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Oesophageal Doppler cardiac output monitoring: A longstanding tool with evolving indications and applications

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Much work has been done over the years to assess cardiac output and better grasp haemodynamic profiles of patients in critical care and during major surgery. Pulmonary artery catheterization has long been considered as the standard of care, especially in critical care environments, however this dogma has been challenged over the last 10–15 years. This has led to a greater focus on alternate, lesser invasive technologies. This review focuses on the scientific and clinical outcomes basis of oesophageal Doppler monitoring. The science underpinning Doppler shift assessment of velocity stretches back over 100 years, whereas the clinical applicability, and specifically clinical outcomes improvement can be attributed to the last 20 years. Oesophageal Doppler monitoring (ODM), and its associated protocol-guided fluid administration, has been shown to reduce complications, length of stay, and overall healthcare cost when incorporated into perioperative fluid management algorithms. However, more recent advances in enhanced recovery after surgery programs have led to similar improvements, leading the clinician to consider the role of Oesophageal Doppler

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Monitor to be more focused in high-risk surgery and/or the high-risk patient.

Introduction

The history of determining blood flow and laterally cardiac output by Doppler principles stretches back to the 1950's through the work of two separate groups working in parallel across the Pacific [1]. Shigeo Satomura and colleagues at the Osaka University in Japan demonstrated potential utility in patients with atherlosclerotic disease by incrementally studying the movements of the heart, eye, peripheral blood vessels and extracranial arteries [1]. Dean Franklin working at University of Washington, Washington, USA was able to document blood flow via Doppler principles and subsequent work from this group lead to the development of the first commercially available devices supporting the emerging field of vascular surgery [1].

The first discussion of use an intra-oesophageal probe to measure blood movement in the descending thoracic aorta was by Side and Gosling who in 1971 described their development of a suitable probe [2]. This work identified the key components of the probe, separate processing, and display unit. Duck in 1974 described the use of a similar device in 15 patients [3]. His work recognised some of the issues around oesophageal air elimination to enable good signal acquisition.

Later work started to look at measurement of cardiac output (as opposed to flow) using assessment of data from suprasternal approaches [4]. However as the intra-oesphageal technologies matured, studies also started to validate this approach for the measurement cardiac output [56]. Based on this work a series of commercial available monitors were developed.

Technology

Underpinning the use of the technology is the Doppler effect named after Christian Doppler whose 1842 Hypothesis stated that the shift in frequency of a reflected wave was proportional to the velocity of the moving object. Finding initial use in astronomy it was later demonstrated to be useful for the determination of the movement of blood within the body [7]. This principle can be described mathematically by Eqs. (1) and (2).

$$f_D = f_T 2V \cos\theta \quad (1)$$

Rearranged to:

$$V = cf_D / 2f_T \cos\theta \quad (2)$$

where:

- f_D is the Doppler shift (which is measured)
- f_T is the transmitted frequency (which is fixed)
- θ is the angle of incidence (or insonation) between the path of the probe and the receiver and is assumed to be 45°. [8]
- V is the velocity of the target (which is derived)

The angle of incidence refers to the angle formed between the ultrasound beam and the target direction of flow (i.e. the blood within the descending thoracic aorta). Commercial devices assume a fixed angle of incidence of 45° related to the bevel-faced design of the probe. Should misalignment of the probe occur then there is potential for introduction of error in the estimation of the velocities, especially as the effective angle of insonation rises above 60° (and the Cosine term rapidly diverges from 0.5) [9]. If this angle rises to 90° the ability to determine the Doppler shift disappears entirely.