SPECIAL ARTICLE

Report of Committee on Cardiac Catheterization and Angiocardiography of the American Heart Association

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Cardiac catheterization and angiocardiography are two methods which are being widely used for the investigation of acquired and congenital heart disease. Since both of these procedures entail some risk to the patient, the Scientific Council of the American Heart Association deemed it advisable to establish a committee to evaluate this risk and to recommend methods to minimize it. The constituent members of the committee were chosen on the basis of their contributions to the evolution of these methods and experience in their application.

Method of Gathering Information for This Report

Two possible methods of gathering the necessary information were suggested: (1) To submit the experiences of the individual members of the committee for analysis; (2) to obtain information from all hospitals where the procedures were being used as to the qualifications of the principal and associate investigators, the adequacy of laboratory personnel and equipment, the number of patients studied, complications, fatalities, and other relevant facts. The first method was chosen because it was felt that evaluation of the experiences of a few laboratories, with a large number of patients, would more adequately reflect the possibilities and limitations of these methods than would a compilation of more data gathered from sources disparate in personnel, physical facilities and experience.

This report is based on the cumulative data of the members of this committee derived from approximately 5,700 right heart catheterizations in eight laboratories (table 1) and from angiocardiograms of 1,325 patients studied in two laboratories. It is divided into two parts: cardiac catheterization and angiocardiography.

Cardiac Catheterization

Catheters have been guided into the cardiac chambers via the venous and the arterial routes. The arterial route involves the introduction of the modified ureteral catheter against the current of flow, and includes potential injury to cardiac valves and heart, as well as injury to the vascular walls due to the force required to overcome local contraction of the arterial wall. The members of the committee are aware of individual instances of myocardial injury, torn aortic valves and introduction of the catheters into the coronary ostia resulting from this procedure. It is impossible at this time to make any specific recommendation except to urge extreme caution in the application of this experimental tool. These difficulties are much less likely to occur when the arterial catheter is not introduced into the left ventricle but is confined to the peripheral arterial system.

Subsequent remarks are confined to venous catheterization, which is established as a useful clinical tool.

Indications

The indications for venous catheterizations are difficult to establish since they will vary...
with the interests of the investigator. In general, the method is currently used to complete the identification of specific congenital or acquired cardiac lesions, to establish

### Table 1.—Survey of Right Heart Catheterizations and Fatalities in Eight Medical Research Units (Complete up to January 1962)

<table>
<thead>
<tr>
<th>Source of Information</th>
<th>Total No. of Catheterizations</th>
<th>No. of Deaths</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Alabama &amp; Johns Hopkins Hospital</td>
<td>1500</td>
<td>1</td>
<td>Autopsy revealed rhabdomyoma of heart.</td>
</tr>
<tr>
<td>Columbia University, Bellevue Hospital</td>
<td>900</td>
<td>1</td>
<td>Silicosis with tachycardia at rest; increased during severe exercise; cardiac asystole, autopsy negative.</td>
</tr>
<tr>
<td>Columbia University, Presbyterian Hospital</td>
<td>350</td>
<td>1</td>
<td>Mitral insufficiency; rigid catheter. Sudden pain in chest and death 2 hours after catheterization while preparing to go home. Autopsy revealed subintimal hemorrhage in infundibulum, right ventricle.</td>
</tr>
<tr>
<td>Emory University</td>
<td>1550</td>
<td>0</td>
<td>1 Patient died during preparation for cardiac catheterization. Not definitely attributed to procedure.</td>
</tr>
<tr>
<td>Mayo Clinic</td>
<td>312</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Michael Reese</td>
<td>287</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>New York Hospital</td>
<td>192</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Peter Bent Brigham</td>
<td>600</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Contraindications

As with "indications," it is impossible categorically to define "contraindications." A contraindication in one laboratory may become the subject of study in another. There is no doubt that paroxysmal ventricular tachycardia constitutes an absolute contraindication to the introduction of a cardiac catheter. Similarly, the study of patients with recent myocardial infarction and subacute bacterial endocarditis will be associated with a considerable risk of accident and patient mortality due to the primary disease itself. Certain experiences of individual committee members are germane to this problem. Thus, manifestations of rheumatic activity clinically or by electrocardiogram constitute a contraindication for immediate study by catheterization in some laboratories. Recent pulmonary embolization is considered an absolute contraindication by others. All agree that investigation of a poorly cooperative or anxious patient usually results in a poor study with inconclusive results, particularly in procedures which require a steady state of circulation and respiration. Finally, a critically ill patient may be expected to tolerate poorly the preparations and manipulations incident to the procedure.

Complications: During Cardiac Catheterization

A. Arrhythmias: These constitute the most common complications. Premature ventricular contractions or short bursts of ventricular tachycardia are the most frequently encountered, and are most often observed when the tip of the catheter is passing through the tricuspid valve or is located in the right ventricular cavity. Consequently, exploration of the right ventricular cavity, using the catheter as a probe, should be restricted to a minimum; lodging of the catheter there should be avoided. Premature auricular beats, auricular flutter, auricular fibrillation, nodal rhythm, and other ventricular rhythms are seldom observed and are usually transient. Their incidence cannot always be related to any specific position of the catheter. Occasionally auricular arrhythmias have persisted for several hours after completion of the procedure, subsiding spontaneously or with the
aid of specific medication (digitalis or quinidine). All of these disturbances of rhythm are more apt to occur in the presence of congenital heart disease where considerable intracardiac manipulation may be necessary to localize the defect and factors such as anoxia may contribute to myocardial irritability.

B. Conduction Defects: The electrocardiographic pattern of right bundle branch system block is sometimes observed after the tip of the catheter has been advanced into the pulmonary artery. A shift in the position of the body of the catheter in the infundibular area may instantaneously arrest the apparent conduction disturbance. If the attack does not subside with change in the position of the catheter, the catheter should be removed.

It is important to recognize that disturbances in rhythm or conduction during cardiac catheterization may not be due to the venous catheter. Similar disturbances have been observed during introduction, and following placement of the arterial needle, with prompt subsidence following more adequate local infiltration with novocaine. Adequate anesthesia of the periarterial tissues will minimize the incidence of this complication.

C. Syncopeal Syndrome: This syndrome is characterized by dilatation of the pupils, facial pallor, perspiration of the hands and upper lip, and yawning, associated with a bradycardia and hypotension. The investigator must always be on the alert to detect the appearance of these symptoms and either arrest the procedure or institute measures to obviate the symptoms. They may occur at any time during the procedure or shortly after its termination. Consequently, it is important to attend the patient even after the procedure is completed.

D. Venospasm: This complication is not unusual. It is manifested by pain above the operative site during manipulation of the catheter, and often subsides with cessation of manipulation. If it persists after infiltration of the site of insertion of the catheter with novocaine, the procedure should be terminated.

E. Loops and Angulations: These should not occur if the catheter is passed under continuous direct vision and if wide loops, especially in the auricle, are avoided. Advancement of the catheter should not be undertaken, even in the upper arm, without fluoroscopy, otherwise, knots may result which are resistant to attempts at uncoiling and may require surgical removal.

F. Trauma to Endocardium: Traumatic lesions of the endocardium have been noted as a frequent occurrence in animals but appear to be exceedingly rare in man. Postmortem examinations have been performed within hours, days and weeks of the procedure in patients who had died of their fundamental disease, or following surgery. In nearly all instances, no evidence of cardiac injury could be detected. However, in one instance of death following cardiac catheterization, an area of subendocardial injury was found in the infundibulum of the right ventricle. In this instance, the lesion could probably be related to the rigidity of the probing catheter.

It cannot be overemphasized that forcing the catheter forward against resistance in any area is to be avoided. The report of instances in which the catheter has been passed in the pericardial cavity, apparently by rupture through one of the cardiac veins, may be cited as emphasis on this particular point.

G. Pyrogenic Reactions: These complications were more frequent in the developmental days of cardiac catheterization. They may be completely avoided if proper care is exerted after catheterization to clean and rinse the catheter lumen, and if infusion sets are equipped with disposable plastic tubing rather than rubber tubing.

H. Air Emboli: These reactions too were more frequent during the earlier development of the method. Their consequences are more serious in the presence of congenital cardiac lesions with right to left shunt.

Complications: Miscellaneous

Specific complications may occur which are peculiar to the particular type of case under investigation. Thus, the cardiac catheter which causes no manifest obstruction or insufficiency of normal pulmonary valves, may in the presence of stenosis of the pulmonary valve precipitate acute anoxia due to impaired pulmonary blood flow.

A. Following Cardiac Catheterization: Local
irritation and thrombosis at the site of introduction of the venous catheter are probably related to the duration of the procedure and degree of manipulation, and are not rare. Fortunately these local thromboses have not been associated clinically with pulmonary infarction. However, pulmonary infarction has been frequently observed in the past in patients with mitral stenosis or pulmonary congestion following wedging of the catheter into a distal pulmonary artery branch for the recording of "pulmonary capillary" pressures. The complication of pulmonary infarction has been more of a problem in some laboratories than in others. The cause of this apparently true difference in the incidence of this complication is unsettled. In the chairman's laboratory this complication has been minimized by substituting autoclaving for chemical sterilization. Other investigators claim that prolonged occlusion of a terminal branch of the pulmonary artery in a congested lung bed may facilitate the occurrence of pulmonary infarction and that, therefore, wedging should be reduced to the practical minimum and probably should not exceed 10 minutes.

B. Fatalities: Four deaths have occurred incident to the 5,691 catheterizations. The members of the committee are aware that other deaths have occurred in laboratories not represented in this report, but for reasons indicated above, these deaths do not lend themselves to adequate analysis. Although no attempt has been made in this report to classify the patients according to the presence, absence and type of heart disease, it is apparent from the known interests of these laboratories that many of the patients had advanced heart disease and were particularly vulnerable to manipulative procedures of any type. This is emphasized by the death of one patient prior to introduction of the cardiac catheter while awaiting the start of the procedure. One of the three deaths that could be ascribed with certainty to the procedure revealed a rhabdomyoma of the heart at autopsy. A rigid catheter contributed to the death of another patient with subendocardial necrosis. Strenuous exercise in a patient with tachycardia at rest terminated in cardiac asystole in a third patient.

In summary, there was a mortality of less than 0.1 per cent in 5,691 cardiac catheterizations, and the possibility exists that, in the light of our present knowledge and experience, this mortality could have been further reduced.

C. Prevention of Serious Complications: Adequate sterilization and preparation of equipment and infusion prior to the procedure need no emphasis. During the procedure there is no better safeguard against serious complications than continuous clinical alertness and electrocardiographic observation. Any complaint of a queer or unusual feeling by the patient, a significant increase in heart rate, evidence of vagal stimulation, persistence of induced premature ventricular contractions or right bundle branch block, should lead, without delay, to termination of the procedure. Premedication with procaine amide or Nembutal are considered to be of no prophylactic value. It is further suggested that transit through the right ventricle should be minimized, and that pressure tracings from this chamber should be recorded only during withdrawal from the pulmonary artery. Mixed venous blood should be drawn from the pulmonary artery rather than right ventricle, except where the latter samples are essential to diagnosis. "Pulmonary capillary" pressures and samples should be obtained as rapidly as feasible.

The minor complications indicated above usually subside spontaneously following termination of the procedure. Arrhythmias which arise or persist following the termination of the procedure, should be managed as any similar spontaneous arrhythmia. The vasovagal reaction can usually be readily relieved by infiltration of the arterial site with more Novocaine, oxygen inhalation and the head-down position. In rare instances, it may become necessary to resort to the use of intravenous atropine for the treatment of this syndrome. Mechanical ventilators using oxygen, with facilities for delivering the gas under positive pressure, should be on hand for resuscitation. Procaine amide and quinidine are recommended for ventricular tachycardia.

Digitalis glycosides, the specific ones varying with the individual preferences of the various laboratories, should be on hand for the arrest of paroxysms of auricular tachycardia or
fibrillation, especially when they are associated with heart failure. Morphine sulfate is advocated for the management of pyrogenic reactions.

However, the dreaded complications are cardiac arrest and ventricular fibrillation. The management of these complications has been of much concern, but the recommendations are fortunately largely theoretic, because of the rarity of these complicating catastrophes. For cardiac arrest there is no prophylaxis and poor prospect of treatment; surgical intervention and direct cardiac massage are advocated by some. The prophylaxis of ventricular fibrillation is the early elimination of the ventricular arrhythmias. When ventricular fibrillation occurs, various types of therapy are available. These include chemical defibrillation by means of drugs (procaine amide, procaine, quinidine) introduced via the catheter which should be removed into the superior vena cava, and various mechanical defibrillators. Once ventricular fibrillation has been established, the value of drug therapy alone is very doubtful. All methods of defibrillation are advocated with more optimism than experience.

**Angiocardiography**

The indications for this procedure and its limitations have been published elsewhere as isolated reports and included in a recent book. Although it is a potentially valuable diagnostic supplement in investigating anatomic alterations and defects in the heart and vascular tree, it is not an innocuous procedure and mere academic interest does not warrant its application. Diodrast is the most commonly used contrast substance, but the specific contrast medium has heretofore not influenced the frequency of undesirable reactions. At the New York Hospital, 1,256 patients were studied by means of 2,197 injections. This large number is the basis for our subsequent comments. The chief complication encountered was syncope, usually regarded as a manifestation of sensitivity. This sensitivity could not be predicted on the basis of skin or eye tests with the contrast substance. Syncope occurred most frequently in patients with congenital heart disease. Premedication did not seem to avert these attacks; drugs did not seem of help in relieving them. No need could be established for the electrocardiogram in this brief procedure. It is of considerable interest that in this large group of patients, there were no deaths, whereas in a group of 6,824 patients culled from 182 centers by correspondence, there were 26 deaths, predominantly in children with congenital cyanotic heart disease. Nearly all received epinephrine following the onset of the reaction but prior to death. The type of death was usually ascribed to respiratory arrest during, or immediately following, injection.

It seems reasonable to indicate that angiocardiography as a supplemental tool has considerable diagnostic potentiality, and should be used only in hospitals which can procure the elaborate equipment and trained personnel essential for the maximum yield of information. It is not an office procedure and at the present time, should be used to define lesions or disordered cardiovascular architecture about which information is necessary, but cannot be obtained by any simpler measures.

**Summary and Conclusions**

1. Cardiac catheterization and angiocardiography can supply, if properly applied, a considerable amount of diagnostic and physiologic information in human subjects, which is otherwise not available.

2. There is a definite risk of injury or death to the subject, which is influenced by the presence, type, and severity of heart disease. This risk can be minimized by adequate precautionary measures which can probably best be effected in large centers, utilizing specially trained medical and technical personnel.

3. It is worthy of emphasis that these methods can serve physicians best as a supplement to, rather than a substitute for, clinical and radiologic examination.
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