acquisition of less critical data should be avoided if it prolongs the procedure unduly or if there is any sign that the patient is tolerating it poorly.

The Contrast Agent

The contrast agent was once considered the major hazard of intravascular radiographic studies, but it has steadily become less important in the major reactions to the procedure. This is a direct consequence of the development of new and less noxious contrast agents such as the diatrizoate group. The composition of the contrast agent used in the heart is critical, however, and the range of acceptable concentrations of the anions and cations is small. Bradycardia remains a routine consequence of the injection of contrast agent into a coronary artery. Ventricular fibrillation is the most frequent serious arrhythmia but seldom leads to death in the laboratory as long as the team is prepared to handle this complication. Its occurrence was slightly higher with the femoral approach.

General Observations

It is important to emphasize that the mortality data derived from this survey probably represent a minimum figure rather than a true representation of risk. Even in an anonymous survey such as the present one, skewed data must be anticipated because arteriographic death has different meanings in different institutions. It should include—but does not—all deaths occurring within 24 hr of the procedure or known to be related to the procedure. That a series of 500 or 900 patients can be studied without a single death (table 2) is remarkable when a population so much at risk is exposed to such a potentially hazardous examination. The high mortality rate among such patients scheduled for arteriography, who die before the arteriogram can be performed, is also well known. In addition, the character of the population under study by coronary arteriography is in transition: sicker patients are now being investigated. Patients in heart failure, or recently out of failure, as well as those with acute ischemic disease, even with early infarction, are increasingly being evaluated for acute surgical intervention. Almost certainly, this higher risk population will mean a higher incidence of complications.

The defects of a study such as this must also be emphasized. No matter how accurate the data on minimum figures for death and complications, they do not indicate the risk for particular groups of patients. Mortality has not been related to duration or severity of coronary disease or to the presence or absence of heart failure. Studies of specific risk factors, which may indicate more clearly those patients for whom a high complication rate must be anticipated, are essential and are, in fact, already underway. The pooled data obscure the risk at an individual hospital. In particular hospitals in which 25 or more arteriograms were performed, mortality rates of 7.7% (brachial), 6% (brachial), 5.7% (femoral) and 5.2% (femoral) were reported in this survey. With over 100 arteriograms, mortality figures of 3.5% (femoral), 2.8% (femoral), 2.3% (brachial), and 2% (brachial, femoral) were documented in individual hospitals. Such figures are hardly acceptable for diagnostic procedures; although they represent a small fraction of the hospitals reporting, they are clearly a local index of the potential hazard of coronary arteriography. They must be added to the local mortality for coronary surgery when defining the risk vs yield of surgical bypass procedures in each individual hospital.
There are important inferences to be derived from this study with regard to the circumstances under which coronary arteriography should be done. Meticulous attention to carefully defined indications is essential. There must be an adequate caseload to maintain the skill of the angiographic team, to expose its members to the potential complications of the procedures, and to maintain the constant awareness and anticipation of reactions which render these complications less noxious to the patient. Coronary arteriography should not be a sporadic procedure performed by individuals who are inexperienced in preventing and treating the complications of cardiac angiographic procedures.

Conclusion

As a result of our survey, we have arrived at three conclusions. First, in the United States today, on the average, the risk of death, myocardial infarction, and cerebral embolus during or following coronary arteriography is greater with the transfemoral than with the transbrachial technique. Second, the risk of thrombosis at the site of catheter entry and contrast agent reaction during or following coronary arteriography is greater with the brachial technique. Third, the risk of death or serious nonlethal complications (myocardial infarction and cerebral embolus) is significantly enhanced in institutions performing a relatively small number of examinations whether the femoral or the brachial technique is employed.

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