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Published in:
British Journal of Anaesthesia

DOI:
10.1016/j.bja.2020.04.065

BJA
British Journal of Anaesthesia

Volume 125, Number 2, August 2020

British Journal of Anaesthesia, 125 (2): 113–115 (2020)
doi: 10.1016/j.bja.2020.04.065
Advance Access Publication Date: 18 May 2020

EDITORIALS

A glimpse into the future of postoperative arterial blood pressure monitoring

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Keywords: anaesthesia; blood pressure; failure to rescue; hypotension; monitoring; postoperative complications; surgery

Postoperative arterial hypotension is common and largely undetected. A recent prospective blinded study[1] done in adults recovering from abdominal surgery with general anaesthesia showed that one in four patients experienced at least one episode of hypotension on the wards. Nearly half of the patients who had an MAP<65 mm Hg for at least 15 min were undetected by routine intermittent vital signs assessment. Postoperative hypotension is strongly associated with postoperative morbidity and mortality. Hypotension on days 1–4 after noncardiac surgery has been shown to be associated with a 183% increase in a composite endpoint of postoperative myocardial injury and death.[2] For the sake of comparison, 10 min of hypotension during surgery was associated with a significant but 23 times lower (8%) increase in the same endpoint.[2]

Although we monitor arterial pressure very closely in the operating room and PACU, we by no means do the same on the wards where surgical patients can develop complications and die.[3,4] This could be described as a blood pressure monitoring paradox. Today, on surgical wards, blood pressure is measured by nurses every 4–8 h with the oscillometric brachial cuff method. This universal approach is intermittent by nature. Closer, at best continuous, blood pressure monitoring may enable early detection, quantification, and treatment of postoperative hypotension.[5] Repeated measurements can be bothersome and are not compatible with good quality sleep. But, several alternatives are emerging, including wireless brachial cuffs, finger cuff volume clamp techniques, pulse wave transit time, and pulse decomposition algorithms (Table 1). In the future, electronic tattoos and predictive analytics may help further.

Wireless brachial cuffs are powered by a light battery and transmit intermittent blood pressure measurements wirelessly (e.g. via Bluetooth) to a bedside or central monitoring system. When other wearables (abdominal patch to capture respiratory rate and finger pulse oximeter to capture pulse rate and SpO_2) are used simultaneously, the early detection of cardiorespiratory and septic complications becomes possible. Such a mobile monitoring system has been tested in patients admitted for an acute emergency on gastroenterology and pulmonology wards.[6] A significant decrease in cardiac arrest and mortality was reported after implementation. Whether these findings can be reproduced in postsurgical patients and what the importance of blood pressure among other vital signs is remains to be determined.

Table 1 Comparison of existing methods for arterial pressure monitoring on the wards. The ideal method remains to be invented. green, yes; yellow, depends on the clinical situation; red, no; grey, unknown

Methods	Non-invasive	Conti-nuous	For absolute measures	To track acute changes	Mobile	Low cost
Brachial cuff	green	red	green	red	red	green
Wireless brachial cuff	green	red	green	red	green	? (grey)
Volume clamp	green	green	+/- (yellow)	green	red	red
Pulse wave transit time	green	green	red	green	green	? (grey)
Pulse decomposition	green	green	+/- (yellow)	green	green	? (grey)
Ideal method	green	green	green	green	green	green

Volume clamp monitoring systems combine an air-filled finger cuff and a photoplethysmographic sensor to continuously determine the cuff pressure needed to maintain finger artery blood volume constant. The derived finger blood pressure signal is mathematically converted into a brachial waveform. Calibration with the oscillometric brachial cuff method is optional (depending on the system). These methods are relatively accurate, meeting the current Association for the Advancement of Medical Instrumentation standards (bias <5 mm Hg, standard deviation <8 mm Hg),[7] as long as the peripheral circulation is not impaired by physiologic vasoconstriction or vasopressor administration.[8] As of today, these are bulky and tethered monitoring systems that cannot follow ambulatory patients. However, they could be kept on crash carts, and used on demand when ward patients become haemodynamically unstable.[9] In addition to blood pressure measurements, volume clamp methods have the advantage of estimating the two main determinants of blood pressure, cardiac output and vascular resistance. They can also be useful in deciding how to treat hypotension.[9]

The pulse wave transit time is the time needed by the blood to travel from the heart to a peripheral site of measurement. In practice, the R wave of the ECG (skin electrodes) is used to approximate when the blood is leaving the heart, and the upstroke of a pulse oximetry waveform to know when it arrives in the periphery. The pulse wave transit time increases when cardiac output and vascular tone decrease, both situations often associated with a decrease in blood pressure. Changes in pulse wave transit time can be useful in predicting blood pressure changes, but less so for assessing absolute pressure values. In this regard, tracking changes in pulse wave transit time has been shown to detect hypotension induced by anaesthesia induction.[10] Although validation studies are lacking, the pulse wave transit time method has also been proposed to track changes in blood pressure in ambulatory ward patients.[1,11]

The pulse decomposition method uses a piezoelectric sensor to capture a blood pressure signal from a finger cuff inflated at a constant low pressure (40 mm Hg). The finger pressure signal is then 'decomposed' by a proprietary algorithm to extract blood pressure values. Calibration with the oscillometric brachial cuff method is mandatory. A single study[12] suggests it is accurate and precise for monitoring blood pressure in the operating room. Because it is easy to use, light, and wireless, this technique has potential for continuous ward monitoring. However, it has not yet been evaluated in this context.

In the future, volume clamp methods could be made wireless and miniaturised. For instance, a volume clamp finger ring is currently under development.[13] Thanks to flexible electronics and new materials, adhesive sensors (i.e. electronic tattoos) able to literally 'feel' the pulse may also become available and enable continuous monitoring of carotid, femoral, or radial pressures.[14] Machine learning systems will likely help to filter artifacts, which are common in ambulatory patients and responsible for false alarms.[15] With the development of predictive analytics, we envision the possibility of predicting arterial pressure values from non-arterial signals (e.g. from the pulse oximetry waveform)[16,17] and forecasting hypotensive events before they actually occur.[18,19]

These digital innovations have the potential to change our blood pressure monitoring practices in hospital wards and beyond. However, we need to stay away from novelty blindness and, before clinical implementation, ensure that we have enough evidence to support their use. First, validation studies are needed to confirm their accuracy or at least their ability to detect changes in blood pressure.[20] Then, clinical studies must confirm that new blood pressure monitoring techniques enable the earlier detection of postoperative hypotension and clarify which patients may benefit the most. A large study[2] showed that patients who became hypotensive during surgery, which is itself associated with adverse outcomes,[21] were also likely to develop postoperative hypotension. Therefore, intraoperative hypotension may be one of the criteria triggering the use of continuous blood pressure monitoring techniques during the postoperative period. Finally, it is key to define who should receive the alerts.[22] Detection of a hypotensive event could first notify the ward nurse to check the patient's clinical status and blood pressure. If confirmed and hypotension is moderate, the ward physician could be notified. When confirmed and hypotension is severe, the rapid response team could be directly notified. Early detection of clinical deterioration (the afferent limb) will not help if it is not followed by the appropriate response (the efferent limb).[22] As experts in perioperative medicine, anaesthetists play a central role in defining rules and processes to be followed when abnormal blood pressures are detected on the wards.

Authors' contributions

Wrote together this editorial and approved the final version: all authors.

Declarations of interest

FM is the founder and managing director of MiCo, a Swiss consulting firm. MiCo does not sell any medical product and FM does not own shares from any medtech company. TWLS received honoraria for consulting and for giving lectures from Edwards Lifesciences, Masimo, and Pulsion Medical Systems. BS received honoraria for consulting and for giving lectures, institutional restricted research grants and refunds of travel expenses from Edwards Lifesciences, Pulsion Medical Systems, CNSystems Medizintechnik, Retia Medical, Philips, and Tensys Medical.

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British Journal of Anaesthesia, 125 (2): 115–117 (2020)
doi: 10.1016/j.bja.2020.04.071
Advance Access Publication Date: 28 May 2020

Asleep or awake: is paediatric regional anaesthesia without general anaesthesia possible?

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This editorial accompanies: Brachial plexus block with ultrasound guidance for upper-limb trauma surgery in children: a retrospective cohort study of 565 cases by Zadrazil et al., *Br J Anaesth* 2020:125: 104–109, doi: 10.1016/j.bja.2020.03.012

DOI of original article: 10.1016/j.bja.2020.03.012.