

This Week's Citation Classic

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Swan H J C, 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.* 283:447-51, 1970.
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A self-guiding flow-directed catheter was developed which permitted catheterization of the right side of the heart and pulmonary artery without the use of fluoroscopy and with minimal complications. The addition of multiple sensors has allowed for the quantitative measurement of cardiac function. This development has permitted the application of quantitative cardiac catheterization procedures to the management of the critically ill. [The *SCI*³ indicates that this paper has been cited over 610 times since 1970.]

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"In the two decades following World War II, the newly developed technique of cardiac catheterization allowed application of basic physiologic principles to clinical diagnosis and made the development of a cardiac surgical treatment of congenital and valvar heart disease possible. My training in the early-1950s at the Mayo Clinic with Earl H. Wood—a true pioneer in the development of cardiac catheterization—established a strong basis for my own career in investigative cardiology. In 1965, I left the Mayo Clinic, a major referral center, to direct cardiology at Cedars of Lebanon Hospital, a community institution. I was amazed by the paucity of knowledge of the hemodynamics of ischemic heart disease and, in particular, of acute myocardial infarction, which then carried a mortality of 20-25 percent. Empirical approaches to treatment appeared to be remarkably ineffective, if not positively harmful. It appeared essential to obtain hemodynamic measurements at the bedside if these clinical syndromes were to be understood. However, my interactions with Wood and John Kirklin convinced me that standard cardiac catheterization techniques could not be applied in the usual clinical setting.

Therefore, the techniques would have to be modified.

"In the fall of 1966, I was watching the sailboats in Santa Monica Bay and conceived the idea that a sail or parachute combined with a highly flexible catheter would be the ideal mechanism to flow-guide a catheter into the central circulation. In discussing the potential fabrication of such a device, the experience of Edwards Labs with the Fogarty embolectomy catheter provided a solution, although, in retrospect, a parachute type device could have had important advantages. When the first batch of catheters actually arrived, I brought them over to my animal laboratory, where my most recent recruit to the then infant division of cardiology, William Ganz, was finishing an experiment on the measurement of ventricular volume, using the dilution principle. I placed the first of the flotation catheters in the right atrium of a dog and inflated the guidance balloon, whereupon the catheter and the balloon immediately disappeared from the field of view. After recognizing that the balloon had not burst, we were able to demonstrate consistent passage to the pulmonary artery within one to two beats after inflation of the guidance balloon. The device worked. The point was proven.

"From there, we took it to the catheterization laboratory and then to the CCU, where the contributions of many, including a then resident in medicine, George Diamond, allowed us to report on the first 100 bedside catheterizations in August 1970. The addition of multiple pressure ports, a thermistor for measurement of cardiac output by the thermodilution principle, and electrodes for atrial and ventricular sensing and pacing represented a natural series of additional applications.

"In 1970, my colleagues and I developed the balloon flotation catheter to investigate the clinical syndromes of ischemic heart disease. The broad application in the field of hemodynamic monitoring and the management of hundreds of thousands or, now, millions of critically ill patients was a secondary objective. The frequency of citation is related to the wide acceptance of a practical technique which permits the measurement of basic physiological data in a clinical setting. Recent work in this field has been published by me and N.L. Pace."^{1,2}

1. Swan H J C. The role of hemodynamic monitoring in the management of the critically ill.

Crit. Care Med. 3:83-9, 1975.

2. Pace N L. A critique of flow-directed pulmonary arterial catheterization. *Anesthesiology* 47:455-65, 1977.