Supporting technologies — pulmonary artery catheter

© RWD Nickalls,
Department of Anaesthesia,
Nottingham University Hospitals,
City Hospital Campus,
Nottingham, UK.

dick@nickalls.org
www.nickalls.org

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Chapter 9

Supporting technologies

9.7 Pulmonary artery catheter[1]

9.7.1 History

Michael Lategola and Hermann Rahn

Balloon-flotation pulmonary artery catheters were first used by the American physiologists Lategola and Rahn for pressure recording, blood sampling and vessel occlusion in experiments with dogs (Lategola and Rahn 1953). Since their balloon covered the distal tip they were only able to measure pressures proximal to the occluded vessel. Thermodilution cardiac output was first described in animals the following year (Fegler 1954).

Ronald Bradley

The first person to describe the use of a pulmonary-artery catheter in man was Ronald Bradley, a physician at St. Thomas' Hospital, London (Bradley 1964). He used an extremely narrow catheter (0·63 mm diam) having no balloon, to determine pulmonary artery pressures and waveforms, and later went on to determine thermodilution cardiac output in man using a thermistor-tipped catheter (Branthwaite and Bradley 1968), and suggested the use of PA-diastolic pressure as an index of mean left-atrial pressure (Jenkins, Bradley and Branthwaite 1970). Bradley also wrote an excellent book on the physiology of heart failure (Bradley 1977).

Harold Swan and William Ganz

Bradley's catheters had no balloon and were extremely difficult to position, and so the technique remained clinically impractical until Swan *et al.* (1970) developed the modern balloon-flotation catheter. Since Swan wished to determine left atrial pressure he arranged that pressures could be measured distal to the balloon. Oddly enough Swan fails to credit Bradley and Branthwaite (1968) with the thermodilution technique in man—instead he credits this to Ganz (Swan 1991).

Swan (1922–2005) graduated from St. Thomas' Hospital Medical School, London, in 1945, and went on to become the Director of the Division of Cardiology at Cedars-Sinai Medical Center in Los Angeles, California. He has set on record the key early ideas and development of the flow-directed balloon-tipped catheter (Swan 1991; 2005) as follows.

> In 1950 as a lecturer in physiology at St. Thomas' Hospital of the University of London, I had come to know a young medical student, Ronald Bradley, who was completing a bachelor's degree in physiology. I had noted a paper published in

[1] `http://www.nickalls.org/dick/papers/thoracic/hand-swanganz.pdf`

> the *Lancet* (Bradley 1964), in which Bradley had claimed that it was possible to catheterize the pulmonary artery for measurement of pressures using an extremely fine Portex tubing ... and I therefore attempted to place it. ... In our hands this approach had little success ...
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> In the fall of 1967, I had the occasion to take my (then young) children to the beach in Santa Monica. On the previous evening, I had spent a frustrating hour with an extraordinary pleasant but elderly lady in an unsuccessful attempt to place one of Bradley's catheters. It was a hot Saturday and the sailboats on the water were becalmed. However, approximately half a mile offshore, I noted a boat with a large spinnaker well set and moving through the water at a reasonable velocity. The idea then came to to put a sail or a parachute on the end of a highly flexible catheter and thereby increase the frequency of passage of the device into the pulmonary artery. I felt convinced that this approach would allow for the rapid and safe placement of a flotation catheter without the use of fluroscopy and would solve the problem of arrhythmias.
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> ... I had been appointed a consultant to the Edwards Laboratories, then a small manufacturing company whose products included the Starr-Edwards heart valve and the Fogarty embolectomy catheter. ... I brought my concept to the attention of Mr David Chonette and Mr Will Perrie. They had the facilities for extrusion of catheters of different sizes ... To test the concept, however, they had the ability to manufacture balloons (as for the Fogarty catheter) and suggested that, as a first effort, a double-lumen extruded catheter should be manufactured with one lumen available to inflate a flotation balloon. This proved to be acceptable and they agreed to fabricate five such catheters.
>
> ... As luck would have it, when the Edwards Laboratories delivered their first catheters, Willie [Ganz] was finishing an experiment with his animal in good condition. I brought the prize catheters to the laboratory and connected the pressure lumen to an appropriate strain gauge manometer. The catheter was then introduced via the exposed jugular vein into the right atrium and, observing with fluroscopy, the balloon was inflated. It immediately disappeared, and the technician reported no change in the recorded pressure. I immediately assumed an inadequacy of balloon tensile strength and mentally blamed faulty construction by the Edwards Laboratory. However, repeat visualization revealed that the catheter had migrated in one heartbeat through the right heart and was recording the wedge pressure in a distal pulmonary artery. Deflation of the balloon allowed its prompt return to the superior vena cava. ... Willie Ganz accepted the responsibility of clearing up the many technical details, but the concept was proved and the new device was born.
>
> ... A triple-lumen catheter allowed measurement of simultaneous pressures in the wedge position (the pulmonary occluded pressure) and in the right atrium. With a slight modification, a thermistor was inserted close to the guiding balloon and the thermodilution technique of Willie Ganz (Ganz *et al.* 1971) for determination of cardiac output was applied.
>
> Swan (1991)

Swan (1922–2005) died on 7th February, 2005, and his last paper (Swan 2005) appeared in the October 2005 issue of *Anesthesiology*. A photograph of Swan can be found on the *Anesthesiology* web site.[2]

- Achan V (1999). Another European view: the origin of pulmonary artery catheterization. *Critical Care Medicine*; 27, 2850–2851.
- Amin DK, Shah PK and Swan HJC (1986). The Swan-Ganz catheter: choosing and using the equipment. *Journal of Critical Illness*; 1, 34–37.

[2] http://www.anesthesiology.org; follow the 'enhancements index' link → 2005.

- Amin DK, Shah PK and Swan HJC (1986). The Swan-Ganz catheter: insertion technique. *Journal of Critical Illness*; 1, 38–45.
- Amin DK, Shah PK and Swan HJC (1986). The Swan-Ganz catheter: tips on interpreting results. *Journal of Critical Illness*; 1, 40–48.
- Amin DK, Shah PK and Swan HJC (1986). The Swan-Ganz catheter: indications for insertion. *Journal of Critical Illness*; 1, 54–61.
- Bradley RD (1964). Diagnostic right-heart catheterisation with miniature catheters in severely ill patients. *Lancet*; 2, 941–942.
- Bradley RD (1977). *Studies in acute heart failure*. (Edward Arnold Ltd., London). ISBN: 0–7131–4295–2. pp. 76.
- Branthwaite MA and Bradley RD (1968). Measurement of cardiac output by thermal dilution in man. *J. Applied Physiology*; 24, 434–438.
- Comroe JH (1977). *Retrospectroscope: insights into medical discovery*. (Von Gehr Press, Menlo Park, California, USA).
- Fegler G (1954). Measurement of cardiac output in anesthetized animals by a thermodilution method. *Quarterly Journal of Experimental Physiology*; 39, 153–164. [from: MacKenzie 2003]
- Ganz W, Donoso R, Marcus HS, Forrester JS and Swan HJC (1971). A new technique for measurement of cardiac output by thermodilution in man. *American Journal of Cardiology*; 27, 392–396.
- Jenkins BS, Bradley RD and Branthwaite MA (1970). Evaluation of pulmonary arterial end diastolic pressure as an indirect estimate of left atrial mean pressure. *Circulation*; 42, 75.
- Lategola M and Rahn H (1953). A self-guiding catheter for cardiac and pulmonary arterial catheterization and occlusion. *Proc. Soc. Exp. Biol. Med.*; 84 667–668.
- Poplausky MR, Rozenblit G, Rundback H *et al.* (2001). Swan-Ganz catheter-induced pulmonary artery pseudoaneurysm formation: three case reports and a review of the literature. *Chest*; 120, 2105–2111.
- Shaw TJI (1979). The Swan-Ganz pulmonary artery catheter: incidence of complications, with particular references to ventricular dysrhythmias, and their prevention. *Anaesthesia*; 34, 651–656. [recommends use of lignocaine 1mg/kg IV]
- Swan HJC (2005). The pulmonary artery catheter in anesthesia practice. *Anesthesiology*, 103, 890-893. [Swan's final paper—includes some interesting historical detail regarding the development of the PA catheter]
- Swan HJC (1991). Development of the pulmonary artery catheter. *Disease-a-Month*; 37 (August), 485–508 (Elsevier). [whole of this classic issue (p. 478–543) is devoted to the Swan-Ganz catheter, including a reprint of the excellent four-part series by Amin, Shah and Swan (1986) listed below. Available on-line via http://www.sciencedirect.com/ & also via the ATHENS internet database]
- Swan HJC, Ganz W, Forrester J, Marcus H, Diamond G and Chonette D (1970). Catheterization of the heart in man with use of a flow-directed balloon-tipped catheter. *New England Journal of Medicine*; 283, 447–451.

9.7.2 Decline in use

In recent years the use of pulmonary artery catheters has declined somewhat, partially owing to lack of good evidence that it improves outcome (ESCAPE committee 2005; Shah *et al.* 2005; Hall 2005), and partly owing to new non-invasive cardiac output monitoring devices (e.g., PiCCO, LiDCO, oesophageal doppler).

- ASA (2003). Practice guide-lines for pulmonary artery catheterisation: an updated report by the American Society of Anesthesiologists Task Force on pulmonary artery catheterisation. *Anesthesiology*; 99, 988–1014.
- ESCAPE committee (2005). Evaluation study of congestive heart failure and pulmonary artery catheter effectiveness: the ESCAPE trial. *JAMA*; 294, 1625–1633.
- Hall JB (2005). Searching for evidence to support pulmonary artery catheter use in critically ill patients. *JAMA*; 294, 1693–1694.
- Shah MR *et al.* (2005). Implication of the pulmonary artery catheter in critically ill patients: meta-analysis of randomized clinical trials. *JAMA*; 294, 1664–1670.