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Thrombogenesis Associated with Swan-Ganz Catheters

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The balloon-tipped, flow-directed, flexible pulmonary-artery (Swan-Ganz) catheter has gained clinical acceptance and increased usage since its introduction in 1970¹

Occasional complications have been reported to occur with the use of this indwelling device.² Pulmonary infarction related to thrombus formation in two patients has been reported.³ In another report, a massive thrombus extending from the tip of a Swan-Ganz catheter and obstructing the main pulmonary artery was stated to be a contributory if not the primary cause of death in a patient on the basis of post-mortem examination.⁴

Although thrombus adherent to the catheter has been occasionally observed,^{1,4} a systematic evaluation of this phenomenon has not been undertaken. Cardiac surgery affords a unique opportunity to examine Swan-Ganz catheters *in situ* when the right atrium is opened to establish cardiopulmonary bypass. This report relates our observations of thrombus formation on Swan-Ganz catheters placed immediately prior to induction of anesthesia and examined at operation.

METHODS

Swan-Ganz catheters were consecutively placed and examined in ten patients undergoing cardiac surgery.

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The catheters were inserted immediately prior to induction of anesthesia and inspected at the time of cardiopulmonary bypass. The catheters were placed percutaneously via the internal jugular vein. After intravenous cannulation,[¶] a flexible steel guide wire** was inserted through the cannula, the cannula removed and an obturator and introducer†† were threaded over the guide wire into the internal jugular vein. Upon removal of the guide wire and obturator, the introducer was flushed with 10 ml heparinized saline solution (1,000 units of heparin in 500 ml saline solution) and a 7F Swan-Ganz thermodilution pulmonary-artery catheter,‡‡ also flushed and filled with 5 ml heparinized saline solution, was immediately placed through the introducer. The catheter was advanced to 20 cm, the balloon inflated, and the catheter floated into the most proximally achieved wedge position in the pulmonary artery during constant electrocardiographic and artery pressure monitoring. Following establishment of the wedge position, the catheter balloon was deflated to ensure that the Swan-Ganz catheter was not in a permanent wedge position. The appearance of a phasic pulmonary artery pressure tracing after balloon deflation provided confirmation of the catheter's position. The catheter balloon was only intermittently inflated when wedge pressures were recorded. Prior to induction of anesthesia, a hemodynamic profile that included heart rate

¶ Argyle Medicut cannula, Sherwood Medical Industries, St. Louis, Missouri.

** 0.032" flexible guide wire (6 inch), Universal Medical Instrument Corp., Ballston Spa, New York.

†† #8F Percutaneous catheter introducer, Universal Medical Instrument Corp., Ballston Spa, New York.

‡‡ Swan-Ganz flow-directed triple-lumen thermodilution catheter 93A-118-7F, Edwards Laboratories, Santa Ana, California.

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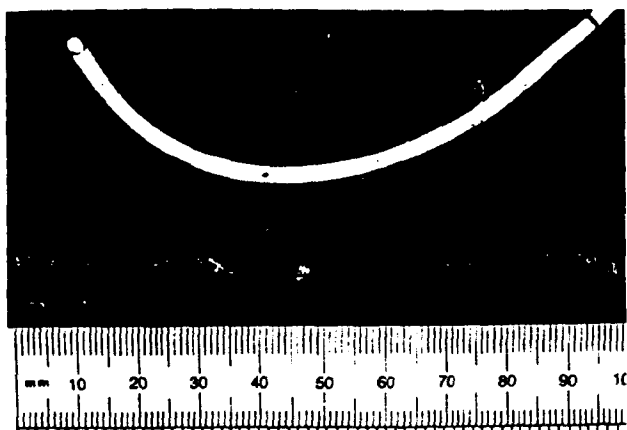


FIG. 1. Thrombus removed from a Swan-Ganz catheter during cardiopulmonary bypass. Thrombus encapsulated the catheter surface extending from the tip retrograde along the shaft.

and rhythm, systemic arterial pressure, pulmonary arterial wedge pressure, and cardiac index was obtained. The pressures were measured by transducers; cardiac outputs were determined by thermal dilution technique, and all values recorded on a thermal tip chart recorder.

Anesthesia was induced with combinations of morphine sulfate (0.5–1.5 mg/kg), diazepam (5–20 mg), and nitrous oxide (50–70 per cent). Muscle relaxation was facilitated with *d*-tubocurarine (2 mg/kg) and respiration controlled to maintain PCO_2 35–40 torr.

The chest was opened through a median sternotomy and heparin (90 mg/m²) administered to all patients 15 minutes prior to bypass. Atriotomy allowed temporary displacement of the Swan-Ganz catheter from the pulmonary artery and right ventricle, and inspection from the tip retrograde to the level of the right atrium.

RESULTS

Ten Swan-Ganz catheters were consecutively examined in seven men and three women at the time of cardiopulmonary bypass. Nine patients were to undergo coronary-artery surgery and one patient was to have both aortic and mitral valves replaced. The hemodynamic profile of the patients is shown in table 1. Five of the patients had cardiac indices below 2.5 l/min/m², but the remaining five had an average cardiac index of 3.10 l/min/m². Two patients were in atrial fibrillation and one had an elevated wedge pressure (25 torr). No patient was hypotensive, and all other hemodynamic variables were within normal limits. Every patient had a normal pre-operative coagulation screen, consisting of prothrombin time, activated partial thromboplastin time, and platelet count.

The mean time from introduction of the catheter to final positioning was less than 2 min. The catheters were inspected 104 ± 6 (SE) min following insertion (table 2).

Thrombus was found on the surfaces of all catheters examined at surgery. The thrombi encapsulated the catheters, extending from the tip along the shaft (fig. 1). Thrombi removed from the catheters at operation had a mean length of 7.8 ± 1.2 (SE) cm and a mean weight of 222 ± 46.8 mg (table 2). The largest weighed 570 mg. Histologic examination of all removed thrombi demonstrated recent thrombus formation with lysis of erythrocytes, layering of leukocytes (forming lines of Zahn) and fibrin deposition. There was no statistical correlation between thrombus size and the hemodynamic status of the patient, the duration of catheter insertion, or the time to catheter inspection.

DISCUSSION

That thrombus formation occurs when any intravascular catheter is placed is not new information. Thrombi have been found on both indwelling arterial and central venous catheters.^{5–7} Massive thrombus formation secondary to Swan-Ganz catheterization was found post mortem in a patient who had had a catheter in place for a prolonged period before dying.⁴ In our series, however, the Swan-Ganz catheters were inserted one to two hours prior to inspection, yet substantial clots were seen along the catheter in all instances.

Factors that may contribute to thrombus formation on Swan-Ganz catheters must be considered. As part of

TABLE 1. Hemodynamic Profile of Ten Patients Undergoing Cardiac Surgery in Whom Swan-Ganz Catheters Were Placed Prior to Anesthetic Induction

	Age (Years)	Heart Rate (Beats/Min)	Mean Systemic Arterial Pressure (torr)	Cardiac Index (l/min/m ²)	Pulmonary Arterial Wedge Pressure (torr)	Central Venous Pressure (torr)
Mean	61	64	84	2.5	7.4	3.2
SE	± 1.7	± 5	± 4	± 0.3	± 2.4	± 0.9
Range	53–70	44–102	70–115	1.79–2.91	0–25	0–7

TABLE 2. Details of Catheter Insertion and Thrombus Formation for Swan-Ganz Catheters Placed Prior to Anesthetic Induction in Ten Patients Undergoing Cardiac Surgery

	Insertion Time (Min)	Time from Insertion to Inspection (Min)	Thrombus Length (cm)	Thrombus Weight (mg)
Mean	1.9	104	7.8	222
SE	$\pm .15$	± 6	± 1.2	± 46.8
Range	0.9–2.7	60–130	3.0–17.0	55–570

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the preoperative evaluation, every patient had a coagulation screen, which was normal in each case. The introducers and catheters were flushed and filled with heparinized saline solution prior to placement in the internal jugular vein. All catheters were rapidly "floated" into the pulmonary artery by the flow-directed technique, and no catheter was left in a permanent wedge position. Although catheters were not all placed with the same rapidity, thrombi were found at operation when the total placement time was less than a minute. The largest thrombus was seen in a patient who was in atrial fibrillation with evidence of congestive heart failure. Yet the second largest thrombus was found in a patient with no evidence of a low-output state. It may be that a low-flow state enhances thrombus accumulation, but this study did not yield evidence to support such a correlation. In any event, patients with impaired hemodynamics are the patients who most need Swan-Ganz catheters for management.

Sawyer *et al.*⁹ have evaluated the thrombogenic characteristics of commercially available catheters and have found them all to induce thrombus formation within hours of implantation in the central venous circulations of dogs and man. The Swan-Ganz catheter was not evaluated by Sawyer *et al.*, but is constructed of polyvinylchloride,^{§§} which does initiate a thrombogenic response.

Heparin in low doses (40 units/kg) has been administered systemically to help prevent thromboembolic complications during angiography.⁹ However, our preliminary studies have demonstrated that preinsertion administration of such low-dose heparin to patients prior to Swan-Ganz catheterization does not prevent thrombus formation on these devices, although thrombus size may be reduced.

Conclusions drawn from this study are: 1) The thermodilution flow-directed Swan-Ganz catheter induces thrombus formation in the central circulation of a patient with either normal or impaired cardiovascular hemodynamics. 2) Thrombus formation probably begins at the time of insertion and can be demonstrated an hour following placement. 3) Thrombus formation occurs despite the precautions of filling the introducer and catheter with heparinized saline solution before introduction, rapid placement of the catheter in the pulmonary artery, and not allowing the device to assume a permanent wedge position.

Despite these observations, no evidence of massive pulmonary embolism (symptomatic or radiologic) has been seen in any of our patients, although several

hundred Swan-Ganz catheters have been inserted with the same technique. It is probable that the thrombi formed did release emboli, but signs and symptoms of small emboli may be clinically inapparent in the postoperative period following cardiac surgery.

It is not the intent of this report to dissuade physicians from placing Swan-Ganz catheters in patients who may benefit from the information provided. In any medical setting, where the management of hemodynamic dysfunction requires intense monitoring, the cost-benefit ratio seems to favor the use of Swan-Ganz catheters. It is the intent of this report, however, to call attention to the potential thrombogenicity of these devices. If other investigators confirm our consistent finding of thrombus adherent to all Swan-Ganz catheters following placement, it may be helpful to treat the catheter surface chemically in order to render it less thrombogenic.^{10,11} However, the effects of such treatment on the structural material may affect the flexibility of the device, altering the physician's ability to position catheters rapidly in the pulmonary artery.^{¶¶}

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