Double Intravenous vasopressors for the management of post spinal anaesthesia hypotension in obstetrics

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Introduction

Spinal anesthesia is popular choice for the conduct of caesarean delivery worldwide. A common serious problem associated with spinal anesthesia remains the rapid onset of hypotension and bradycardia which may result in potentially detrimental maternal and fetal effects.

Optimal management of blood pressure (BP) during spinal anaesthesia requires accurate maternal blood pressure (BP) monitoring, early detection of haemodynamic deterioration and timely treatment, especially with respect to the appropriate administration of vasopressors. Therefore, having an automated and interactive system, including a closed loop one, could be beneficial in improving the efficacy and safety of treatment.

An automated and interactive BP management system comprises the following components:

1) sensor or device to determine the BP and heart rate or other haemodynamic parameters ;
2) microprocessor-based control unit which uses an algorithm to direct intervention if required;
3) effector that attempts to return the measured variables (BP / heart rate, etc) to the set-point.

The Measurement of Blood Pressure

An accurate and near instant measurement of BP is crucial for the computer-controlled management system to function effectively and efficiently. The current standard of care in most institutions for a vast majority of caesarean sections involves conventional non-invasive oscillometric BP monitoring of the brachial artery at one-to five-minute intervals. The lack of a 'real-time' measurement of BP may lead to a failure to react in a timely manner to the BP changes when they occur. During spinal anaesthesia for caesarean delivery, haemodynamic instability could occur rapidly and suddenly; hence, the importance of shortening the lag-time between detection and treatment of hypotension cannot be overemphasized. In the context of spinal anaesthesia for caesarean delivery, the ideal monitoring should be non-invasive, easy to operate, and able to provide continuous, accurate and precise haemodynamic data. A recent study comparing continuous non-invasive blood pressure monitoring versus standard oscillometric monitoring at three-minute intervals in parturients undergoing caesarean section under spinal anaesthesia reported that standard monitoring missed 36% of hypotensive episodes and failed to detect lower blood pressures picked up by continuous monitoring. There was an increased risk of fetal acidosis in subjects who received standard monitoring, suggesting that continuous blood pressure monitoring may detect hypotensive episodes earlier, thus, permitting prompt treatment.

Several continuous, non-invasive blood pressure devices based on the vascular-unloading or volume-clamped method have been developed and are now available at the bedside: Nexfin (BMEYE B.V., Amsterdam, The Netherlands); CNAP (CNSystems, Graz, Austria); and T-line (Tensys Medical, Inc., San Diego, CA). The technique principally involves measurement of blood volume in a finger via infrared plethysmography, which is fed back to a pneumatic pump connected to a proximal inflatable cuff. The cuff is then inflated with the precise pressure needed to keep the blood volume in the finger constant and measurements can be obtained continuously in real-time.

Both CNAP and Nexfin have recently been validated in prospective trials; they have demonstrated good agreement with intra-arterial measurements and a reliability to detect rapid blood pressure changes, including hypotensive episodes. However, a systematic review in 2015 found that the margins of error in accuracy and precision rendered by continuous noninvasive arterial pressure monitoring devices are larger than what was defined as acceptable by the Association for the Advancement of Medical Instrumentation. The role of these devices in terms of clinical decision-making, patient outcome, and patient safety warrants further research.

Vasopressors in the closed- loop system

As the principal mechanism of hypotension during spinal anaesthesia is a decrease in arteriolar tone, vasopressors are commonly employed for the prevention and treatment of arterial hypotension after spinal anesthesia. These vasopressors primarily include phenylephrine and ephedrine. Phenylephrine is a selective α1-adrenergic receptor agonist whilst ephedrine act directly and indirectly on both and adrenergic receptor.

Though ephedrine had been the preferred vasopressor in obstetrics for decades, its role has recently been superseded by phenylephrine. However, one of the undesirable effects of phenylephrine is maternal bradycardia that may vagolytic therapy. Separately, parturients who experience a high sympathetic block may be both bradycardic and hypotensive, a situation that would render phenylephrine administration unsuitable as this may exacerbate the slow heart rate. Hence, even though phenylephrine is the first-line vasopressor for hypotension, the application of ephedrine is appropriate to counteract low BP with bradycardia.

Close-loop Automated Vasopressor Delivery System

The critical component for a robust automated and interactive BP management system is the control algorithm (microprocessor-based control unit). An ideal controller achieves the set point with minimal delay and with little deviation. As haemodynamic instability could happen swiftly during spinal anaesthesia for Caesarean delivery, rapid control of the hemodynamic status and timely interventions to these changes are critical.

Specific to the management of blood pressure in the obstetric population, the basic on-off, and simple proportional algorithms have been utilised clinically. In the basic on-off algorithm, the controller automatically triggers a fixed response (infusion of vasopressors) when it detects a change in the variable (BP) beyond a preset threshold in the measured variable. Ngan Kee et al. used oscillometric BP measurements at one-minute intervals and an on-off algorithm that activated phenylephrine infusion (100 μg/min) when maternal BP was equal to or below baseline. With the tight protocol to maintain BP, the investigators reported the incidence of hypotension of only 13.2%, although 37.7% of the patients had one or more episodes of reactive hypertension. In the simple proportional algorithm, the size of infusion is varied in accordance with the degree of hypotension. This principle was employed by Ngan Kee et al via regulating the infusion of phenylephrine between 0 and 100μg/min, depending on the BP reading. When compared to an on-off algorithm that activated phenylephrine infusion (100μg/min) at or below baseline blood pressure, the proportional infusion regimen decreased interventions required to manage blood pressure but there were no differences in hypotension, reactive hypertension or clinical outcomes.

Sia et al had developed a novel closed-loop double-vasopressor automated system that administered phenylephrine or ephedrine that leveraged on CNAP monitoring. The on-off algorithm activated 50 μg boluses of phenylephrine every minute when systolic BP fell below 90% of baseline, but switched to ephedrine 4 mg every minute when the parturient was both hypotensive and bradycardic (heart rate <60 beats/min). Though the set target was 10% below the normal BP only some 10% of the continuous BP values that were recorded deviated by more than 20% below baseline. But only 11% of women had one or more episodes of overshoot or reactive hypertension. The investigators subsequently enhanced the control algorithm by decreasing the time interval for the administration of 50μg boluses of phenylephrine to 30 seconds. In the randomised, controlled, double-blinded trial, which involved 213 healthy women who underwent elective caesarean delivery under spinal anaesthesia, this augmented algorithm resulted in better systolic pressure control compared with patients who received manual boluses the vasopressors, without a difference in the incidence of reactive hypertension or total vasopressors used. The automated vasopressor group also had a reduced incidence of nausea.

Sng et al incorporated Nexfin monitor in the simple proportional algorithm as shown in Figure 1. This system provides continuous non-invasive arterial pressure and cardiac output monitoring, with an infrequent need for recalibration.

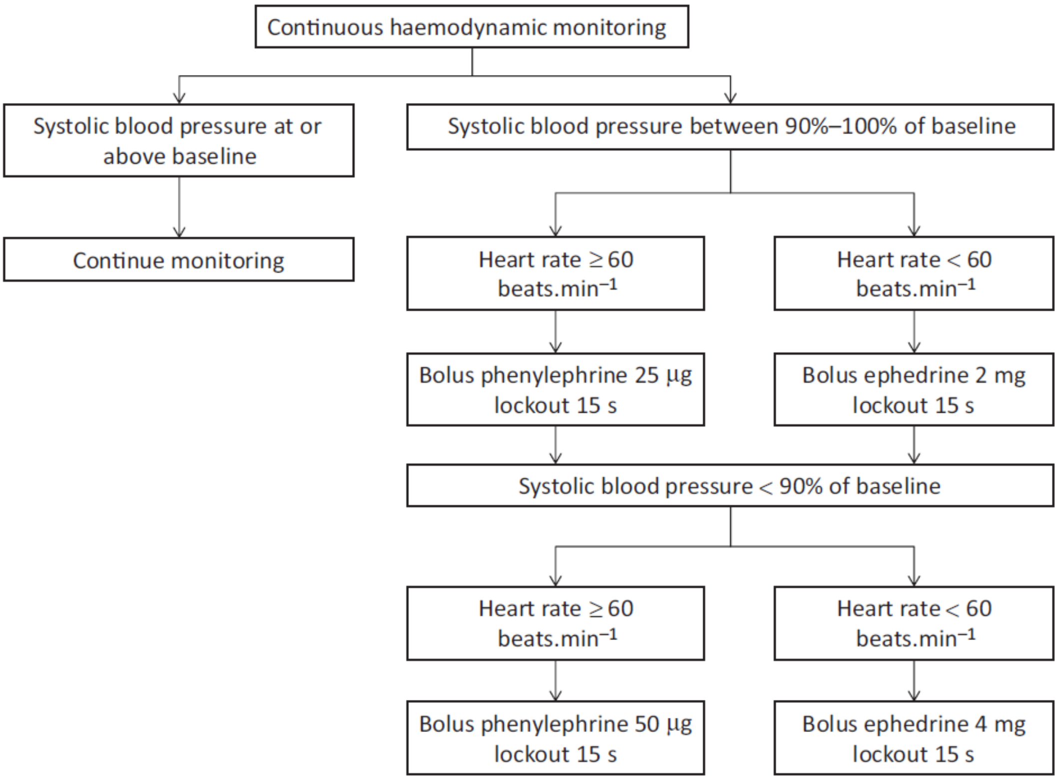

Figure 1. Schematic diagram of the algorithm used in our double-intravenous vasopressor automated system.

Essentially, when systolic pressure fell below baseline, commands were sent to activate either one of two syringe driver pumps containing phenylephrine and one ephedrine. An intravenous bolus of phenylephrine 25 µg was administered if the heart rate was ≥60 beats/min and ephedrine 2 mg if it was < 60 beats/min. The size of the boluses was doubled if systolic BP was < 90% of baseline. Each bolus was administered over 10 seconds, followed by a 20 seconds lockout period to allow the vasopressors to take effect. This system was able to achieve some 80% of all systolic blood pressure readings within 20% of the baseline, with good maternal and fetal outcomes.

Conclusion

The closed loop system is an exciting development to manage hypotension during spinal anaesthesia. The evidence suggests a potential role of automation by the vasopressor dosing algorithms, coupled by non-invasive continuous monitoring in more precisely maintaining hemodynamic parameters. The recent advances in non-invasive hemodynamic monitoring offer new opportunities for the anaesthetist to monitor parameters, including cardiac output, systemic vascular resistance, and etc apart from BP. The closed loop system could decrease inter-individual variability and help standardize therapy protocol across clinicians and institutions.

References

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