In the Intensive Care setting, the measurement of cardiac output (CO) is a vital component necessary for the understanding of cardiovascular dysfunction. Until recently, however, it had only been possible to measure a patient's CO invasively using a pulmonary artery catheter (PAC). Lately, several new and less invasive technologies have become available. This article focuses on the use of one such minimally invasive technology, namely arterial pressure waveform monitoring, that has greatly increased the assessment of a patient's CO in the intensive care setting.

Newer CO monitoring algorithms

Introduction

Haemodynamic monitoring is a vital tool in the treatment of the critically ill. It provides a comprehensive overview of the circulatory status of the patient and allows for earlier detection of cardiovascular dysfunction. Until recently, the most common way to obtain CO information was through the use of a pulmonary artery catheter (PAC). In recent years, however, there has been concern regarding both the safety and efficacy of this monitoring modality.1

As a direct result, several innovative, minimally invasive technologies have been introduced for the monitoring of a patient's CO, including the use of the arterial pressure waveform. This type of haemodynamic monitoring not only allows physicians to adapt their treatment almost immediately upon a patient's changing health status, but can be described as being virtually non-invasive since most critically ill patients already have an arterial access site. Currently, there are a number of companies that market devices that use the arterial pressure waveform to measure stroke volume or CO.

Correcting the pressure waveform for a patient's arterial vascular compliance presented a problem that until recently prevented the accurate conversion from arterial pressure to a volume (stroke volume). The vascular compliance relationship between pressure and volume, and unfortunately this relationship is both non-linear and difficult to predict for any given patient at any given time. Lately, however, some industrial companies have made enough technological progress to solve the underlying problem and to allow engineers to design monitoring systems that are sophisticated enough to warrant being made available on a large scale.

Pioneering technologies

The two technologies that have been around longest both utilise an initial calibration process that converts the arterial pressure waveform as measured by the FloTrac sensor and the complementarity Vigileo monitor.2

A second technology, pioneered by LiDCO, measured the power of the arterial waveform. In order to correct for the specific compliance of a patient, calibration was performed with a lithium dilution curve.3 Both of these systems use a calibration technique that is intrinsically accurate. However, both systems require a complementary manual input that carries with it an inevitable potential for error during episodes of acute haemodynamic instability. For the calibration to be both valid and effective, it must be performed with the utmost attention to detail. If errors do occur, the result is that instead of the calibration being helpful it could complicate things and in time even lead to clinicians questioning the value of the data obtained. To avoid this potential for human error, a number of new CO monitoring methods have been developed over the last few years. They have the value of providing an adequate degree of accuracy without requiring specific calibration to correct for the differences in arterial compliance.

APCO model

The Arterial Pressure Cardiac Output (APCO) algorithm developed by Edward's Lifesciences is a method that relates blood flow to arterial pressure using a haemodynamic model. This uses basic cardiovascular haemodynamic concepts according to which the arterial circulation, acting as an elastic storage system, transforms the discontinuous flow due to the pumping of the heart into a steady flow in the peripheral arterial circulation, acting as an elastic storage system, transforms the discontinuous flow due to the pumping of the heart into a steady flow in the peripheral circulation. The relationship thus required to correct for compliance.

APCO algorithm

The Pressure Recording Analytical Method (PRAM) is based on the physics of perturbations.4 The monitor based on this algorithm performs beat-to-beat analysis of the entire arterial wave profile, using an acquisition signal of 1000 Hz. The points in the wave that are most critical to compute are the initial point of the pulse wave (diastolic pressure), the highest point (systolic pressure) and the point of closure of the aortic valve. The PRAM algorithm then analyses other points of ‘perturbation’ and calculates the impedance of the system. The stroke volume (SV) is then calculated from the area under the curve in the interval between the diastolic part of the curve and the dicrotic notch, considering the correction of the impedance derived from the ‘perturbation analysis’ of the curve. No calibration is thus required to correct for compliance.

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Conclusions

Before throwing out old technologies in order to embrace the new, we should insist that the new technique has an accuracy at the very least approaching that of the older technology or offer other advantages to the user.5 Results of the two studies briefly described above suggest that the monitoring system using the APCO algorithm has an accuracy level similar to that obtained by the continuous pulmonary artery catheter, which for a long time has been perceived as the gold standard tool for measuring CO. In addition to the accuracy, it is a minimally invasive device that provides near-real time data without the need for calibration.


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