INCREMENTAL SPINAL ANAESTHESIA FOR ELECTIVE CAESAREAN SECTION: MATERNAL AND FETAL HAEMODYNAMIC EFFECTS

S. C. ROBSON, G. SAMSOON, R. J. BOYS, C. RODECK AND B. MORGAN

SUMMARY

We have performed serial haemodynamic investigations in 20 women undergoing elective Caesarean section under continuous spinal anaesthesia with a 32-gauge catheter with 0.5% heavy bupivacaine. Cardiac output was measured by Doppler and cross-sectional echocardiography at the aortic valve. Doppler flow velocity waveforms were recorded also from the umbilical artery. A block to 74 or above was achieved in all patients. The median dose of 0.5% bupivacaine administered was 2.0 ml (range 1.5-4.5 ml). Mean cardiac output increased from 7 to 8 litre min
-1 after preloading with Ringer lactate solution 1.5 litre and then remained unchanged after injection of bupivacaine. Two subjects developed hypotension, although mean values of arterial pressure and umbilical artery pulsatility index did not change. The median umbilical artery pH was 7.27 (range 6.98-7.32) and there was a significant correlation between pH and the maximum percentage decrease in cardiac output. The results suggest that continuous spinal anaesthesia is associated with greater haemodynamic stability than single bolus spinal injection. (Br. J. Anaesth. 1993; 70: 634-638)

KEY WORDS


Spinal anaesthesia has several advantages in comparison with extradural anaesthesia for elective Caesarean section; the block is faster and more reliable and, because smaller doses of local anaesthetic are used, the risk of toxicity is reduced [1, 2]. However, decreases in arterial pressure and cardiac output are greater with a single subarachnoid injection and these haemodynamic changes have been associated with alterations in Doppler waveform indices in the umbilical artery and a decrease in umbilical arterial pH at delivery [3,4].

Spinal anaesthesia using a catheter allows incremental injection of local anaesthetic. This produces a more gradual and predictable block which may be associated with a smaller incidence of hypotension [5]. However, changes in arterial pressure do not accurately reflect changes in maternal cardiac output; indeed, we have shown recently that, unlike changes in maternal cardiac output and umbilical artery Doppler flow velocity waveform indices, changes in arterial pressure do not correlate with umbilical arterial pH at delivery [3]. Although several workers have investigated the haemodynamic changes after single injection spinal anaesthesia, comparable studies have not been performed during incremental spinal anaesthesia.

Cardiac output can be calculated from aortic blood velocity, measured by Doppler ultrasound, combined with aortic orifice cross-sectional area, measured by cross-sectional echocardiography. The technique has been validated in pregnancy [6] and allows reproducible, non-invasive measurements of cardiac output [7]. Doppler ultrasound can also be used to assess the fetal umbilical circulation and flow velocity waveform indices have been shown to be superior to cardiotocography in predicting fetal compromise [8]. We have used these techniques to study maternal and fetal haemodynamic changes during incremental subarachnoid injection of bupivacaine for elective Caesarean section.

PATIENTS AND METHODS

We studied 23 healthy women with a singleton pregnancy admitted for elective Caesarean section at term. Three women were excluded subsequently because of failure to insert the subarachnoid catheter. Details of the remaining 20 subjects are shown in table I. The procedure was explained to each subject and written consent was obtained. The study was approved by the local Ethics Committee.

Each subject received oral ranitidine 150 mg on the evening before and on the morning of the operation. Sodium citrate 0.3 mol litre
-1 (30 ml) was given on arrival of the patient in the operating theatre. After insertion of an i.v. cannula, Ringer lactate solution 1 litre was infused over approximately 15 min immediately before anaesthesia. With the subject in the left lateral position, a 25-gauge spinal needle (Becton Dickinson) was introduced into the subarachnoid space at the L3-4 intervertebral space. A 32-gauge catheter (Microspinal) was then threaded, via the needle, 3 cm into the...
The average of eight to 10 from five consecutive beats were averaged and cross-sectional area was calculated from \( \pi(D/2)^2 \), where \( D \) = mean aortic orifice diameter. Cardiac output was calculated from the formula: cardiac output (litre min\(^{-1}\)) = stroke volume (ml) \times \text{heart rate (beat min}^{-1})\), where stroke volume = velocity integral (cm) \times \text{cross-sectional area (cm}^2\).

Flow velocity waveforms from the umbilical artery were recorded using a 4-MHz continuous wave transducer linked to the same spectral analyser. Pulsatility index was calculated automatically by the computer using 15/16 of the maximum recorded frequency. The average of three consecutive cycles was used for each determination.

Investigations were performed in the operating theatre with the subject in the left semi-lateral (45°) position. Doppler recordings were completed in 2–3 min and cross-sectional echocardiographic recordings in 1–2 min. Echocardiographic measurements were performed before any intervention, after pre-loading with Ringer’s lactate solution 1 litre and at 5-min intervals after the initial injection of bupivacaine until the time of preparation for surgery. Arterial pressure measurements were continued during the echocardiographic measurements and the mean of two consecutive measurements was used for analysis.

The time between the initial spinal injection of bupivacaine and the start of surgery and the time between the uterine incision and delivery were recorded. At the time of delivery, the umbilical cord was double clamped. Umbilical arterial and venous samples were collected and pH and blood-gas analysis performed within 10 min of delivery of the infant (Radiometer ABL-30). One- and 5-min Apgar scores were assigned by the paediatrician. All subjects had an uncomplicated Caesarean section with a median blood loss of 500 ml (range 300–750 ml).

The haemodynamic results from the 20 subjects having incremental spinal anaesthesia were compared with those from 16 women undergoing elective Caesarean section under standard, single-bolus spinal anaesthesia (mean dose 0.5% bupivacaine 2.2 (so 0.2) ml). The haemodynamic results in the latter group were obtained using exactly the same methodology; data have been reported previously [3].

### Statistical analysis

A repeated measures analysis of variance was performed for each variable using the statistical package BMDP. To overcome the problem of multiple significance testing, the differences between time points were compared using the Studentized range at the 1 % level:

\[
\text{Range} = q_{\alpha} \times (s^2 / \sqrt{n})
\]

where \( q_{\alpha} \) = critical value for comparing two time points; \( s^2 \) = residual mean square with \( v \) degrees of freedom; \( n \) = number of subjects. Differences between the incremental and standard spinal groups were compared using Student’s \( \bar{t} \) test for normally distributed data and the median test for non-normally distributed data. The association between the change in various haemodynamic variables and umbilical artery pH was assessed by Pearson’s correlation coefficient.
The median dose of 0.5% bupivacaine administered was 2.0 ml (range 1.5–4.5 ml); five subjects required more than 2.5 ml (3.0 ml (n = 3), 3.5 ml (n = 1), 4.5 ml (n = 1)). The number of additional doses required to achieve a block to T4 were: one in four subjects, two in 10 subjects, three in one subject, four in four subjects and five in one subject. A block to T4 or above was achieved by 20 min after the initial injection in 15 subjects (75%). Upper levels of sensory block achieved were: T4 (n = 15); T3 (n = 2); T2 (n = 3). Details of operations and neonates are shown in table II. Hypotension occurred in two of 20 subjects (10%). The umbilical artery pH was < 7.2 in two fetuses (7.19 and 6.98), although in both the 1- and 5-min Apgar scores were normal. Satisfactory Doppler and cross-sectional recordings were obtained in all subjects. The mean results, together with those of arterial pressure are shown in table III. No patient developed hypotension between the completion of the final haemodynamic recordings and delivery. Because of delay in establishing the block, measurements were continued until 20 min in three subjects and 30 min in one subject; cardiac output and umbilical artery pulsatility index remained stable in each. Systolic, diastolic and mean arterial pressure did not change during the study period. Stroke volume and cardiac output increased after preloading and then returned to basal values at 5 min and 10 min, respectively, after the initial dose of bupivacaine. Thereafter there was no further change. Heart rate was increased at 5 min and remained increased. Fetal heart rate was increased at 15 min. No statistically significant changes were observed in umbilical artery pulsatility index.

The maximum percentage change in haemodynamic measurements, expressed as a percentage of the baseline value, after injection of bupivacaine. Where there was no decrease, the minimum increase was used in the analysis. SAP = Systolic arterial pressure; MAP = mean arterial pressure; HR = heart rate; SV = stroke volume; CO = cardiac output.

### Table II. Details of operations and neonates (mean (SD) or median (range))

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Basal</th>
<th>After preload</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>SE</th>
<th>SR†</th>
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</thead>
<tbody>
<tr>
<td>iv. fluid (ml)</td>
<td>1373 (156)</td>
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<tr>
<td>Ephedrine (mg)</td>
<td>22.4 (9.4)</td>
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<tr>
<td>Injection-skin incision</td>
<td>32.5 (25–53)</td>
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<tr>
<td>Uterine incision–delivery</td>
<td>0.9 (0.3)</td>
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<tr>
<td>Umbilical artery pH</td>
<td>7.27 (6.98–7.32)</td>
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<tr>
<td>Pco₂ (kPa)</td>
<td>7.2 (1.0)</td>
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<tr>
<td>Pco₂ (kPa)</td>
<td>2.0 (0.7)</td>
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<tr>
<td>Base excess (mmol litre⁻¹)</td>
<td>–3.5 (–1.7 to –17.3)</td>
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<tr>
<td>Umbilical vein pH</td>
<td>7.33 (7.13 to 7.37)</td>
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<tr>
<td>Pco₂</td>
<td>5.7 (0.5)</td>
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<tr>
<td>Po₂</td>
<td>3.5 (0.9)</td>
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<tr>
<td>Base excess (mmol litre⁻¹)</td>
<td>–3.0 (–1.1 to –14.2)</td>
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<tr>
<td>Apgar &lt; 7 at 1 min</td>
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<tr>
<td>Apgar &lt; 7 at 5 min</td>
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### Table III. Haemodynamic data in the spinal catheter group. † Studentized range. Differences between time points greater than SR significant at P < 0.01

For umbilical artery pulsatility index (UAPI), figures are calculated from the maximum percentage increase. For other variables, figures were calculated from the maximum decrease, expressed as a percentage of the baseline value, after injection of bupivacaine. Where there was no decrease, the minimum increase was used in the analysis. SAP = Systolic arterial pressure; MAP = mean arterial pressure; HR = heart rate; SV = stroke volume; CO = cardiac output.

### Fig. 1 Maximum percentage change in haemodynamic measurements during incremental spinal anaesthesia for elective Caesarean section (n = 20) (□) compared with those previously reported by the authors using similar methodology during standard spinal anaesthesia (n = 16) (□) (median or mean and 95% confidence intervals). Comparison between groups use median test † or Student's t test. For umbilical artery pulsatility index (UAPI), figures are calculated from the maximum percentage increase.
subject who subsequently delivered the only acidaemic infant (umbilical artery pH 6.98, base deficit 17.3 mmol litre\(^{-1}\)). Interestingly, although the cardiotocograph showed reduced baseline variability after this episode, umbilical artery pulsatility index did not change. Comparative data during standard spinal anaesthesia are shown also in figure 1. The maximum percentage decreases in systolic arterial pressure, mean arterial pressure and cardiac output were greater with the standard spinal technique. There was a significant correlation between umbilical artery pH and the maximum percentage decrease in cardiac output \((r = 0.55)\) during incremental spinal anaesthesia, but not with the maximum changes in other haemodynamic measurements.

One subject complained of headache 24 h after operation; she described this as mild, lasting less than 24 h and being relieved by simple analgesics. All the spinal catheters were removed intact. No neurological sequelae were evident in any of the subjects at the time of discharge from hospital.

**DISCUSSION**

The haemodynamic changes associated with spinal anaesthesia represent the greatest potential hazard of this technique for mother and fetus. The results of the present study show that incremental injection of 0.5 \% bupivacaine using a spinal microcatheter provided a satisfactory block, with little alteration in maternal arterial pressure and cardiac output. Fetal umbilical arterial flow velocity waveform indices also remained stable during anaesthesia.

Since the completion of this study, reports of cauda equina syndrome associated with the use of small-bore catheters for continuous spinal anaesthesia have led the Food and Drug Administration in the U.S.A. to recall all spinal microcatheters of 27 gauge and smaller [9]. This complication has been reported in 11 patients in whom a small-bore catheter was used to inject 5 \% lignocaine with 7.5 \% glucose into the intrathecal space. Because of the potential benefits of continuous spinal anaesthesia and because the potential hazards and means of avoiding them are known, the Department of Health have taken the view that small-bore catheters should continue to be made available for use in the U.K. [10].

Rigler and colleagues [11] reported four cases of cauda equina syndrome in which the dose of local anaesthetic given was greater than that usually administered with a single injection technique. The authors postulated that neurotoxicity resulted from a combination of maldistribution and a relatively large dose of local anaesthetic. Several characteristics of microcatheters may permit maldistribution: the greater resistance reduces the maximum rate of injection and the small size and flexibility may increase the risk of unintentional sacral positioning [11]. Ross, Coda and Heath [12] studied local anaesthetic distribution in a spinal model. They showed that distribution of lignocaine was less uniform and lignocaine concentration in the dependent portions of the model greater after injection through microcatheters compared with a 20-gauge catheter. Wildsmith [13] also drew attention to the possibility of osmotic damage. Although large doses of local anaesthetic have been given during continuous spinal anaesthesia without ill effect [14], it would seem prudent, in view of the probable association with neural damage, to avoid doses far in excess of those given during standard single-injection spinal anaesthesia [15].

Kestin and colleagues [5] compared incremental spinal anaesthesia using a 32-gauge catheter with extradural anaesthesia in women undergoing elective Caesarean section. The spinal catheter was quicker to place and spinal anaesthesia was quicker to establish compared with the extradural technique. Haemodynamic stability and the quality of the block were similar in the two groups. As no previous study had compared haemodynamic changes during continuous and single injection spinal anaesthesia for Caesarean section, we compared the present results with those from 16 previously reported women given a single bolus of 0.5 \% bupivacaine [3]. Both groups received the same preload and ephedrine regimen and both had identical measurements performed at the same time points. We therefore felt this was an appropriate comparison. Single bolus injection of bupivacaine was associated with greater reductions in arterial pressure and cardiac output. The incidence of hypotension (decrease in systolic pressure > 20 \%) was also greater in the single bolus group (11 of 16 compared with two of 20 \((P < 0.01))\). These changes were associated with a tendency towards improved umbilical arterial acid-base values in the incremental group (median pH 7.27 (range 6.98–7.32) compared with 7.23 (7.02–7.32) \((P = 0.09)\) and base deficit 5.2 (1.8–15.7) mmol litre\(^{-1}\) compared with 3.5 (1.7–17.3) mmol litre\(^{-1}\) \((P < 0.05)\), respectively). Thus continuous spinal anaesthesia was associated with greater haemodynamic stability and a slight improvement in fetal blood-gas tensions.

The median dose of intrathecal bupivacaine administered was 2.0 ml. Kestin and colleagues [5] gave a mean dose of 2.7 ml (range 1.5–7.4 ml) to achieve a similar level of block (T4). We felt that their initial dose (1.5 ml) was too large, as three of 20 women had a sensory block to T3 after this dose. Five women in the present study required more than 2.5 ml of bupivacaine and in each an adequate block was not achieved within 30 min. Kestin’s group [5] also reported some patients who needed several increments of bupivacaine: one subject required a total of 7.4 ml. As an alternative to continued administration of the same local anaesthetic, various manoeuvres have been advocated, such as changing patient position, manipulating catheter position and switching to a different local anaesthetic [15, 16].

While the first two of these seem reasonable, there is no evidence to suggest that administration of a second drug is safer than additional doses of the first.

Much attention regarding the use of continuous spinal anaesthesia has been directed at the difficulties encountered inserting the 32-gauge catheter and the risk of postdural puncture headache. Most technical "failures" have been related to catheter kinking [17, 18]. We encountered this problem in three subjects (13\%)—a rate consistent with the preliminary
experience of other workers [17, 19]. With further experience, the failure rate appears to decrease to < 5% [5]. Although the present series was small, no subject developed a headache typical of dural puncture. The incidence of postdural puncture headache with spinal catheters has varied from 1% to 10% [4, 5]. However, there have been no sizable studies of the use of 32-gauge catheters in obstetric patients to enable the true incidence of postdural puncture headache to be determined.

In conclusion, the results of the present study suggest that continuous spinal anaesthesia combines the reliability of subarachnoid injection and the advantages of repeatability, without the risk of reduction in maternal cardiac output and fetal pH. While these attributes may be valuable in some clinical situations, the advantages must be balanced against the increased cost of technique and the possible risk of neurotoxicity if excessive doses of local anaesthetic are required.

REFERENCES