Original Research

COMPARISON OF CONTINUOUS NON-INVASIVE ARTERIAL PRESSURE (CNAP) MONITORING VERSUS INTERMITTENT NON-INVASIVE BLOOD PRESSURE (NIBP) MONITORING FOR DETECTION OF HYPOTENSION DURING SPINAL ANAESTHESIA FOR ELECTIVE CAESAREAN SECTION

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ABSTRACT

Background and Aims: Hypotension following spinal anaesthesia for caesarean section is common and, if undetected, may compromise uteroplacental perfusion. Intermittent non-invasive blood pressure (NIBP) monitoring may miss or delay detection of hypotensive episodes. The continuous non-invasive arterial pressure (CNAP) monitor, based on the vascular unloading technique, provides beat-to-beat blood pressure values without arterial cannulation. We compared the ability of CNAP and intermittent oscillometric NIBP to detect hypotension during spinal anaesthesia for caesarean section.

Methods: In this prospective, randomized, observer-blinded study, 50 healthy parturients of ASA physical status I–II undergoing elective caesarean section under spinal anaesthesia were monitored simultaneously with NIBP (every 1 minute until delivery, then every 3 minutes) and CNAP (continuous, recorded every 10 seconds until delivery) from the time of subarachnoid block until delivery of the baby. Clinical decisions regarding vasopressor and fluid therapy were based solely on NIBP readings. Incidence and time of detection of hypotension, systolic (SBP), diastolic (DBP) and mean arterial pressure (MAP) differences between the two techniques, side effects, and neonatal outcome (APGAR score, umbilical vein pH) were recorded.

Results: The incidence of hypotension detected was 18% with NIBP compared with 78% with CNAP ($p<0.05$). CNAP detected hypotension earlier than NIBP (mean time 1.87±0.52 min vs 2.66±0.86 min; $p<0.05$). CNAP recorded consistently and significantly lower SBP and MAP than NIBP at every time point studied ($p<0.05$), while DBP values were comparable between the two techniques. Nausea and vomiting occurred in 80% of NIBP-normotensive patients but in none of the CNAP-normotensive patients. APGAR scores and umbilical vein pH were comparable between hypotensive and normotensive mothers as classified by either technique.

Conclusion: Intermittent NIBP monitoring at 1-minute intervals under-detects and delays detection of hypotension during spinal anaesthesia for caesarean section compared with continuous CNAP monitoring. CNAP may be a useful adjunct to routine intermittent monitoring in this high-risk, time-critical setting.

Keywords: Spinal Anaesthesia, Caesarean Section, Hypotension, Continuous Non-Invasive Arterial Pressure, CNAP, Vascular Unloading Technique, NIBP.

INTRODUCTION

Regional anaesthesia is now firmly established as the technique of choice for caesarean section, largely because of its lower maternal morbidity and mortality compared with general anaesthesia and because it allows the mother to remain awake for the birth of her child.[1] Among the neuraxial techniques, single-shot spinal anaesthesia has become the default approach for most elective and many emergency caesarean deliveries, since it is faster to perform, produces a denser and more reliable block, and is more economical than epidural or combined spinal-epidural techniques. Despite these advantages, spinal anaesthesia is almost invariably accompanied by sympathetic blockade, and the resulting fall in systemic vascular resistance and venous return produces maternal hypotension in a substantial proportion of parturients. Reported incidences vary widely-from about half to almost all women-depending on the definition of hypotension used, the local anaesthetic and dose employed, and the frequency of blood pressure measurement.[2,3]

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Because uteroplacental perfusion is directly dependent on maternal arterial pressure, unrecognised or prolonged hypotension can result in reduced placental blood flow, fetal hypoxaemia and acidosis, and maternal symptoms such as nausea, vomiting, and altered consciousness.[2] Consequently, international consensus statements recommend that maternal arterial pressure be monitored closely and that hypotension be treated promptly and aggressively, typically with a combination of crystalloid or colloid co-loading and a vasopressor such as phenylephrine or ephedrine.[2]

In routine obstetric anaesthetic practice, arterial pressure is monitored using intermittent oscillometric NIBP measurement at an upper-arm cuff.[4] While simple, inexpensive, and free of the complications of arterial cannulation, this technique is by definition discontinuous: the true haemodynamic trajectory between two consecutive readings is unknown, and clinically important hypotensive episodes may therefore be missed entirely or detected only after some delay.[5] Reducing the inter-measurement interval improves temporal resolution but increases cuff cycling time, patient discomfort, and the risk of cuff-related complications, and even one-minute cycling cannot guarantee that a transient hypotensive nadir will coincide with a measurement.[5] Continuous invasive arterial pressure monitoring via radial artery cannulation is the reference standard for beat-to-beat pressure measurement, but it is invasive, requires technical expertise, carries a small but recognised risk of complications, and is difficult to justify for a procedure of the short duration of most caesarean deliveries.[4]

The continuous non-invasive arterial pressure (CNAP) monitor was developed to bridge this gap. Based on the volume-clamp (vascular unloading) principle originally described by Penaz,[6] the device uses a double finger cuff to hold digital arterial blood volume constant by means of a rapidly responding servo-controlled counter-pressure; this counter-pressure tracks the intra-arterial pressure waveform beat-to-beat and is periodically calibrated against an oscillometric upper-arm NIBP measurement. The system has shown acceptable agreement with invasive arterial pressure in several surgical and critical care populations[13,14,15] and has been used to detect hypotension earlier than intermittent NIBP monitoring in emergency department and endoscopy patients.[10,11]

A small number of studies have specifically examined CNAP monitoring during caesarean section under spinal anaesthesia and have suggested that it detects more, and earlier, episodes of hypotension than intermittent NIBP.[7,8,9] However, published data remain limited, and no consensus yet exists on how continuous non-invasive monitoring should be incorporated into routine obstetric anaesthetic practice. We therefore designed this prospective, randomized, observer-blinded study to compare the incidence and timing of detection of hypotension, and its associated maternal and fetal effects, using simultaneous CNAP and one-minute interval NIBP monitoring in women undergoing elective caesarean section under spinal anaesthesia.

MATERIALS AND METHODS

This prospective, randomized, observer-blinded study was conducted in the Department of Anaesthesiology, Umaid Hospital, attached to Dr. S.N. Medical College, Jodhpur, after approval from the Institutional Ethics Committee and after obtaining written informed consent from all participants. Fifty normotensive parturients of American Society of Anesthesiologists (ASA) physical status I or II, aged 18-35 years, with a gestational age greater than 30 weeks and scheduled for elective caesarean section under spinal anaesthesia, were enrolled.

Women were excluded if they were younger than 18 or older than 35 years; were ASA physical status III or above; or had known cardiac disease, chronic renal disease, chronic hypertension, thrombocytopenia (platelet count <1 lakh/mm³), eclampsia or HELLP syndrome, antepartum haemorrhage or coagulopathy, cardiac arrhythmia, use of anticoagulant or antiplatelet therapy, peripheral vascular disease, or fetal distress. Patients who developed excessive intraoperative movement such as shivering or seizures were also excluded from analysis.

All patients were assessed in the pre-anaesthetic clinic one day before surgery, including a detailed general and systemic examination and a review of antenatal history and investigations. The procedure, along with its risks and benefits, was explained, written informed consent obtained, and patients were kept fasting for 8 hours preoperatively.

On arrival in the operating room, intravenous access was secured on the non-dominant hand with an 18G cannula, and preloading with Ringer's lactate 10 ml/kg was commenced. Standard monitoring (ECG, pulse oximetry, and an oscillometric NIBP cuff on the arm contralateral to the intravenous line) was instituted, and baseline heart rate, oxygen saturation, and blood pressure were recorded. In addition, every patient was monitored with the CNAP device (CNSystems, Graz, Austria) using an oscillometric upper-arm cuff for calibration together with a double finger cuff, both applied to the arm ipsilateral to the intravenous cannula. Finger and upper-arm cuff sizes (small, medium, or large) were selected according to individual limb circumference. CNAP finger-cuff blood pressure was calibrated to the ipsilateral oscillometric upper-arm reading at baseline and re-calibrated every 30 minutes thereafter.

Subarachnoid block was performed with the patient in the sitting position with the spine well flexed. After identification of the L3-L4 interspace and under strict aseptic precautions, a midline lumbar puncture was performed with a 25G Quincke spinal needle. After free flow of clear cerebrospinal fluid and negative aspiration for blood, 12.5 mg (2.5 ml) of hyperbaric 0.5% bupivacaine was injected slowly, following which patients were placed supine with 30° left lateral tilt. Baseline heart rate, systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) by NIBP, and oxygen saturation, were recorded, and sensory block height (loss of cold sensation) was assessed after 5 minutes.

From the time of subarachnoid injection until delivery of the baby, oscillometric NIBP measurements were obtained at 1-minute intervals, while CNAP recorded continuous values, sampled and tabulated every 10 seconds by a second, blinded observer. After delivery, blood pressure monitoring continued with NIBP alone, at 3-minute intervals, until the end of surgery. All therapeutic decisions were based solely on the NIBP readings: an SBP below 90 mmHg detected by NIBP was treated with a rapid crystalloid bolus and an intravenous bolus of ephedrine 6 mg, repeated as required until normotension was restored. After delivery, an oxytocin infusion (10 units) was commenced. Time from spinal injection to delivery, APGAR scores at 1 and 5 minutes, and umbilical venous pH were recorded for every neonate.

Data recorded included sensory block level, time to delivery, heart rate, blood pressure by both techniques, fluid and vasopressor requirements, incidence of nausea and vomiting, APGAR scores, and umbilical vein pH. Statistical analysis was performed using InStat software; comparisons between the two monitoring techniques were made using Student's t-test or the Mann-Whitney U test as appropriate, and categorical data were compared using the chi-square test. A p value <0.05 was considered statistically significant. Results are expressed as mean ± standard deviation or as number (percentage).

RESULTS

Fifty parturients completed the study protocol. Baseline demographic and obstetric characteristics were comparable across the study population, and all patients achieved an adequate sensory block for surgery.

Table 1. Incidence of Hypotension Detected By NIBP versus CNAP (N = 50)

Monitoring technique	Hypotensive episodes detected, n (%)	Normotensive, n (%)	p value
NIBP (1-min interval)	9 (18%)	41 (82%)	
CNAP (continuous)	39 (78%)	11 (22%)	<0.05

CNAP detected a significantly higher incidence of hypotensive episodes than intermittent NIBP monitoring (78% vs 18%, p<0.05), indicating that a large proportion of hypotensive episodes went undetected by 1-minute interval NIBP monitoring.

Table 2. Mean Time to Detection of Hypotension after Spinal Anaesthesia

Monitoring technique	Mean time to detection (min) ± SD	p value
NIBP	2.66 ± 0.86	
CNAP	1.87 ± 0.52	<0.05

CNAP identified the onset of hypotension significantly earlier than NIBP, with a mean difference in detection time of approximately 0.8 minutes (p<0.05).

Table 3. Difference between NIBP and CNAP Systolic and Mean Arterial Pressure Values (NIBP − CNAP, Mmhg) At Successive Time Points after Spinal Injection

Time (min)	ΔSBP (mmHg) ± SD	ΔMAP (mmHg) ± SD	p value
1	4.80 ± 0.38	4.56 ± 0.51	<0.05
2	5.76 ± 0.30	3.78 ± 1.78	<0.05
3	6.14 ± 0.37	4.13 ± 3.69	<0.05
4	8.08 ± 0.37	6.03 ± 4.74	<0.05
5	10.96 ± 2.05	8.71 ± 6.25	<0.05

At every time point studied, CNAP recorded consistently and significantly lower systolic and mean arterial pressures than simultaneous NIBP readings, and this difference widened progressively over the first five minutes after spinal injection.

Table 4. Difference between NIBP and CNAP Diastolic Arterial Pressure Values (NIBP − CNAP, Mmhg)

Time (min)	**ΔDBP (mmHg) ± SD**	**p value**
1	0.02 ± 1.01	>0.05
2	0.28 ± 1.46	>0.05
3	-1.16 ± 3.95	>0.05
4	-0.96 ± 4.26	>0.05
5	0.39 ± 4.90	>0.05

Unlike SBP and MAP, diastolic blood pressure values recorded by the two techniques did not differ significantly at any time point, indicating comparable diastolic pressure tracking by CNAP and NIBP.

Table 5. Incidence of Nausea and Vomiting According To Haemodynamic Status by Each Technique

Group	**Nausea/vomiting**	**p value**
NIBP-normotensive patients (n = 41)	80%	<0.05 vs CNAP-normotensive
CNAP-normotensive patients (n = 11)	0%	
NIBP-hypotensive vs CNAP-hypotensive patients	Comparable incidence	>0.05

A striking finding was that 80% of patients classified as normotensive by NIBP nonetheless experienced nausea and vomiting-symptoms typical of unrecognised hypotension-whereas none of the patients classified as normotensive by CNAP had these symptoms. Among patients identified as hypotensive by either technique, the incidence of nausea and vomiting was comparable.

Fetal outcome, assessed by APGAR scores at 1 and 5 minutes and by umbilical venous pH, was comparable between hypotensive and normotensive mothers as classified by either NIBP or CNAP, and no statistically significant differences were observed (p>0.05).

DISCUSSION

The widespread adoption of spinal anaesthesia for caesarean section has substantially reduced maternal morbidity and mortality compared with general anaesthesia, but sympathetically mediated hypotension remains its most frequent side effect, with reported incidences of up to 95% depending on the definition used.[2,3] Because fetal oxygenation is directly dependent on maternal arterial pressure, prompt recognition and treatment of hypotension is essential.[2] Continuous invasive arterial monitoring, although the reference standard, is rarely justified for a procedure as brief as caesarean section because of its inherent risks and technical demands, so intermittent oscillometric NIBP remains the routine monitoring method-despite evidence that more than 20% of hypotensive episodes may be missed by intermittent monitoring and a further 20% detected only with delay.

In the present study, NIBP measured at 1-minute intervals detected hypotension in only 18% of parturients, compared with 78% detected by continuous CNAP monitoring, and CNAP identified hypotension significantly earlier than NIBP (1.87±0.52 vs 2.66±0.86 minutes). These findings are consistent with those of Ilies et al.,[7] who reported an incidence of hypotension (defined as SBP<100 mmHg) of 91% with CNAP compared with 55% with NIBP, and with Hanss et al.,[8] who similarly found that continuous monitoring detected substantially more hypotensive episodes than intermittent measurement. McCarthy et al.[9] compared the ability of NIBP and CNAP to provide a new reading in every 1-minute interval between spinal injection and delivery and found that, although both devices produced new readings in a similar proportion of intervals overall, CNAP was more likely to fail on two or more consecutive minutes-a limitation that our study design, with a dedicated observer recording CNAP values every 10 seconds, was able to minimise.

CNAP also recorded consistently lower systolic and mean arterial pressures than NIBP at every time point in the first five minutes after spinal injection, with the discrepancy widening over time, while diastolic pressures agreed closely between the two methods. A similar pattern-close agreement for MAP and DBP but wider discrepancies for SBP-has been reported by Wagner et al.[10] in acutely ill emergency department patients, who found a mean bias of -5 mmHg for SBP, -2 mmHg for DBP, and -6 mmHg for MAP between CNAP and oscillometric measurement, and by McCarthy et al.,[9] who reported comparable limits of agreement before induction of spinal anaesthesia. Siebig et al.[11] similarly demonstrated that vascular-unloading-based continuous monitoring identified rapid blood pressure changes during interventional endoscopy that were missed by intermittent oscillometric measurement, reinforcing the principle that continuous waveform monitoring captures transient events that discrete sampling cannot.

Despite the higher incidence and earlier detection of hypotension by CNAP, neonatal outcome-as measured by APGAR score and umbilical venous pH-did not differ significantly between hypotensive and normotensive mothers in our cohort, in contrast to Ilies et al.,[7] who reported an association between lower CNAP-derived SBP nadirs and fetal acidosis. This discrepancy may reflect the relatively brief and promptly treated episodes of hypotension in our patients, since prolonged, uncorrected maternal hypotension rather than isolated transient episodes has been associated with fetal acidosis. Notably, 80% of patients who were classified as normotensive by NIBP nonetheless experienced nausea and vomiting-a recognised clinical marker of unrecognised hypotension-whereas no CNAP-normotensive patient had these symptoms, suggesting that NIBP under-detection of hypotension has real, symptomatic consequences for the mother even when fetal biochemical markers remain reassuring.

The reliability of CNAP as a surrogate for invasive arterial pressure has been demonstrated across diverse clinical settings, including cardiac surgical intensive care,[14] cardiothoracic surgery,[13] and critically ill children,[12] lending broader support to its use as a continuous, non-invasive alternative to arterial cannulation in short, high-acuity procedures such as caesarean section, where invasive monitoring is difficult to justify but rapid haemodynamic change is expected.

Strengths and Limitations

A key strength of this study is its design: NIBP readings were obtained at 1-minute intervals-the shortest clinically practicable interval-allowing a rigorous comparison with continuous CNAP monitoring, and a dedicated blinded observer recorded CNAP values every 10 seconds. The study also captured clinically relevant secondary outcomes, including maternal nausea and vomiting and neonatal biochemical status. Limitations include the absence of a pre-specified statistical limit of agreement between the two techniques, since the AAMI guidelines for validation of blood pressure devices do not extend to finger-cuff-based continuous monitors.[5] No treatment decisions were based on CNAP values, so the study cannot address whether CNAP-guided intervention would improve maternal or fetal outcome. Finally, because CNAP calibration is itself dependent on intermittent oscillometric NIBP measurement, any bias intrinsic to the calibrating NIBP reading may be carried forward into the continuous CNAP trace.

CONCLUSION

Intermittent NIBP monitoring, even at 1-minute intervals, substantially under-detects and delays detection of hypotension during spinal anaesthesia for caesarean section compared with continuous, non-invasive CNAP monitoring. CNAP identified a markedly higher incidence of hypotension, detected it earlier, and recorded lower systolic and mean arterial pressures throughout the critical period between spinal injection and delivery, without any difference in diastolic pressure tracking between the two methods. Although neonatal outcome was not different between groups in this study, the clinical correlation between undetected NIBP-defined normotension and maternal nausea and vomiting suggests that routine intermittent monitoring may under-represent the true haemodynamic burden of spinal anaesthesia. Continuous non-invasive arterial pressure monitoring using the vascular unloading technique appears to be a feasible, safe adjunct to routine intermittent monitoring in parturients undergoing caesarean section, with the potential to improve early recognition and treatment of hypotension. Further, adequately powered studies examining outcome-directed intervention based on continuous non-invasive monitoring are warranted to determine its impact on maternal and fetal outcome.

REFERENCES

1. Kinsella SM, Carvalho B, Dyer RA, Fernando R, McDonnell N, Mercier FJ, et al. International consensus statement on the management of hypotension with vasopressors during caesarean section under spinal anaesthesia. Anaesthesia. 2018;73(1):71-92.
2. Ngan Kee WD. Prevention of maternal hypotension after regional anaesthesia for caesarean section. Curr Opin Anaesthesiol. 2010;23(3):304-9.
3. Klöhr S, Roth R, Hofmann T, Rossaint R, Heesen M. Definitions of hypotension after spinal anaesthesia for caesarean section: literature search and application to parturients. Acta Anaesthesiol Scand. 2010;54(8):909-21.
4. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, et al. Recommendations for blood pressure measurement in humans and experimental animals: Part 1: blood

pressure measurement in humans. Circulation. 2005;111(5):697-716.

5. Association for the Advancement of Medical Instrumentation. American National Standard for Manual, Electronic, or Automated Sphygmomanometers. Arlington (VA): AAMI; 2003.
6. Penaz J. Photoelectric measurement of blood pressure, volume and flow in the finger. Digest of the 10th International Conference on Medical and Biological Engineering; Dresden, Germany; 1973. p. 104.
7. Ilies C, Kiskalt H, Siedenhans D, Meybohm P, Steinfath M, Bein B, et al. Detection of hypotension during Caesarean section with continuous non-invasive arterial pressure device or intermittent oscillometric arterial pressure measurement. Br J Anaesth. 2012;109(3):413-9.
8. Hanss R, Ilies C, Missalla H, Steinfath M, Bein B. Continuous non-invasive blood pressure monitoring during spinal anesthesia for cesarean section. Eur J Anaesthesiol. 2010;27:166-7.
9. McCarthy T, Telec N, Dennis A, Griffiths J, Buettner A. Ability of non-invasive intermittent blood pressure monitoring and a continuous non-invasive arterial pressure monitor (CNAP™) to provide new readings in each 1-min interval during elective caesarean section under spinal anaesthesia. Anaesthesia. 2012;67(3):274-9.
10. Wagner JY, Prantner JS, Meidert AS, Hapfelmeier A, Schmid RM, Saugel B. Noninvasive continuous versus intermittent arterial pressure monitoring: evaluation of the vascular unloading technique (CNAP device) in the emergency department. Scand J Trauma Resusc Emerg Med. 2014;22:8.
11. Siebig S, Rockmann F, Sabel K, Zuber-Jerger I, Dierkes C, Brünnler T, et al. Continuous non-invasive arterial pressure technique improves patient monitoring during interventional endoscopy. Int J Med Sci. 2009;6(1):37-42.
12. Lemson J, Hofhuizen CM, Schraa O, Settels JJ, Scheffer GJ, van der Hoeven JG. The reliability of continuous noninvasive finger blood pressure measurement in critically ill children. Anesth Analg. 2009;108(3):814-21.
13. Hofhuizen CM, Lemson J, Hemelaar AE, Settels JJ, Schraa O, van der Hoeven JG, et al. Continuous non-invasive finger arterial pressure monitoring reflects intra-arterial pressure changes in children undergoing cardiac surgery. Br J Anaesth. 2010;105(4):493-500.
14. Jagadeesh AM, Singh NG, Mahankali S. A comparison of a continuous noninvasive arterial pressure (CNAP™) monitor with an invasive arterial blood pressure monitor in the cardiac surgical ICU. Ann Card Anaesth. 2012;15(3):180-4.
15. Ilies C, Bauer M, Berg P, Rosenberg J, Hedderich J, Bein B, et al. Investigation of the agreement of a continuous non-invasive arterial pressure device in comparison with invasive radial artery measurement. Br J Anaesth. 2012;108(2):202-10.

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