Complications of Right Heart Catheterization*
A Prospective Autopsy Study
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The purpose of this study was to characterize the type and prevalence of abnormalities associated with right heart catheterization. We performed detailed post-mortem examinations of 32 consecutive patients brought to autopsy with a right heart catheter in the pulmonary artery. Thrombosis (17 patients, 53 percent), hemorrhagic lesions (25 patients, 78 percent), and intimal fibrin deposition (21 patients, 66 percent) were found at sites along the entire path of the catheter. Twenty-nine patients (91 percent) had either thrombosis, hemorrhage or both. While the superior vena cava was the most common site for all lesions, seven patients had thrombosis involving the chambers and valves of the heart and four had thrombosis involving the pulmonary artery. The incidence of thrombosis was significantly higher after 36 hours of catheterization (p<0.05). All five patients with thromboemboli in the more proximal pulmonary arteries had catheter-related thrombosis. We conclude that there is a high prevalence of thrombotic and hemorrhagic lesions in patients dying with pulmonary catheters in place; that the risk of thrombotic complications increases with duration of catheterization; and that patients with catheter-related thrombosis are at increased risk of thromboemboli to the proximal pulmonary arteries.

While the potential benefit of right heart catheterization has been established in critically ill patients with and without acute myocardial infarction, questions remain about the incidence and severity of the complications of this procedure. A variety of complications have been recognized clinically during prolonged catheterization, including bacterial contamination, catheter induced sepsis, venous thrombosis, and pulmonary emboli. Case reports of thrombosis of the subclavian vein, internal jugular vein, superior vena cava, and pulmonary artery following pulmonary artery catheterization serve to emphasize the severity of thrombotic complications, but do not allow estimates of their incidence or prevalence. There have been several reports, however, which suggest that the prevalence of thrombosis associated with right heart catheterization is much higher than noted in those studies which reported only clinically apparent events.

The purpose of this study was to characterize the type and prevalence of abnormalities associated with right heart catheterization in patients brought to autopsy with right heart catheters in place.

METHODS

Between August 2, 1982 and October 20, 1983, 32 patients who died with a balloon-tipped, flow-directed catheter in the pulmonary artery came to autopsy at Cleveland Metropolitan General Hospital.

Post-mortem Examination

One of the authors was present at each of the post-mortem examinations. After the thoracic cavity was exposed, the superior vena cava was identified, tied off with the catheter inside, and severed just below the clavicle. All of the thoracic organs were then removed for bench dissection. The entire route of the catheter was inspected and all gross abnormalities were sampled for histologic examination. Routine sections were taken from the superior vena cava, right atrium, tricuspid valve, right ventricle, pulmonic valve, and main pulmonary artery. The lungs were examined for pulmonary thromboemboli or infarction. At least one section of the lung parenchyma was obtained from each pulmonary lobe. Sections of all parenchymal lesions observed grossly were taken for histologic examination.

Tissue blocks were imbedded in paraflin, cut at 5 μm thickness and stained with hematoxylin and eosin. Stains for elastic tissue, fungi, and bacteria were used when indicated. Standard criteria were used to distinguish ante-mortem thrombi from post-mortem blood clots. Only microscopically confirmed pre-mortem thrombosis is reported in this study.

Clinical Information

We recorded the date and hour of catheter insertion, duration of catheterization, mean cardiac index for 48 hours before death, platelet count, prothrombin time, activated partial thromboplastin time obtained within 48 hours of death, and the drug therapy and disease processes present at time of death. With the exception of the disease processes present at time of death, this information was not available to the physicians performing the post-mortem examination.

Data Analysis

For continuous variables, the Mann-Whitney U-test was used to determine whether the values in each group were drawn from the same population. All values are reported as mean ± standard error of
the mean (SEM). Chi-square analysis was used to compare the difference in prevalence of abnormalities between groups. Fisher’s exact test was used to compare the difference in prevalence of abnormalities between groups when the expected value in any cell was less than five.

RESULTS

Clinical Findings

Nineteen men and 13 women, whose average age at death was 58.3 years (range 19-80), were included in this study. They died of a variety of severe acute illnesses (Table 1) in one of three specialty units: either medical (20 patients), surgical (six patients), or coronary (six patients) intensive care. The catheters had been in place for an average of 39.9 ± 6.4 (SEM) hours at time of death.

Autopsy Findings

The prevalence and location of the lesions found at post-mortem examination are shown in Table 2. Thrombosis was defined as macroscopic ante-mortem fibrin and platelet aggregates which were adherent to the damaged endocardial or endothelial surface and projected into the vascular lumen. The thromboses varied in size from endocardial vegetations a few millimeters in diameter to large thrombi which almost occluded the superior vena cava. The larger thrombi formed cylindrical casts around the catheter in many instances (Fig 1). In no case was ante-mortem clot found adherent to the catheter alone without also being attached to the underlying endothelium. Fibrin deposition consisted of a thin layer of fibrin along the denuded intimal surface (Fig 2). This lesion was either undetectable grossly or appeared as a fine granular stippling of the endothelial surface. Hemorrhages consisted of 0.5 to 1.0 cm ecchymoses or, more commonly, intimal petechial hemorrhages (Fig 3).

The superior vena cava was the most common site for all three of these abnormalities, but they were also noted along the entire path of the catheter. Seven patients (22 percent) had intracardiac thrombosis; five of these (16 percent) had aseptic valvular thrombotic vegetations. Infective endocarditis was excluded histologically in all cases. Fibrin deposition was frequently seen in the right atrium and on the pulmonic valve. Hemorrhages also occurred frequently on the tricuspid and pulmonic valves. Only three patients had no endocardial or endocardial abnormalities. Twenty-nine patients (90.6 percent) had either thrombosis, hemorrhage, or both; and 35 patients (71.9 percent) had either thrombosis, fibrin deposition, or both. Thrombosis was found in 15 of the 21 patients with fibrin deposition and in 13 of the 25 patients with hemorrhagic lesions.

Pulmonary emboli were seen at post-mortem examination in 19 of the 32 (59.4 percent) patients. Five patients had thromboemboli visible in the proximal pulmonary arteries, while ten patients had thromboemboli only found by microscopic examination of the lung parenchyma. Four patients had only fibrin-platelet thrombi in the microvasculature, associated with diffuse alveolar damage. Seven patients had pulmonary infarcts. In one patient with thrombophlebitis of the superior vena cava, the emboli found in the lung were histologically similar to the inflamed, catheter-related thrombotic lesion.

Other complications occurred infrequently. Two catheters passed through the chordae tendineae of the tricuspid valve but did not cause any structural disruption of the valve. In one patient, a massive mediastinal hemorrhage was found at post-mortem examination. This was the only instance in which the right heart catheter was directly implicated in the cause of death.

Risk Factors

There was a relationship between the duration of catheterization and the prevalence of thrombosis. As seen in Figure 4, the mean duration of catheterization in the 17 subjects with thrombosis was 53.6 ± 10.3 (SEM) hours, while in the 15 subjects without thrombosis it was 24.3 ± 5.0 (SEM) hours (p<0.05). In addition, the prevalence of thrombosis in subjects catheterized for more than 36 hours (11 of 15, 73.3 percent) was greater than that in subjects catheterized for less than 36 hours (6 of 17, 35.3%) (p<0.05). There was no relationship between catheter duration and the prevalence of fibrin deposition, hemorrhage, pulmonary emboli, or pulmonary infarcts.

Table 1—Disease Processes Which Required Right Heart Catheterization for Diagnosis or Monitoring

<table>
<thead>
<tr>
<th>Disease</th>
<th>Number of Patients</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepsis</td>
<td>11</td>
<td>34</td>
</tr>
<tr>
<td>Gastrointestinal Bleeding</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Acute Myocardial Infarction</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Recent Cardiac Surgery</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Cardiopulmonary Arrest</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Acute Tuberculosis</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Hypotension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncertain Cause</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2—Location of Three Types of Abnormalities Found in 32 Consecutive Autopsies of Patients Who Died with a Right Heart Catheter in Place

<table>
<thead>
<tr>
<th>Location</th>
<th>Thrombosis (N = 17)</th>
<th>Fibrin Deposition (N = 21)</th>
<th>Hemorrhage (N = 25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior vena cava</td>
<td>16 (50)</td>
<td>18 (56)</td>
<td>17 (50)</td>
</tr>
<tr>
<td>Right atrium</td>
<td>3 (9)</td>
<td>5 (16)</td>
<td>6 (19)</td>
</tr>
<tr>
<td>Tricuspid valve</td>
<td>4 (13)</td>
<td>1 (3)</td>
<td>8 (25)</td>
</tr>
<tr>
<td>Right ventricle</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>4 (13)</td>
</tr>
<tr>
<td>Pulmonic valve</td>
<td>2 (6)</td>
<td>9 (28)</td>
<td>8 (25)</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>4 (13)</td>
<td>2 (6)</td>
<td>2 (6)</td>
</tr>
</tbody>
</table>

*Percentage of all subjects who were found to have an abnormality in the location.
There was a relationship between the presence of thrombosis and thromboemboli in the larger pulmonary vessels. Each of the five patients with visible thromboemboli in the proximal pulmonary artery had catheter-related thrombosis (p<0.05). There was, however, no apparent relationship between the presence of thrombosis and the prevalence of microscopic pulmonary emboli. Five of the seven patients with pulmonary infarcts had catheter-related thrombi detected at autopsy (p>0.10).

There was no relationship between cardiac index and catheter-related thrombosis. The mean cardiac index in the 48 hours before death was 3.7 ± 0.7 (SEM) L/min/m² in 15 patients with thrombosis and 3.7 ± 0.4 (SEM) L/min/m² in 14 patients without thrombosis.

The prevalence of thrombosis was lower in subjects whose prothrombin time was more than 3.0 seconds...
The duration of catheterization prior to death in patients with and without catheter-related thrombosis is shown. The mean value (\( \Delta \)) ± standard error is indicated.

prolonged (p<0.05) or whose activated partial thromboplastin time was more than 10.0 seconds greater than control values (p<0.01). Thirteen patients had abnormally prolonged prothrombin and/or activated partial thromboplastin times due to chronic liver disease (five patients), bacterial sepsis (six patients), or disseminated fungal or mycobacterial infection (two patients). Only three of these 13 patients (23 percent) with coagulation abnormalities had thrombosis, while 14 of 19 (74 percent) patients with normal coagulation had thrombosis (p<0.01). None of the patients received heparin or coumadin during the catheterization.

Eight patients had underlying malignancy. None had evidence of a hypercoagulable state. There was no difference between the prevalence of thrombosis in this group (five of eight patients, 63 percent) and that of patients without malignancy (12 of 24 patients, 50 percent).

Twenty patients had either a central venous catheter, a pulmonary artery catheter, or both at some time during their hospitalization prior to the final pulmonary artery catheterization. Nine had had pulmonary artery catheters removed an average of 7.8 ± 1.8 (SEM) days, (range 2 to 17 days) prior to the final catheterization. In seven, a central venous catheter had been placed within 48 hours of the final catheterization and, in eight, within two to seven days of the final catheterization. There was no detectable influence of prior catheterization on the prevalence of thrombosis, fibrin deposition, hemorrhage, pulmonary embolus, or pulmonary infarction.

**DISCUSSION**

In this prospective study of 32 consecutive autopsies of patients who died with a balloon-tipped, flow-directed right heart catheter in place, we found a high prevalence of hemorrhagic, thrombotic, and thromboembolic abnormalities. The prevalence of thrombosis was directly related to the duration of catheterization. Patients with catheter-related thrombosis were at increased risk of macroscopic pulmonary thromboemboli.

Several prospective and retrospective studies of the complications of right heart catheterization reported that clinically apparent thrombotic events occurred in less than 2 percent of patients.\(^6\) However, thrombosis is notoriously difficult to detect on the basis of clinical signs.\(^7\) Other investigators detected a higher prevalence of thrombotic lesions by using invasive diagnostic procedures or post-mortem examination. There are several reports of aseptic endocardial thrombotic vegetations,\(^8\) bacterial endocarditis,\(^9\) ecchymoses,\(^10\) and petechial hemorrhage\(^10\) at autopsy in patients who had received right heart catheterization prior to death. Unfortunately, the studies were mostly retrospective, the number of patients with right heart catheters in each study was small, correlation with clinical events not sought, and in many patients, the catheters had been removed days to weeks prior to death.

Chastre et al\(^11\) found internal jugular vein thrombosis by venography or at post-mortem examination in 22 of 33 (66 percent) consecutive patients immediately following removal of their right heart catheters. However, no comment could be made about thrombosis elsewhere along the path of the catheter, and no relationship was found between thrombosis and the duration of catheterization. Lange et al\(^12\) reviewed the autopsy files of two hospitals over a six-year period and found 36 cases in which the heart had been preserved and the patient had died with a right heart catheter in place. They found bland thrombosis in 62 percent of the specimens and aseptic valvaral vegetations in 8 percent. Unfortunately, the proximal superior vena cava and lungs were not available for examination, histologic sampling was not standardized or performed routinely, and the selection process was biased towards patients with recent cardiac surgery, acute myocardial infarction or congestive heart failure (30 of 36 patients, 83 percent).

Our study followed a comprehensive protocol which assured that each dissection was done with the same care and attention to detail. Only patients who came to autopsy with a catheter in place in the pulmonary artery were included. We studied every patient who met this criterion over the 14 month period. Consequently, this study provides a reliable estimate of the prevalence of the complications of right heart catheterization.
terization at autopsy and their relationship to the duration of catheterization and abnormalities of coagulation.

Because of the aggressive support we give to hemodynamically unstable patients in our hospital, a control group was not possible. However, the prevalence of thrombotic and hemorrhagic lesions at post-mortem examination is less than 1 percent in patients with no history of central vascular catheterization. In autopsies of patients with no history of central vascular catheterization, thrombotic lesions were found in one of 205 patients in one study, while none was found in 76 patients in another. Thus, it is a reasonable assumption that the abnormalities we report here are related to right heart catheterization.

There are two principal mechanisms by which right heart catheterization may increase the risk of thrombosis. First, the endothelium and endocardium are traumatized by repeated contact with the catheter as a result of cardiac contraction. Fibrin deposition and thrombosis then occur on the damaged endothelial surface. Second, the right heart catheter itself is thrombogenic and may act as a foreign body to trigger the coagulation cascade. However, this mechanism of thrombus formation did not appear to be important in producing the thrombotic lesions reported in this study. While the catheter was frequently observed to be surrounded by thrombus, there was no instance of a histologically confirmed ante-mortem thrombus adherent only to the catheter and not also adherent to a damaged endothelial surface. We conclude that trauma to the vascular wall from the catheter causes endothelial and endocardial damage and thrombus forms on this damaged surface. Heparin coating of the catheter reduces the tendency of clot to adhere to its surface; however, characteristics of the catheter which promote or inhibit thrombus formation were probably of secondary importance in the genesis of the thrombi found in this study.

Thrombotic, thromboembolic, and hemorrhagic complications of right heart catheterization occur commonly in critically ill patients. The prevalence of thrombosis increases with the duration of catheterization. Patients with catheter-related thrombosis appear to be at increased risk of proximal pulmonary artery thromboemboli. We conclude that invasive hemodynamic monitoring with a right heart catheter should only be employed when the anticipated benefits of the information gained from this procedure clearly outweigh these risks. Perhaps of greater importance, the clinician should remove the catheter promptly when it is no longer needed, keeping the duration of catheterization to a minimum.

**Addendum**

Rowley et al published a report of right-sided infective endocarditis due to pulmonary artery catheterization after this manuscript was submitted for publication. Twenty-nine of 55 patients who died within one month of their catheterization had right-sided endocardial lesions (thrombus or hemorrhage) and four of these had infective endocarditis. By studying only patients who died with a catheter in the pulmonary artery and including the superior vena cava and pulmonary artery in our examination, we found a higher prevalence of endocardial and endothelial lesions (91 percent). None of our patients had bacterial endocarditis, although only one of the seven patients with intracardiac thrombotic lesions had bacteremia documented during the period of catheterization.

ACKNOWLEDGMENTS: The authors would like to thank Murray D. Altose, M.D. for his thoughtful review of this manuscript; Christine E. McLaren, Ph.D. for her assistance in the statistical analysis of the data; Neal Dawson, M.D. and Harold Goldberg, M.D. for their critical analysis of the study's design; and Sandy ShafT, Kerrie Kaiser and Elissa Sevier for their excellent secretarial assistance.

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