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Goal Directed Therapy and the principle of advanced haemodynamic monitoring

True of False:

1 Regarding high risk patients – true or false?

- 80% of post-operative deaths in the UK are in high risk patients.
- Risk scoring at the end of surgery is less predictive of outcome.
- For colorectal surgery, predicted mortality with POSSUM equals actual mortality.
- Patients who develop complications but survive to hospital discharge then have no reduction in long term survival.
- 21.8% of all operations performed in the UK are on ASA III-V patients.

2 Regarding pulse contour analysis – true or false?

- Patients with an SVV of 15% or greater are likely to benefit from a fluid bolus.
- FloTraq is an example of a calibrated pulse pressure analysis device.
- PiCCO uses a transpulmonary thermodilution technique for intermittent calibration.
- PiCCO is not affected by aortic regurgitation.
- The arterial pressure waveform is directly proportional to stroke volume.

3 Regarding perioperative fluid management – true or false?

- The use of a goal directed treatment protocol based on advanced haemodynamic monitoring has been shown to shorten hospital length of stay.
- ASA I & II patients who have been starved for 10 hours will need replacement of their fluid deficit.
- Fluid responsiveness can be defined as an increase in stroke volume or cardiac output by 10-15% in response to a fluid challenge.
- Central venous pressure reflects left ventricular preload and blood volume well.
- Pulmonary artery wedge pressure is a good measure of left ventricular preload.

4 Regarding oesophageal Doppler – true or false?

- The oesophageal Doppler measures the velocity of blood in the ascending aorta in cm/s.
- Oesophageal Doppler is well tolerated in awake patients.
- The FTc is the duration of flow during systole corrected for a heart rate of 60bpm.
- Nomograms to calculate the diameter of the aorta require the patient's age, sex, weight and height.
- NICE advocates its use in patients undergoing high-risk surgery.

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5 A 52 year old gentleman with no co-morbidities is undergoing a right hemicolectomy for bowel cancer. Intra-operatively his pulse is 70bpm, BP is 90/50 mmHg and his oesophageal Doppler displays the following variables – CO 4.2L/min, SV 43ml, FTc 300 and PV 55cm/s. Which of the following would be the best intervention?

- Start an iv infusion of dopexamine
- Start an iv infusion of dobutamine
- Give a 200ml fluid challenge
- Start an iv infusion of noradrenaline
- Give a 500ml fluid challenge

Key points:

- Goal Directed therapy (GDT) is the use of, normally advanced, haemodynamic monitoring systems to help guide the treatment of patients with fluids, vasopressors and inotropes to achieve a balance between systemic oxygen delivery and demand.
- Perioperative GDT decreases postoperative complications and hospital length of stay when compared to standard fluid management.
- The majority of centres now use either minimally or non-invasive methods for monitoring haemodynamic variables as part of goal directed therapy protocol.
- There are numerous devices available for advanced haemodynamic monitoring and there is a vast amount of evidence on each; the choice of which monitor to use may be less important compared to having an evidence driven protocol to follow to improve patient outcome.

Introduction

At a time when the NHS is being faced with an ageing population with increasing complex needs and limited budget and resources, healthcare professionals need to be acutely aware that whilst we provide our patients with the best possible care we are mindful of cost effectiveness. Around 21.8% of operations performed in the UK are on ASA III-V patients, 42.3% of those being non-elective 1. About 10% of all patients

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undergoing surgery in the UK are at high risk of complications and these then go on to account for 80% of postoperative deaths 2. As anaesthetists we should be using evidence based medicine in a patient specific fashion to try and prevent post-operative complications and thus reduce length of stay. To be able to do this we should be using goal directed therapy which will normally require some kind of advanced haemodynamic monitoring.

Goal Directed Therapy

Goal Directed therapy (GDT) is the use of, normally advanced, haemodynamic monitoring systems to help guide the treatment of patients with fluids, vasopressors and inotropes to achieve a balance between systemic oxygen delivery and demand 3,4,5. Historically, intravenous fluid administration to treat hypovolaemia has been guided by measuring the heart rate, arterial blood pressure and central venous pressure. However, this approach seems to lack sensitivity and specificity in identifying volume deficit, leading to both inadequate and excessive fluid administration 6. Ever since the pivotal paper by Rivers et al in 2001, GDT has been a term used more and more commonly. This approach has been shown to modify inflammatory pathways and improve tissue perfusion and oxygenation and therefore the use of a haemodynamic therapy algorithm has been recommended by the UK National Institute for Health and Care Excellence (NICE) and the US Centres for Medicare and Medicaid Services 7. Several single centre randomized controlled trials, meta-analysis and quality improvement programs have shown that perioperative GDT decreases postoperative complications and hospital length of stay when compared to standard fluid management 8.

In the past there have been numerous schools of thought on which is the best way to give intravenous fluids perioperatively; standard (often stated as liberal) or restricted being common terminologies used. Both techniques have their advantages and disadvantages and they have been researched extensively.

Liberal regimes often use empirical formulas for calculating not only replacement fluids for the starvation period but also maintenance fluid, fluids to account for insensible losses according to surgical specialty as well as boluses often lead to patients receiving large amounts of fluids. These large amounts of fluid were often given in the hope to avoid an acute kidney injury 9. Excessive fluid replacement leads to an increase in demand in cardiac function as a result of a, sometimes extreme, right wards shift on the starling myocardial performance curve. This can lead to fluid accumulation in the lungs

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predisposing the patient to pneumonia and respiratory failure as well as an inhibited gastric motility and poor wound healing 10.

However, studies have found that intravascular volumes remain stable in healthy patients, even after 10 hours of fasting (unless additional loses are added.)9 Add to this the ongoing dispute into the existence and or relevance of third space losses following numerous studies that have been unable to locate or quantify it 11 and a restricted regime may seem like a better alternative to a liberal one. Many studies have shown this theory to be true with restricted fluid regimes having better outcomes with regards to fewer perioperative complications and shorter hospital stays.12 However, some restricted regimes may not be able to meet fluid requirements in as many as 25-28% of patients 9.

The use of individualized GDT in surgical patients therefore allows us to target specific haemodynamic and tissue perfusion end points by using continuous flow-based haemodynamics. This then allows for patient specific fluid replacement and inotropic support in the hope to improve patient outcome 13.

Advanced Haemodynamic Monitoring

Haemodynamic monitoring describes the 'real-time' measurement of cardiovascular variables and dynamic parameters of fluid responsiveness to guide administration of intravenous fluids, vasopressors and inotropic support 5. The number of monitoring systems available for use are vast.

The pulmonary arterial catheter (PAC) had been considered to be the gold standard for monitoring preload, afterload, contractility and tissue oxygenation since its introduction by Harold Swan in 1970. However, the invasive nature of the PAC and its high rate of complications (such as infection, arrhythmias, thrombosis and pulmonary rupture) rendered it unsuitable for routine care in most cases 9, 14,15.

Another once commonly used method to monitor haemodynamic variables was via a central venous catheter. Central Venous pressure (CVP) has previously been used to guide perioperative fluid therapy but studies have shown that a CVP of between 5 and 20 mmHg has certainly almost no predictive value, and changes in CVP with a fluid bolus have not shown to be predictive of fluid status 16. Central venous pressure is well-known to be affected by other variables, such as intrathoracic pressure, venous resistance and pulmonary vascular resistance, and a recent study demonstrated that

there is little value in using CVP as a marker of adequate systemic oxygen delivery after major surgery 17.

The majority of centres now use either minimally or non-invasive methods for monitoring haemodynamic variables. Which one to use and when is a choice made by the institution often on financial basis as well as expertise available, the patient population and clinical pathways followed in that centre. This paper will go into detail on a few of the most commonly used.

Pulse Pressure Analysis

The theory for pulse contour analysis was first described by Erlanger and Hooker back in 1904; they suggested that cardiac output was proportional to arterial pulse pressure and many of the devices used today work on this principle 18,19. Pulse pressure analysis uses the arterial waveform to calculate cardiac output and stroke volume. The arterial pressure waveform is not directly proportional to the stroke volume, it is related to the changes between stroke volume, vascular resistance, compliance and impedance and therefore uses complex algorithms to determine the stroke volume 5. There are many different pulse pressure analysis devices on the market, such as FloTraq, PiCCO Plus and LidCO Rapid. The use of complex algorithms means that many of the devices are calibrated for accuracy. The available devices can be categorised by whether they are calibrated or not and details of different devices can be found within the table in the appendix.

The devices can also calculate dynamic parameters such as stroke volume variation (SVV) and pulse pressure variation (PPV). SVV is the change in stroke volume during the respiratory cycle. Intrathoracic pressure changes throughout the respiratory cycle which impacts on preload and therefore stroke volume. Many studies have shown SVV to be a reliable predictor of fluid responsiveness 10 and it is often incorporated into perioperative fluid management protocols 8. A change in SVV of 10-13% in a mechanically ventilated patient in sinus rhythm has been shown to far more predictive of fluid responsiveness than clinical assessment alone 5.

Oesophageal Doppler

The use of an oesophageal Doppler to monitor cardiac output was first described in the mid 1970s however it wasn't until the 1990s when its popularity rose. This coincided with not on the decline in use of pulmonary artery catheters but also with several small

studies that demonstrated a positive outcome with its use in patients undergoing high risk surgery 20. The oesophageal Doppler measures the velocity of blood in the descending aorta in cm/s. The device then uses published nomograms based on age, sex, weight and height to calculate the diameter of the aorta to convert the figure into ml/s and thus calculate cardiac output15. The oesophageal Doppler can also calculate the corrected flow time (FTc) which is the duration of flow during systole and can be used as a measure of preload. The oesophageal Doppler, like any other device, has pros and cons. The waveform is highly dependent on being correctly positioned with regards to its depth and orientation and often requires readjustment20. Interference with other electronic devices, such as diathermy, is also an issue. However, the oesophageal Doppler is probably the most thoroughly researched device and the evidence, on the whole, supports its use. So much so that NICE now advocates its use in patients undergoing high-risk surgery. This is due to its reduction in post-operative complications and hospital stay compared to conventional clinical assessment with or without invasive cardiac output monitoring 21.

Bioreactance

These non-invasive cardiac output monitors are modifications on the monitors based on bioimpedance monitors. The theory behind bioimpedance monitors was actually developed before that of oesophageal Doppler monitors and their use in clinical settings was first described by Kubieck and co in 196620,22. Both types of devices are completely non-invasive with most using placement of 4-6 skin electrodes connected to a monitor. Bioimpedance monitors work via the application of a high frequency, low magnitude current and analysis of variations of the voltage with each heartbeat. The devices work on the assumption that the impedance of the thorax (i.e. resistance to electrical current) is dependent on the amount of fluid within the thoracic cavity. This changes during the cardiac cycle according to the volume of blood within the aorta and mathematical equations are then used to calculate the cardiac output assuming that the changes in thoracic impedance are proportional to stroke volume 15,22.

Bioreactance devices are a modification on bioimpedance monitors that work on the concept that changes in aortic blood volume induce small changes in the frequency of electrical signals rather than on the changes in amplitude 23. Bioreactance refers to the electrical resistance, capacitive and inductive properties of the thoracic blood and biological tissues 15 and represents the phase shift in voltage across the thorax. It is thought that this phase shift depends more heavily on pulsatile flow therefore

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Bioreactance is more closely related to aortic blood flow than Bioimpedance which is also affected by intra and extravascular lung water22. Compared to bioimpedance monitors Bioreactance monitors are much more accurate, they yield a signal-to-noise ratio of about 100-fold greater than the Bioimpedance devices and it is not affected by electrode placement, body movement, respiratory excursion, body mass index or other electrical noise 15,24.

Due to their non-invasive nature, numerous studies have looked into their efficacy and accuracy at measuring cardiovascular parameters; there has been no consensus on this matter and results vary massively.

Summary

Our ageing population, complex cases and increasing trend for a perioperative medicine approach to anaesthesia means that goal directed therapy and therefore advanced haemodynamic monitors are fast becoming part of everyday procedures. The evidence out there is vast and it seems that the choice of which monitor to use may be less important compared to having an evidence driven protocol to follow to improve patient outcome.

Answers:

1 TFTFT

2 TFTFF

3 TFTFF

4 FFTTT

5 FFTFF

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