Arterial Thrombus Formation During Clinical Percutaneous Catheterization

By Gustave Formanek, M.D., Robert S. Frech, M.D., and Kurt Amplatz, M.D.

SUMMARY
Deposition of thrombotic material on catheters was observed following more than 50% of 93 diagnostic catheterizations. The incidence of deposition of thrombotic material on catheters remaining in the body for more than 1 day was 100%.
Polyethylene and siliconized polyurethane catheters were less thrombogenic than Teflon end-occluded catheters.
A definite time relationship between the thrombus formation and the duration of the catheterization procedure was noted.
The growth of thrombi on the outside of catheters does not appear to be linear since catheters can remain in place for 10 days or more.
Postcatheterization thrombosis is believed to be due to thrombi stripped from the catheter by the arterial wall. The thrombus which originally encases the catheter will pile up at the puncture site as the catheter is withdrawn. The thrombus may remain attached at the puncture site or embolize peripherally.

Additional Indexing Words:
Arteriography Teflon catheters Seldinger technic

Cardiac and vascular catheterizations are generally carried out with various types of plastic catheters. Thrombosis of the catheterized vessel is the most common complication. The plastic foreign body and arterial puncture trauma are thought to stimulate the thrombosis.
Arteriograms of catheterized vessels have frequently demonstrated thrombi. Siegelman and associates1 observed thrombi at the puncture site in 44% of 173 catheterizations. In a study of seven patients with catheters indwelling for 5 to 23 days, Jacobsson and Schlossman2 found thrombi on all the catheters. Bjork's group3 described brachial arterial abnormalities in 56% of patients with catheters indwelling for 11 hours.
In autopsy studies of indwelling venous catheters, thrombi were noted about the catheters in 40%4 to 91%.5 The site from which the catheter was removed was described as a "fibrin channel" and a "cannulated thrombus." Jacobsson and co-workers6 demonstrated similar thrombotic encasement of the catheter in the arteries of dogs.
Clinical signs of thrombotic vascular occlusion are much less common. In a survey of 6,160 cardiac catheterizations, clinical arterial thrombosis was diagnosed in 0.5%.7 By oscillographic monitoring of calf pulsations, Jacobson and associates8 identified arterial occlusion in 1.4% of patients undergoing femoral artery catheterizations. With routine angiograms made prior to withdrawal of the catheter, Siegelman and associates1 found surgical thrombectomy indicated following 2.3% of arteriograms.
It is the purpose of this study to determine (1) the incidence of thrombus formation on catheters in clinical practice; (2) the relation of thrombus formation to the duration of the catheterization procedure; (3) the throm-
Examples of arteriograms made prior to withdrawal of the catheter at the end of diagnostic catheterization. The size of the radiolucent clot surrounding the opaque catheter varied from none (a), small (b), and large (c) to complete occlusion (d).

Methods
Following percutaneous arterial catheterization the arteries were routinely examined for thrombus formation. The catheter was withdrawn close to the puncture site, and roentgenograms were obtained during the manual injection of 5 to 10 ml of contrast material. These withdrawal films were made in 93 patients undergoing various studies and procedures including aortography and selective arteriography of coronary, carotid, brachial, celiac, renal, or iliac arteries. Similarly, 13 selective hepatic, celiac, or hypogastric catheters were examined after use in chemotherapy infusion for 1 to 14 days. Additional arteriograms were made during different stages of withdrawal of some of these perfusion catheters by injecting contrast material through a needle introduced 1 inch distal to the catheter. The diameter of the catheter, material, and duration of the procedure were recorded. The roentgenograms were examined for thrombi.

Thrombi were recognized arteriographically as an area of radiolucency around the outside of the catheter. Normally, the opaque catheter blends completely with the injected contrast material. If an encasement thrombus is present, radiolucency of various magnitudes can be recognized (fig. 1). This diagnostic criterion cannot be used for nonopaque catheters which invariably show an area of radiolucency.

Results
Thrombus formation was noted in 50 of 93 diagnostic catheterizations (54%) (table 1). Figure 1 illustrates the appearance of these thrombi.

Polyethylene, Teflon, and siliconized polyurethane catheters were used during this study. The frequency of clot formation was

<table>
<thead>
<tr>
<th>Table 1 Thrombus Formation in 93 Diagnostic Percutaneous Arterial Catheterizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteriographic demonstration</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Adults</td>
</tr>
<tr>
<td>Children</td>
</tr>
</tbody>
</table>
Table 2

<table>
<thead>
<tr>
<th>Catheter Material and the Occurrence of Thrombus Formation</th>
<th>Thrombus</th>
<th>No thrombus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Polyurethane, siliconized</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Teflon*</td>
<td>22</td>
<td>10</td>
</tr>
</tbody>
</table>

*Teflon catheters were used mainly for semiselective renal arteriography and had side holes and metallic end occluders.

Table 3

<table>
<thead>
<tr>
<th>Catheterization Time and the Occurrence of Thrombus Formation</th>
<th>Thrombus</th>
<th>No thrombus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of catheterization (min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 or less</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>31 or more</td>
<td>20</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 4

<table>
<thead>
<tr>
<th>Catheter Diameter and the Occurrence of Thrombus Formation</th>
<th>Thrombus</th>
<th>No thrombus</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 F or less</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>8 F</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>9 F</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

much higher in the group in which Teflon catheters were used (table 2).

The duration of catheterization was directly related to thrombus formation (table 3). From 38 cases in which the period of catheterization was 30 min or less, a thrombus was observed only 15 times (39%). On the other hand, a thrombus was detected on 20 of 31 catheters indwelling for longer than 30 min (65%).

The diameter of the catheters did not appear to play an important role in initiation of the thrombus formation (table 4). We could not find any relation between the frequency of clot formation and the size of the catheter.

In eight diagnostic cases the peripheral pulse disappeared. In four women the pulse returned spontaneously and spasm of the punctured artery was postulated. In one 2-year-old child an occluding thrombus was surgically removed from the femoral artery (table 5). Deep femoral emboli were shown radiographically in one patient whose pedal pulse also returned spontaneously. Thrombotic occlusion was asymptomatic in one patient and improved after sympathetic block in another.

Thirteen catheters used in arterial chemotherapy perfusion were indwelling from 1 to 14 days. Size 6 French polyethylene catheters were used. All showed considerable thrombus formation. Complete occlusion of the femoral artery was noted in one patient. In two other patients there was clinical evidence for peripheral embolization following removal of the catheter. Septicemia and septic emboli developed in another (table 5).

During withdrawal of the catheter the encasement thrombus remained fixed or became mobile. The fixed thrombi were adherent to the iliac or femoral arterial wall and remained unchanged during withdrawal of the catheter (fig. 2).

The mobile thrombi were adherent to the catheter and moved distally when the catheter was withdrawn (fig. 3). They were peeled from the surface of the catheters by the arterial wall at the entry site where they enlarged as withdrawal of the catheter progressed. After complete removal of the catheters these thrombi either remained in the femoral artery at the catheterization site (fig. 4) or were washed away as emboli toward the periphery. Embolization occurred four times, and emboli were identified angiographically twice in the deep femoral artery (fig. 5). In another patient, however, the thrombus at the puncture site had disappeared. We were not able to find the embolus by femoral...
Removal of a catheter following celiac axis perfusion for 11 days. The arteriograms made after the catheter was withdrawn show the gradual increase in thrombus size. (a) Before withdrawal a thin layer of thrombus surrounds the length of the catheter. (b) After partial withdrawal, the catheter is surrounded by a large clot which has been peeled off and has accumulated at the puncture site. (c) Just before removal of the catheter the lumen of the artery is completely occluded with thrombus.

Femoral arteriograms via Teflon sheath in a patient with celiac catheter indwelling for 7 days before withdrawal (a) and after complete removal of the catheter (b). The fixed thrombi remain attached to the wall of the iliac artery. The thrombus at the puncture site has slightly enlarged.
THROMBUS FORMATION DURING CATHETERIZATION

Figure 4

Mobile thrombus. During withdrawal of the catheter (a) the thrombus moved distally. After withdrawal of the catheter (b) the thrombus stayed at the site of the arterial puncture.

Discussion

The Seldinger percutaneous arterial catheterization modus has become the technic of choice for various vascular catheterization procedures. The rate of complication with this technic is 2.5% in our series, primarily due to postcatheterization thrombosis requiring surgical thrombectomy.

Many theories have been advanced as to the mechanism of thrombosis of the catheterized vessel following percutaneous introduction of catheters. The most popular opinions were: (1) localized trauma to the arterial wall and thrombus formation at the puncture site; (2) hypercoagulability state; (3) large catheter in relation to the internal diameter of the catheterized vessel; and (4) prolonged intravascular position of the catheter.

The results presented in this study strongly suggest that postcatheterization thrombosis is due to clot formation on the outside of the catheter. As the catheter is withdrawn the thrombus grows, piles up, and may occlude the arterial lumen, but the catheter emerges free of thrombi from the puncture site.

As it is well known from extensive experiments dealing with circulatory assist devices and artificial heart mechanisms, a truly nonthrombogenic plastic material is not available at the present time. In animals, particularly the dog, a fibrin layer is deposited in a few minutes on all plastic surfaces. There is no great difference in the thrombogenicity of various plastics. Clots are readily formed on Teflon which has distinct hydrophobic characteristics. Numerous animal studies performed in this laboratory consistently showed thrombi on catheters within 15 min and complete thrombosis of the artery in 30 to 60 min.

arteriography and we suggest that the clot had fragmented and embolized smaller arteries.
A large embolus straddles the origin of the lateral femoral circumflex artery. More thrombus is present distally. A celiac catheter had been indwelling for 9 days. This embolus was noted on three studies made at the time of catheter removal and also 2 and 11 days later.

The formed clot which finally encases the entire catheter grows to a certain size. In the present clinical study clot formation was observed as early as 15 min after the introduction of the catheter. If the progression of clot formation were indeed linear, no catheter could remain in the arterial system for more than a few hours. It is very likely, therefore, that the formation of thrombi on catheters occurs rather rapidly but diminishes or ceases when an encasement thrombus has formed.

This hypothesis seems to be supported by well-known facts from cardiovascular surgery. It is common to introduce a knitted plastic graft for arterial and aortic surgery which initiates the deposition of fibrin shortly after insertion into the human body. This fibrin layer, now referred to as "neointima," however, no longer increases in size and it now acts as a new, nonthrombogenic lining of the plastic material.

The well-known fact that arterial thrombosis following percutaneous arterial catheterization is more likely to occur with larger catheters can be explained as follows: (1) The larger the catheter the greater its circumference and consequently the larger the encasement thrombus. Consequently, following the withdrawal of the catheter more thrombotic material is piled up in a smaller artery, resulting in a higher incidence of thrombotic occlusion of the catheterized artery. (2) Large catheters tend to decrease or eliminate flow through the catheterized vessel, stimulating thrombus formation induced by stasis.

The exact fate of the thrombus either remaining at the puncture site or embolizing into the peripheral artery is not known. In one of our cases an embolus remained 11 days later, indicating that lysis does not occur or at least is much slower than seen in the venous system as with the pulmonary arterial tree. Reported instances of delayed development of ischemia suggest that the arterial thrombus may occasionally enlarge.

At the present time no satisfactory solution to this problem is available. Nejad and associates suggested heparinization of the patient during the catheterization procedure and neutralization of the injected heparin by protamine before the catheter is removed. This suggestion was based on the observation...
that clot formation on catheters in dogs is markedly reduced by systemic heparinization. The drawback of this suggestion is the fact that inadvertent vascular or cardiac perforations may lead to a fatal hemorrhage. In our opinion therefore systemic heparinization is not advisable during catheterization procedures since perforations of the arteries, veins, and myocardium are fairly frequent but usually of no serious consequence due to the normal clotting mechanism.

The obvious solution to this problem appears to be an heparin-impregnated plastic which would prevent thrombosis at least during the time of catheterization. Unfortunately, most of the described technics involve surface binding and potent solvents which tend to alter the consistency of the plastic material used. Presently, studies are under way in this laboratory to investigate an insoluble heparin compound which can be wiped on the catheter prior to the procedure and does not alter its plastic characteristics. Preliminary studies are promising and results will be reported elsewhere.

References
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