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The Effect of Maintaining Baseline Heart Rate and Blood Pressure on Cardiac Output Changes During Spinal Anaesthesia for Caesarean Section

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Abstract

Introduction
Significant haemodynamic changes occur during caesarean section, which may affect uteroplacental perfusion. Anaesthetists should aim to keep blood pressure (BP) within 90% of baseline but maintenance of BP alone does not ensure cardiac output (CO) is maintained. We aimed to determine CO changes when heart rate (HR) in addition to BP is maintained at baseline.

Methods
CO was recorded using NICOM in 30 women undergoing elective caesarean section under spinal anaesthesia. Phenylephrine and ephedrine boluses were given to maintain BP and HR at baseline.

Results
CO was maintained with mean maximum increase of 0.8 $L.min^{-1}$ (95% CI 0.45 to 1.19 $L.min^{-1}$, P=0.002) immediately after spinal anaesthesia. Mean maximum decrease of systolic BP was 20.4 mmHg (95% CI 8.7 to 32, P<0.0001). There was no significant change in HR at any time point. CO correlated with HR (r=0.6, 95% CI 0.1 to 0.86, P=0.04) and stroke volume (r=0.7, 95% CI 0.3 to 0.9, P=0.006), while systolic BP correlated with total peripheral resistance (r=0.8, 95% CI 0.4 to 0.9, P=0.002) during the study period. Five patients required ephedrine boluses.

Conclusions
CO was preserved during elective caesarean section when HR was maintained at baseline. In a subset of patient's ephedrine boluses were required in addition to phenylephrine to maintain CO. BP fell in line with total peripheral resistance despite the increase in CO.

Introduction

Women undergoing caesarean section under spinal anaesthesia face significant haemodynamic challenges. Maintaining systolic blood pressure (SBP) at >90% of baseline is recommended to ensure uteroplacental perfusion and avoid maternal symptoms of hypotension. Currently guidelines recommend the use of phenylephrine, an alpha-1 agonist as the first line agent to manage hypotension secondary to spinal anaesthesia,[1] with use of ephedrine (a mixed alpha and beta agonist) recommended for the treatment of hypotension with low heart rate (HR).

Changes in cardiac output (CO) following spinal anaesthesia may be important for both the mother and fetus.[2] CO has been shown to correlate better with foetal umbilical artery pulsatility index and pH at delivery than blood pressure (BP)[2] and an inverse correlation exists between CO and the uterine resistance index during pregnancy.[3] Parturients in high risk groups such as those with significant cardiac disease may decompensate rapidly with changes in CO. The current practice of solely focusing on BP management may fail to appreciate a reduction in CO caused by bradycardia,[1] which can frequently occur secondary to phenylephrine infusion.[4]

HR changes during elective caesarean section have been shown to mirror CO changes[5] and can be used as a surrogate marker for CO[1]. Despite this observation few studies have focused on maintenance of CO by preservation of HR at baseline. The aim of this study was to observe the changes in CO when both HR and BP were maintained at baseline using a combination of phenylephrine and ephedrine boluses. We hypothesized that CO would be maintained in such instances.

Methods

This is a prospective observational cohort study. It is a hospital based, single centre study. The study was approved by the ethics committee of the Coombe Women and Infants University Hospital. This manuscript adheres to the applicable STROBE statement. Informed written consent was obtained from all participants.

Patients suitable for inclusion were women undergoing elective caesarean section, aged between 18 and 40 years with American Society of Anesthesiologists (ASA) physical status grade I or II, gestation ≥37 weeks, singleton pregnancy and non-smoker.

We used Non-Invasive Cardiac Output Monitor (NICOM, Cheetah Medical Inc, Portland, Oregon, USA), to measure CO. NICOM is non-invasive monitor using bioreactance technology involving transmission of a harmless high frequency current through the thorax. NICOM has been validated in human subjects in several clinical settings.[6,7]

The NICOM monitor was attached to all patients in addition to standard monitoring prior to spinal anaesthesia. We then placed patients in the supine position for three minutes with 10° left lateral tilt. Automated BP readings were taken three times at one minute intervals and baseline SBP was taken as the average of the SBP readings during this time.

All patients were coloaded with 1000 mL of crystalloid Hartmann's solution during spinal insertion. Patients received a single shot spinal anaesthetic using hyperbaric 0.5% bupivacaine 12.5 mg plus fentanyl 25 mcg and morphine 150 mcg injected in the lumbar region in the sitting position.

Following injection patients were placed supine with 10° left lateral tilt. Automated blood pressure readings were taken at 1 minute intervals using the NICOM monitor. CO, BP, HR, stroke volume (SV) and total peripheral resistance (TPR) were similarly assessed at 1 minute intervals throughout the procedure. Anaesthetists were instructed to administer phenylephrine 50 µg and ephedrine 6 mg boluses whenever HR or BP readings fell from baseline. A fall in the SBP of greater than 10 mmHg and a change in HR by greater than five beats/min from baseline, were used as cut off points to initiate intervention. Phenylephrine was administered when there was a sole drop in BP, with or without a rise in HR while ephedrine was administered when a drop in HR with an associated drop in BP occurred. Persistent bradycardia, as defined as HR less than 50 beats/min was treated with an atropine 500 mcg bolus.

Following delivery and cord clamping all patients received a bolus of 5 units of oxytocin, given slowly over one to two minutes. Umbilical arterial and venous cord blood, foetal weights and Apgar scores were recorded.

The primary outcome in this study was change in CO during caesarean section. Secondary outcomes included changes in SBP, SV, TPR and HR. A convenience sample of 30 was chosen for the purposes of the study. Statistical analyses were performed using Graph Pad Prism version 8. Comparisons between paired values were performed using paired t-tests or Wilcoxin signed-rank tests as appropriate. Repeated measures ANOVA was carried out for variables with normal distribution. Tukey adjustment was used for multiple comparisons. The Shapiro-Wilk test was used to test for normal distribution. Spearman's correlation analysis was performed to analyse the correlation between variables. Differences were considered significant if $P<0.05$. Results are presented at time intervals baseline (t0), 1 minute post spinal insertion (PS), 5 minutes post spinal insertion (PS+5min), 10 minutes post spinal insertion (PS+10min), delivery, time of oxytocin administration and then at 1 minute intervals following oxytocin administration until the time period 7 minutes post oxytocin administration. Results are analysed for post-spinal and post-delivery periods.

Results

Thirty patients were recruited for the study. The patient flow diagram is illustrated in figure 1. Thirty-five patients were assessed for eligibility at the preassessment clinic. Three patients were subsequently excluded as they didn't meet eligibility criteria while one patient refused to participate. The NICOM machine recorded inadequate data in one patient to allow full analysis, due to faulty electrode placement, so this patient was excluded. In cases where there were missing entry points (total of 24 missing entry points), the last data observation was carried forward.

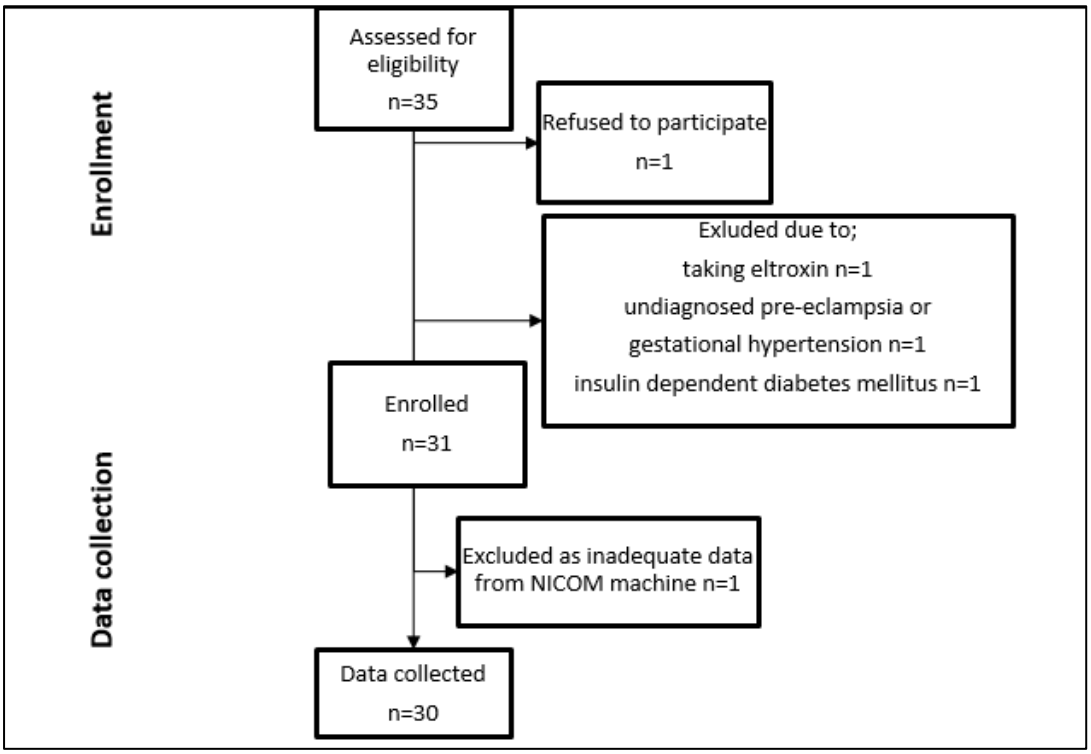

Figure 1. Flow diagram of the study

The indications for caesarean section included previous caesarean section in 66% of patients (n=20), previous 3rd degree tear in 13% of patients (n=4) and breech presentation in 20% of patients (n=6). Baseline patient characteristics are shown in table 1. Median (IQ range) ASA status was 1(0).

Table 1. Patient characteristics

Parameter	Mean (SD)
Age	34.57 (0.77) years
Weight	67.5 (2.08) kg
Height	160 (5.58) cm
BMI	26.17 (0.66) kg/m^2
Gestational age	38.9 (0.19) weeks
Parity	1.1 (0.11)
Preoperative Hg	12.04 (0.95) g/dl

BMI – body mass index. Hg - haemoglobin

Changes in CO, SV, TPR and BP following spinal anaesthesia

Changes in CO, HR, SV, SBP and TPR are illustrated in figure 2. Mean (SD) baseline CO was 5.6 (1.2) $L.min^{-1}$. CO increased following spinal anaesthesia. Mean maximum increase in CO was 0.8 $L.min^{-1}$ (95% CI 0.45 to 1.19 $L.min^{-1}$, P=0.002) (+14%) from baseline). This occurred immediately following administration of spinal anaesthesia and return of the patient to the supine position.

Baseline values for HR, SV, SBP and TPR were 90.6 (16.2) beats/min, 62.71 (14.3) ml, 123.03 (13.2) mmHg and 1417.6 (328.5) $dynes.sec.cm^{-5}$ respectively. TPR values decreased following spinal anaesthesia with the largest significant mean decrease of 313.4 dynes. sec. cm^{-5} (95% CI 196.7 to 430.0 dynes. sec. cm^{-5}, p<0.0001) (-22%) at the time interval 5 minutes post spinal anaesthesia. There was no significant difference in HR at any time point throughout the study. Max change in HR from baseline (t(0)) was at delivery (reduction by 7.3s CI -6.1 to 20.8, p = 0.84). Max change in HR at any one time point post-spinal was between PS+5min and PS+10min (reduction by 8.2s CI -5.2 to 21.6, p = 0.7). SV significantly increased following spinal anaesthesia with mean maximum increase at time period 1-minute post spinal anaesthesia of 7.9 ml (95% CI 2.81 to 12.94, P=0.0035) (+13%). There was a significant decrease in SBP following spinal anaesthesia with a mean maximum decrease at 5 minutes post spinal of 18.1 mmHg (95% CI 6.4 to 29.8 mmHg, P<0.0001) (-14%).

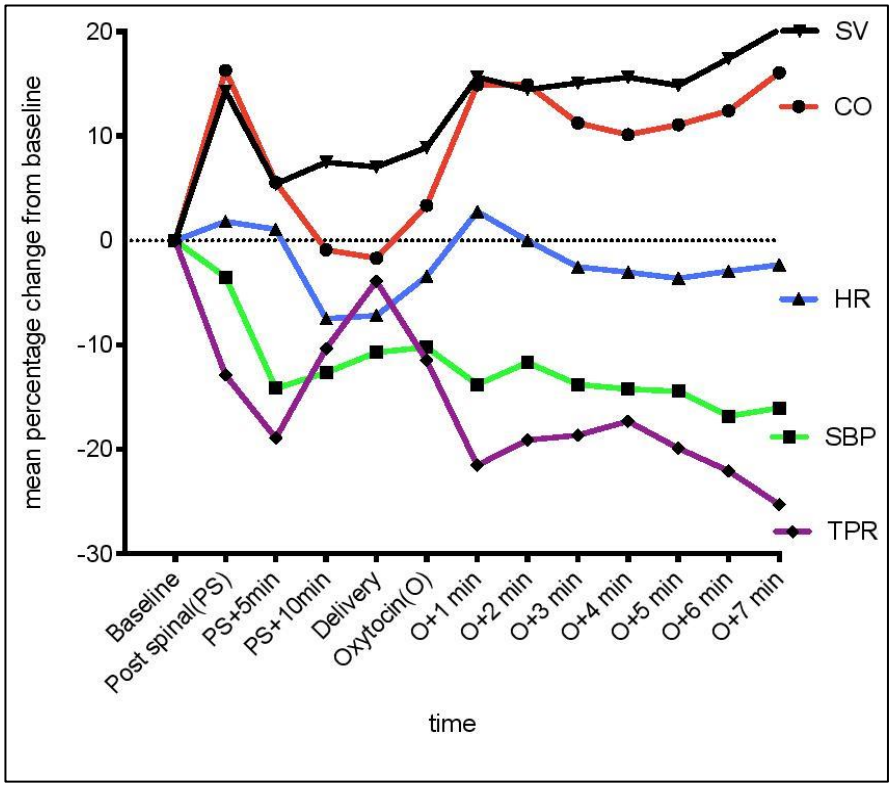

Figure 2. Haemodynamic changes during caesarean section. Post Spinal (PS) represent 1-minute post spinal administration.

Changes in CO, SV, TPR and BP following delivery

Mean (SD) baseline CO was 5.4 (1.2) $L.min^{-1}$ at delivery. Baseline values for HR, SV, SBP and TPR were 83.3 (17) beats/min, 65.8 (15.4) ml, 108.7 (13.6) mmHg and 1274.1 (649.6) $dynes.sec.cm^{-5}$ respectively.

There was no significant change in CO and SV after delivery. Following delivery there was a significant decrease in TPR with mean maximum decrease at time interval 7 minutes post oxytocin administration of 389 $dynes.sec.cm^{-5}$ (95% CI 87.1 to 690.9 $dynes.sec.cm^{-5}$, P=0.004) (-27%). There was no significant change in HR at any time point after delivery (max change between oxytocin administration (O) and 1-minute post oxytocin (O+1 min) administration (increase of 5.7s CI -19.5 to 7.7, p = 0.97)). There was a significant decrease in SBP after delivery with a mean maximal decrease of 20.4 mmHg (95% CI 8.7 to 32, P<0.0001) (-16%) at 7 minutes after delivery.

CO correlated with HR (r=0.6, 95% CI 0.1 to 0.86, P=0.04) and SV (r=0.7, 95% CI 0.3 to 0.9, P=0.006) during the study period. SBP correlated with TPR (r=0.8, 95% CI 0.4 to 0.9, P=0.002) and CO correlated negatively with TPR (r=0.7, 95% CI -0.9 to -0.2, P=0.01). There was no significant correlation between SBP and CO or the rest of the indices.

Mean (SD) phenylephrine doses administered were 151 (20.67) mcg while mean (SD) ephedrine dose administered was 2.2 (1.01) mg. Three patients (10%) received no phenylephrine or ephedrine boluses. Five patients (17%) received ephedrine boluses while 27 patients (90%) received phenylephrine boluses. In those patients that required ephedrine, mean (SD) doses were 15.6 (5.4) mg. No patient received atropine or glycopyrrolate. Mean (SD) blood loss during the procedure was 406.7 (163.9) mls.

Maternal symptoms experienced included nausea in 7 patients (23%), vomiting in 2 patients (7%), shivering in 1 patient (3%) and dizziness in 1 patient (3%). Mean (SD) foetal weight was 3.5 (0.09) kg. Mean (SD) arterial and venous cord pH values were 7.32 (0.05) and 7.34 (0.04) respectively. Mean (SD) Apgar scores at 1 and 5 minutes were 8.83 (0.91) and 9.93 (0.25).

Discussion

Significant haemodynamic changes occur in women undergoing caesarean section under spinal anaesthesia. These can be explained by physiological changes occurring after spinal anaesthesia and following delivery and oxytocin administration.[5,8,9] Our study showed that SBP correlated with TPR. The reduction in BP occurring immediately after spinal anaesthesia is due to sympathectomy causing vasodilatation which is reflected in the reduction of TPR resulting in a decrease in afterload. This, together with reduced preload from aortocaval compression and pooling of blood in the splanchnic bed and lower extremities results in the rapid decline of SBP after spinal anaesthesia.[10] CO was maintained following spinal anaesthesia due to the compensatory increase in HR and SV due to increased contractility and reduced afterload.[11] Our study demonstrated an increase in CO of 14% immediately after spinal anaesthesia. In an attempt to maintain SBP after spinal anaesthesia, boluses of phenylephrine, a pure alpha agonist, increased the TPR resulting in a reflex bradycardia. At delivery, there was a sustained increase in CO which can be attributed to the autotransfusion of blood from the placenta[9] and a reduction in TPR (CO correlated negatively with TPR). This is possibly due to the removal of the vascular placental bed and administration of oxytocin, which has a vasodilatory effect.[12]

Despite a fall in SBP (max change in SBP -16%), CO was maintained by preservation of HR at baseline. This was likely due in part to our approach of using a combination of phenylephrine and ephedrine boluses. It has been shown that CO is preserved when BP is maintained during caesarean section in both healthy parturients and those with pre-eclampsia[8,13,14] but little research has focused specifically on HR maintenance as was the case in our observational study. This is despite the fact that HR has previously been shown to highly correlate (r=0.87) with CO (observed also in our study).[5]

The use of vasopressors in the management of spinal hypotension during caesarean section has been extensively studied. Current international guidelines recommend that phenylephrine be the first line agent for managing hypotension following spinal anaesthesia[1] due to its effectiveness and favourable foetal cord pH values compared to ephedrine.[15,16] Phenylephrine however has a known risk of bradycardia with associated drop in CO[4,17] and the incidence of brady-arrythmias during caesarean section may be higher than expected, with severe bradycardia (HR < 50 beats/min) reported in 7% of cases.[18] Several approaches have been investigated to reduce the risk of bradycardias and associated drops in CO. These include use of glycopyrrolate,[19] altering phenylephrine infusion doses[20] and use of noradrenaline[21] or metaraminol[22] as first line agents. Similarly the effects of ephedrine and phenylephrine on CO during caesarean section have been studied[23] but the preservation of HR at baseline (rather than prevention of bradycardia) has not been the focus of these or other studies to our knowledge. The authors acknowledge that limited conclusions on vasopressor use can be drawn from our observational study, given its design. Nonetheless we are reassured that with our protocol of using a combination of ephedrine and phenylephrine boluses resulted in maintenance of CO with no incidences of severe bradycardia and no foetal cord pH value less than the acceptable threshold of 7.2. The authors agree with recommendations that ephedrine still has a role to play in managing hypotension associated with spinal anaesthesia during caesarean section.[1]

The main limitation of our study was that SBP was not maintained at baseline. This was due to our approach of reactive therapy where the vasopressors were only administered when a fall in BP was observed. Proactive vasopressor administration or administration by infusion as recommended by recent guidelines[1] (published after our study was conducted) would likely have resulted in tighter haemodynamic control but greater propensity for bradycardia and hypertension.[24] The effects of tighter BP and HR control on CO could be explored in future studies along with an examination in more at risk groups, such as those with pre-eclampsia and cardiac disease, where the impact of drops in CO may be more clinically significant.[25] Future studies could also make use of a fall of 10% from baselines HR and SBP readings as triggers for intervention versus our approach of using a change in HR and SBP of 5 beats/min and 10 mmHg respectively. This could take account for the wide variability in baseline haemodynamic values within a population. Furthermore, recording data at one-minute intervals following spinal anaesthesia (compared to the five-minute intervals in our study) may have resulted in more accurate plotting of haemodynamic changes immediately following spinal anaesthesia.

Declaration of Conflict of Interests:

The authors have no conflicts of interest to declare

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