

Right-sided endocardial lesions and flow-directed pulmonary artery catheters¹

Richard C. Becker, M.D.²
Raquel G. Martin, D.O.
Donald A. Underwood, M.D.

Sixty-five consecutive patients were examined at autopsy for the presence of right-sided endocardial lesions. Twenty-eight patients (43%) had undergone flow-directed pulmonary artery catheterization during their final hospital stay; of these, 10 (36%) had hemorrhagic and/or thrombotic lesions involving the right side of the heart and the pulmonary outflow tract. Lesions were rarely observed in patients who had not had indwelling catheters ($P < 0.025$). There were no cases of infective endocarditis. Of the 16 right-sided endocardial lesions identified, seven (44%) involved the right atrium, one (6%) the tricuspid valve, six (38%) the right ventricle, and two (12%) the pulmonic valve. Six patients (60%) had multiple lesions. A bacteremia/fungemia developed in seven patients (25%) with flow-directed pulmonary artery catheters and correlated with the duration of insertion ($P < .005$). Fatal *Staphylococcus aureus* septicemia with left ventricular abscess formation occurred in two patients. The authors conclude that endocardial trauma to the right side of the heart is not infrequent in patients with flow-directed pulmonary artery catheters. Systemic infection is also seen in this group, and, although secondary infection of the endocardium is uncommon, its potential occurrence must not be overlooked. The indication(s) for insertion of a pulmonary artery catheter must be carefully considered in each individual case.

Index terms: Catheters, indwelling • Endocarditis • Pulmonary artery

Cleve Clin J Med 54:384-388, Sep/Oct 1987

¹ Departments of Cardiology (R.C.B., D.A.U.) and Internal Medicine (R.G.M.), The Cleveland Clinic Foundation. Submitted for publication Dec 1986; revision accepted June 1987.

² Current address: Department of Cardiovascular Medicine, University of Massachusetts Medical Center, Worcester, MA.

0891-1150/87/05/0384/05/\$2.25/0

Copyright © 1987, The Cleveland Clinic Foundation

The flow-directed, balloon-tipped pulmonary artery (Swan-Ganz) catheter is a common and, at times, vital component of both diagnostic and therapeutic critical care. Since its introduction for clinical use in 1970,¹ the Swan-Ganz catheter has gained widespread popularity and is

used routinely to monitor critically ill patients. Although it is usually well tolerated, a number of complications have been observed.²⁻²⁷ The potential for catheter-induced endocardial injury was recognized by early investigators,¹ and has been the focus of subsequent reports.²⁸⁻³⁶

Swan-Ganz catheters are frequently used in The Cleveland Clinic Foundation's medical and surgical intensive care units. Therefore, we sought to define the incidence, anatomic site, morphologic characteristics, and overall clinical relevance of Swan-Ganz catheter-related endocardial injury.

Methods

During the period from January 1, 1986 through April 1, 1986, hearts obtained from 65 consecutive autopsies at The Cleveland Clinic Foundation were examined by members of the Department of Pathology. The presence of endocardial lesions was determined, including right atrial hemorrhage/thrombosis, tricuspid valve hemorrhage/thrombosis, right ventricular hemorrhage/thrombosis, and pulmonic valve hemorrhage/thrombosis. Documented areas of thrombosis were sectioned and examined histologically for evidence of infective endocarditis. The diagnosis required identification of organisms in an area of inflammation. Positive post-mortem blood cultures and/or growth from the isolated region of inflammation were not required. Cardiac lesions including thrombosis, hemorrhage, and/or endocarditis involving left-sided heart structures were also noted.

Clinical records for each patient entered into the study were obtained and critically reviewed by two coauthors. The following information was recorded: age, sex, admitting diagnosis, insertion of a Swan-Ganz catheter or central venous catheter within 1 month before death, duration of catheter placement, documented bacteremia/fungemia or other blood-borne infection while the catheter was in place, antemortem diagnosis of infective endocarditis, and cardiac events during the final hospitalization. The cause of death was established following review of final pathologic reports.

Results

Patient characteristics

Specimens obtained from the hearts of 65 consecutive patients coming to autopsy at The Cleveland Clinic Foundation form the basis of this study. There were 44 men, and 21 women, with

an average age of 49.2 years (range 4 months–89 years). Admitting diagnoses included: accelerated hypertension, unstable angina pectoris, acute myocardial infarction, congestive heart failure, orthotopic heart transplantation, complex congenital heart disease, acquired immunodeficiency syndrome, sepsis, disseminated neoplasm, pulmonary embolism, chronic lung disease, primary pulmonary hypertension, subarachnoid hemorrhage, mesenteric ischemia, and Addisonian crisis. There were no patients with an admitting diagnosis of infective endocarditis.

Pathologic causes of death included: cardiogenic shock, cardiac tamponade, septic shock, clostridial sepsis with massive intravascular hemolysis, necrotizing pneumonia, pulmonary Kaposi's sarcoma, pulmonary embolism, acute graft versus host disease, acquired immunodeficiency syndrome with opportunistic infection, disseminated neoplasm, and massive gastrointestinal bleeding. There were no cases in which infective endocarditis was considered the cause of death.

Infection

Of the 65 patients studied, 28 (43%) had flow-directed pulmonary artery (Swan-Ganz) catheters inserted during their final hospitalization. Catheters were in place an average of 9.9 days (range 6 hours–68 days) before death. Seven of 28 patients (25%) had bacteremia and/or fungemia while the catheter was in place. Organisms isolated included: *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Streptococcus faecalis*, *Escherichia coli*, *Candida albicans*, and *Aspergillus fumigatus*. Patients in whom a blood-borne infection developed had a catheter in place for an average of 17.2 days. The incidence of infection directly correlated with increasing length of catheter insertion ($P < .005$). A blood-borne infection developed in 11 of 37 patients (29%) without Swan-Ganz catheters. Four patients suffered from acquired immunodeficiency syndrome; other diseases within the group included non-Hodgkins lymphoma (1 patient), chronic myelogenous leukemia in blast crisis (1 patient), renal transplant and immunosuppressive therapy (1 patient), and dermatopolymyositis during immunosuppressive therapy (1 patient). Therefore, eight of 11 patients (73%) were severely immunocompromised; in addition, six patients (55%) had central venous pressure catheters in place at the time of death.

Autopsy findings

The cardiac lesions identified at autopsy in patients with Swan-Ganz catheters are outlined

in *Table 1*. Ten patients (36%) had lesions involving the right side of the heart and pulmonary outflow tract. Six (60%) had multiple lesions, including two at three locations and four at two locations. Seven (44%) of the 16 lesions identified involved the right atrium, one (6%) the tricuspid valve, six (38%) the right ventricle, and two (12%) the pulmonic valve. None of the lesions were classified as infectious based on established criteria. There was a trend toward an increased incidence of endocardial lesions with increasing catheter placement time (*Table 2*); however, it failed to reach statistical significance. There were two patients with Swan-Ganz catheters in whom *Staphylococcus aureus* septicemia and left ventricular myocardial abscesses developed and contributed directly to their deaths.

Discussion

Flow-directed pulmonary artery (Swan-Ganz) catheters have become an integral part of the therapeutic and diagnostic regimen used in the care of critically ill patients. Indications for their use include: cardiogenic shock,³⁷ septic shock,^{38,39} decompensated chronic obstructive lung disease with cardiac dysfunction,⁴⁰ acute drug overdose,⁴¹ adult respiratory distress syndrome (ARDS),⁴²⁻⁴⁴ and perioperative hemodynamic monitoring of high-cardiac-risk surgical patients.^{45,46}

The potential for catheter-related endocardial damage within the right side of the heart and pulmonary outflow tract is readily apparent. Early studies concerning the pathogenesis of infective endocarditis performed by Garrison and Freedman⁴⁷ used polyethylene catheters to induce the formation of sterile platelet-fibrin thrombi in the hearts of rabbits. Subsequent contamination of the catheters with *Staphylococcus aureus* resulted in the production of infective endocarditis at the site(s) of previous endocardial damage.

Durack and Beeson⁴⁸ inserted polyethylene catheters into the hearts of rabbits via the external jugular vein and sutured them in place for 7-10 days. The animals were then killed and their hearts carefully examined. Sterile vegetations involving the right atrium, tricuspid valve, and/or a right ventricle were observed in each animal. The procedure was repeated in a second group of rabbits, who, in addition, received an intravenous injection of *Streptococcus viridans*. Infective lesions were observed in areas of catheter-induced endocardial injury.

Table 1. Endocardial lesions in patients with flow-directed pulmonary artery catheters

Location	Hemorrhage	Sterile Thrombus	Infective Endocarditis
Right atrium	3	4	0
Tricuspid valve	0	1	0
Right ventricle	4	2	0
Pulmonic valve	2	0	0
Multiple:			
Right atrial hemorrhage and thrombus: 3 patients			
Right atrial hemorrhage and thrombus, plus tricuspid valve thrombus: 1 patient			
Right ventricular hemorrhage and thrombus: 1 patient			
Right atrial hemorrhage and thrombus, plus right ventricular hemorrhage: 1 patient			

Table 2. Right-sided heart lesions and duration of catheter placement

No. Days Catheter in Place before Death	No. Patients	Lesions	
		No.	%
0-7	16	3	19
8-14	6	2	33
15-21	3	3	100
>21	3	2	67

Many critically ill patients with hemodynamic instability have Swan-Ganz catheters in place for an extended period. A major concern in this setting is the development of catheter-induced endocardial disruption,⁴⁹ which, in the presence of bacteremia, may become secondarily infected. Greene and Cumming²⁹ reviewed the clinical records from 294 consecutive autopsies and found that 24 of the patients had had a Swan-Ganz catheter inserted during their final hospitalization. Eight (33%) of these patients were found to have right-sided endocardial lesions at postmortem examination.

Pace and Horton³¹ in a study of 413 autopsies found a 3.4% incidence of aseptic (bland) endocarditis in patients with Swan-Ganz catheters. Green et al³⁰ reported a case of fatal *Staphylococcus aureus* endocarditis involving the right atrium and tricuspid valve along the path of a Swan-Ganz catheter.

The postmortem finding of acute right-sided infective endocarditis in a burn patient monitored with a Swan-Ganz catheter prompted Ehrie et al³² to examine the hearts of burn patients coming to autopsy in whom a Swan-Ganz catheter was in place at the time of death. Right-sided endocardial lesions were observed in the majority of cases, many of them secondarily infected with *Staphylococcus aureus*.

In a prospective study of 81 patients in whom Swan-Ganz catheters were inserted for hemodynamic monitoring in the intensive care setting, Elliot et al³³ found a 21% incidence of aseptic right-sided endocarditis. Ford and Manley³⁴ identified endocardial lesions in 75% of patients with Swan-Ganz catheters. Lange et al³⁵ observed a 31% incidence of tricuspid valve hemorrhage and an 8% incidence of aseptic thrombosis.

In a recent study by Rowley et al³⁶ of 142 consecutive autopsies, 55 patients (38%) had Swan-Ganz catheters inserted within a month of death.³⁶ Of these, 29 (53%) had one or more right-sided cardiac lesions, including four (7%) with infective endocarditis.

The Cleveland Clinic Foundation is a tertiary-care facility, and, like other major medical centers, cares for a large number of patients in unstable condition. Therefore, information concerning cardiovascular hemodynamics is frequently sought in diagnostic and therapeutic decision making. Almost 50% of the patients included in our prospective study had Swan-Ganz catheters inserted during their final hospital stay. As is evident from the inclusion criteria for this study, all patients were critically ill, and the majority spent time in one or more intensive care units before death. Endocardial lesions involving the right side of the heart and pulmonary outflow tract were documented at necropsy in more than one third of patients with Swan-Ganz catheters. Multiple lesions were observed in almost two thirds. An obvious trend favoring the development of endocardial lesions with increasing catheter placement time was seen; however, this was not statistically significant. Although three patients without Swan-Ganz catheters were found to have right-sided lesions, it was of interest that each had right atrial endocardial thrombi and triple-lumen CVP catheters in place at the time of death.

Infective endocarditis was not observed, despite a high incidence of endocardial lesions. There are a number of possible explanations. The size of our study population was small, thereby limiting our ability to observe its occurrence. Secondly, of all endocardial lesions, approximately one-third were hemorrhagic, and therefore may have failed to provide an adequate substrate for bacterial or fungal adherence. Thirdly, many of the lesions we observed involved the atrial and/or ventricular endocardium, which, for hemodynamic reasons (most notably, the lack of a direct venturi effect), may

provide a less than ideal environment for the development of infective endocarditis.

The incidence of blood-borne infection was high in both groups. Patients with Swan-Ganz catheters mainly had cardiogenic shock secondary to acute myocardial infarction, cardiomyopathy, or cardiothoracic surgery. In contrast, the group of patients without Swan-Ganz catheters consisted largely of immunocompromised hosts. Exclusion of these "high risk" individuals from the second group yielded a significant difference between the study groups. Although the incidence of infection was shown to correlate with the length of catheter placement, we cannot exclude the length of intensive care unit stay as an independent or additive risk factor.

In conclusion, flow-directed pulmonary artery catheters are frequently used in acute care. Patients with catheters are at risk for endocardial trauma involving the right side of the heart and pulmonary outflow tract. The immediate and long-term clinical manifestations remain to be fully elucidated. Prolonged intravascular placement increases the risk of serious systemic infection.

Acknowledgment

We wish to thank Chuck Biscotti, M.D., and the Department of Pathology for their assistance in reviewing the pathologic specimens.

References

1. Swan HJC, Ganz W, Forrester J, Marcus H, Diamond G, Chonette D. Catheterization of the heart in man with use of a flow-directed balloon-tipped catheter. *N Engl J Med* 1970; **283**:447-451.
2. Wiedemann HP, Matthay MA, Matthay RA. Cardiovascular-pulmonary monitoring in the intensive care unit (part 2). *Chest* 1984; **85**:656-668.
3. Bernard RW, Stahl WM. Subclavian vein catheterizations: A prospective study. I. Non-infectious complications. *Ann Surg* 1971; **173**:184-190.
4. Lipp H, O'Donoghue K, Resnekov L. Intracardiac knotting of a flow-directed balloon catheter. *N Engl J Med* 1971; **284**:220.
5. Feliciano DV, Mattox KL, Graham JM, Beall AC Jr, Jordon GL Jr. Major complications of percutaneous subclavian vein catheters. *Am J Surg* 1979; **138**:869-874.
6. Chastre J, Cornud F, Bouchama A, Viau F, Benacerraf R, Gibert C. Thrombosis as a complication of pulmonary-artery catheterization via the internal jugular vein. *N Engl J Med* 1982; **306**:278-281.
7. Yorra FH, Oblath R, Jaffe H, Simmons DH, Levy SE. Massive thrombosis associated with use of the Swan-Ganz catheter. *Chest* 1974; **65**:682-684.
8. Dye LE, Segall PH, Russell RO, Mantle JA, Rogers WJ, Rackley CE. Deep venous thrombosis of the upper extremity associated with use of the Swan-Ganz catheter. *Chest* 1978; **73**:673-675.

9. Sprung CL, Jacobs LJ, Caralis PV, Karpf M. Ventricular arrhythmias during Swan-Ganz catheterization of the critically ill. *Chest* 1981; **79**:413-415.
10. Sprung CL, Pozen RG, Rozanski JJ, Pinero JR, Eisler BR, Castellanos A. Advanced ventricular arrhythmias during bedside pulmonary artery catheterization. *Am J Med* 1982; **72**:203-208.
11. Boyd KD, Thomas SJ, Gold J, Boyd AD. A prospective study of complications of pulmonary artery catheterizations in 500 consecutive patients. *Chest* 1983; **84**:245-249.
12. Abernathy WS. Complete heart block caused by the Swan-Ganz catheter. *Chest* 1974; **65**:349.
13. Geha DG, Davis NJ, Lappas DG. Persistent atrial arrhythmias associated with placement of a Swan-Ganz catheter. *Anesthesiology* 1973; **39**:651-653.
14. Prachar H, Dittel M, Jobst C, et al. Bacterial contamination of pulmonary artery catheters. *Intensive Care Med* 1978; **4**:79-82.
15. Michel L, Marsh HM, McMichan JC, Southorn PA, Brewer NS. Infection of pulmonary artery catheters in critically ill patients. *JAMA* 1981; **245**:1032-1036.
16. Chun GMH, Ellestad MH. Perforation of the pulmonary artery by a Swan-Ganz catheter. *N Engl J Med* 1971; **284**:1041-1042.
17. Foote GA, Schabel SI, Hodges M. Pulmonary complications of the flow-directed balloon-tipped catheter. *N Engl J Med* 1974; **290**:927-931.
18. Lemen R, Jones JG, Cowan G. A mechanism of pulmonary artery perforation by Swan-Ganz catheters. *N Engl J Med* 1975; **292**:211-212.
19. Pape LA, Haffajee CI, Markis JE, et al. Fatal pulmonary hemorrhage after use of the flow-directed balloon-tipped catheter. *Ann Intern Med* 1979; **90**:344-347.
20. Barash PG, Nardi D, Hammond G, et al. Catheter-induced pulmonary artery perforation. *J Thorac Cardiovasc Surg* 1981; **82**:5-12.
21. Scott ML, Webre DR, Arens JF, Ochsner JL. Clinical application of a flow-directed balloon-tipped cardiac catheter. *Am Surg* 1972; **38**:690-696.
22. Herbst CA Jr. Indications, management and complications of percutaneous subclavian catheters. *Arch Surg* 1978; **113**:1421-1425.
23. Mattox KL, Fisher RG. Persistent hemothorax secondary to malposition of a subclavian venous catheter. *J Trauma* 1977; **17**:387-388.
24. Adar R, Mozes M. Hydromediastinum. *JAMA* 1970; **214**:372.
25. Marlon AM, Cohn LH, Fogarty TJ, Harrison DC. Retrieval of catheter fragments. Report of two cases. *Calif Med* 1971; **115**:61-63.
26. Peters JL, Armstrong R. Air embolism occurring as a complication of central venous catheterization. *Ann Surg* 1978; **187**:375.
27. Flanagan JP, Gradisar IA, Gross RJ, Kelly TR. Air embolus—a lethal complication of subclavian venipuncture. *N Engl J Med* 1969; **281**:488-489.
28. Becker AE, Becker MJ, Martin FH, Edwards JE. Bland thrombosis and infection in relation to intracardiac catheters. *Circulation* 1972; **46**:200-203.
29. Greene JF, Cummings KC. Aseptic thrombotic endocardial vegetations. *JAMA* 1973; **225**:1525-1526.
30. Greene JF Jr, Fitzwater JE, Clemmer TP. Septic endocarditis and indwelling pulmonary artery catheters. *JAMA* 1975; **233**:891-892.
31. Pace NL, Horton W. Indwelling pulmonary artery catheters. Their relationship to aseptic thrombotic endocardial vegetations. *JAMA* 1975; **233**:893-894.
32. Ehrie M, Morgan AP, Moore FP, O'Connor NE. Endocarditis with the indwelling balloon-tipped pulmonary artery catheter in burn patients. *J Trauma* 1978; **18**:664-666.
33. Elliott CG, Zimmerman GA, Clemmer TP. Complications of pulmonary artery catheterization in the care of critically ill patients. *Chest* 1979; **76**:647-652.
34. Ford SE, Manley PN. Indwelling cardiac catheters: An autopsy study of associated endocardial lesions. *Arch Pathol Lab Med* 1982; **106**:314-317.
35. Lange HW, Galliani CA, Edwards JE. Local complications associated with indwelling Swan-Ganz catheters. *Am J Cardiol* 1983; **52**:1108-1111.
36. Rowley KM, Clubb KS, Smith GJW, Cabin HS. Right-sided infective endocarditis as a consequence of flow-directed pulmonary-artery catheterization. *N Engl J Med* 1984; **311**:1152-1156.
37. Shaver JA. Hemodynamic monitoring in the critically ill patient. *N Engl J Med* 1983; **308**:277-279.
38. Connors AF, McCaffree DR, Gray BA. Evaluation of right-heart catheterization in the critically ill patient without acute myocardial infarction. *N Engl J Med* 1983; **308**:263-267.
39. Hess ML, Hastillo A, Greenfield LJ. Spectrum of cardiovascular function during gram-negative sepsis. *Prog Cardiovasc Dis* 1981; **23**:279-298.
40. Mathay MA, Hopewell PC. The adult respiratory distress syndrome: Pathogenesis and treatment. [In] Simmons DH, ed. *Current Pulmonology*. Vol 3. New York, John Wiley and Sons, 1981, pp 1-29.
41. Goodman JM, Bischel MD, Wagers PW, Barbour BH. Barbiturate intoxication: morbidity and mortality. *West J Med* 1976; **124**:179-186.
42. Unger KM, Shibel EM, Moser KM. Detection of left ventricular failure in patients with adult respiratory distress syndrome. *Chest* 1975; **67**:8-13.
43. Zimmerman GA, Morris AH, Cengiz M. Cardiovascular alterations in the adult respiratory distress syndrome. *Am J Med* 1982; **73**:25-34.
44. Jardin F, Farcot JC, Boisante L, Curien N, Margairaz A, Bourdarias JP. Influence of positive end-expiratory pressure on left ventricular performance. *N Engl J Med* 1981; **304**:387-392.
45. Goldman L. Cardiac risks and complications of noncardiac surgery. *Ann Intern Med* 1983; **98**:504-513.
46. Rao TLK, El-Etr AA. Myocardial reinfarction following anesthesia in patients with recent infarction. *Anesth Analg* 1981; **60**:271-272.
47. Garrison PK, Freedman LR. Experimental endocarditis. I. Staphylococcal endocarditis in rabbits resulting from placement of a polyethylene catheter in the right side of the heart. *Yale J Biol Med* 1970; **42**:394-410.
48. Durack DT, Beeson PB. Experimental bacterial endocarditis. II. Survival of bacteria in endocardial vegetations. *Br J Exp Path* 1972; **53**:50-53.
49. Connors AF, Castele RJ, Farhat NZ, Tomaszewski JF. Complications of right heart catheterization. A prospective autopsy study. *Chest* 1985; **88**:567-572.

Richard C. Becker, M.D.
 Department of Cardiovascular Medicine
 University of Massachusetts Medical Center
 55 Lake Avenue North
 Worcester, MA 01605