FETAL BLOOD FLOW DURING INTRATHecal ANAESTHESIA FOR ELECTIVE CAESAREAN SECTION

A. LINDBLAD, J. BERNOW AND K. MARŠÁL

During the past two decades there has been an increase in the incidence of elective Caesarean section, both in Europe and in the U.S.A. There has also been a growing desire among mothers to remain awake during the operative delivery of their infant. Apart from a beneficial psychological effect, the risk of regurgitation and aspiration is reduced when the mother is awake. Although extradural anaesthesia is the regional technique most commonly used for Caesarean section, spinal (intrathecal) anaesthesia might be an alternative when rapid and more profound analgesia is required. In two previous studies, in which a combined ultrasound and Doppler method was used to record fetal blood flow during extradural anaesthesia for Caesarean section, we found that the fetal circulation remained stable and within normal limits, indicating that extradural anaesthesia is safe for the fetus as long as maternal hypotension is avoided [1,2]. With spinal anaesthesia, however, there is a higher risk than with extradural anaesthesia of associated maternal hypotension with a consequent risk of decreases in perfusion pressure both in the uterine vessels and in the placental vascular bed. Hypotension associated with spinal anaesthesia might be prevented by a combination of pre-loading and the infusion of ephedrine. The aim of this study was, by means of the same combined ultrasound and Doppler technique, to ascertain whether the fetal circulation is affected when spinal (intrathecal) anaesthesia is used along with pre-loading and the infusion of ephedrine.

SUMMARY

Fetal aortic and umbilical blood flows were studied in 15 mothers before and during spinal (intrathecal) anaesthesia for elective Caesarean section, using a method combining real-time ultrasonography and a pulsed Doppler technique. Spinal anaesthesia with 0.5% bupivacaine hydrochloride 2.5 ml in 8% glucose monohydrate solution was administered after pre-loading with 2 litre of lactated Ringer’s solution. Simultaneously with the subarachnoid injection, an infusion i.v. of ephedrine 50 mg in 500 ml normal saline was initiated. Maternal heart rate and systolic arterial pressure remained stable during the spinal anaesthesia, but diastolic arterial pressure decreased (P < 0.05). Fetal heart rate increased (P < 0.05) 30 min after the introduction of the spinal anaesthesia, but blood flows in the fetal descending aorta and umbilical vein were unaffected. The pulsatility index of the fetal blood velocity decreased (P < 0.05) both in the fetal aorta and in the umbilical artery 30 min after induction of the spinal anaesthesia, indicating a possible decrease in the placental vascular resistance. We conclude that, when normotension is maintained in the mother with a preload infusion and an infusion of ephedrine, spinal anaesthesia for Caesarean section has no harmful effect on the fetal circulation.

PATIENTS AND METHODS

Fifteen pregnant women scheduled for elective Caesarean section participated in the study, which was approved by the Ethics Committee of the Medical Faculty, University of Lund. Informed consent was obtained from all participants who comprised a homogeneous group with regard to age, weight, height and gestational age (means (SD): 30 (4.6) yr, 75.8 (13.5) kg, 163 (10.2) cm, 38
The indications for Caesarean section were cephalo-pelvic disproportion \( (n = 11) \), bad obstetric history \( (n = 2) \), placenta praevia \( (n = 1) \) and cervical myoma \( (n = 1) \). All newborns were term with birthweights appropriate to their gestational ages \( (3331 \pm 578 \text{ g}) \).

The patients, lying in bed and tilted 15° to the left, received prehydration with an i.v. infusion of lactated Ringer's solution 2 litre over a 20-min period. No premedication was given. An extradural catheter was inserted at the L1-2 space, and a 26-gauge spinal needle at the L3-4 space with the patient in the sitting position. A dose of 0.5 % bupivacaine hydrochloride 2.5 ml in 8 % glucose monohydrate solution (Marcain heavy, Astra, Sweden) was injected without barbotage through the spinal needle with the patient still in the sitting position. Simultaneously, an i.v. infusion of ephedrine 50 mg in normal saline 500 ml was started at a rate of 0.15 mg min\(^{-1}\). Immediately after the spinal injection, the mother resumed the supine position tilted 15° to the left, to avoid aorto—caval compression. Maternal heart rate was recorded continuously by cardioscope. Maternal systolic and diastolic arterial pressures were measured by a sphygmomanometer twice before prehydration and at 1-min intervals for the first 15 min after the induction of spinal anaesthesia, and every 2.5 min thereafter. By adjusting the rate of the i.v. infusion of ephedrine, the anaesthetist aimed to maintain maternal systolic arterial pressure within 90–100 % of its initial value. The cephalad spread of the sensory block was tested by pin-prick, using the blunt end of a 27-gauge Brunswick dental needle, at 5, 15, 30 and 60 min after the subarachnoid injection. Motor blockade was assessed on the basis of motor function in the legs at the same intervals as for the sensory block, using Bromage scale \( (1 = \text{inability to move feet or knees}; 2 = \text{ability to move feet only}; 3 = \text{just able to move knees}; 4 = \text{full flexion of knees and feet}) \) [3].

Before prehydration and 15 and 30 min after the induction of spinal anaesthesia, blood velocity and vessel diameters were measured in the fetal descending aorta above the level of the diaphragm and in the intra-abdominal part of the umbilical vein, using the ultrasound method described by Eik-Nes and colleagues [4]. Blood velocity was also recorded in the umbilical artery in the umbilical cord. Fetal heart rate was counted from the blood velocity traces. The ultrasound method combines a real-time linear array scanner (ADR, Model 2130, Advanced Diagnostic Research Corporation, Tempe, Arizona; 3.5 MHz), and a pulsed Doppler instrument (Alfred, Vingmed A/S, Oslo, Norway; 2.0 MHz). The ultrasound intensities used were within recommended limits [5]. The Doppler transducer was attached to the real-time transducer at a fixed angle of 45°, thus enabling correction of the recorded blood velocity for the angle. A 100-Hz high-pass filtering of the
Segmented spread of analgesia and motor blockade 5, 15, 30 and 60 min after induction of spinal anaesthesia. * 1 = inability to move feet and knees; 2 = ability to move feet only; 3 = just able to move knees; 4 = full flexion of knees and feet

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Sensory analgesia</th>
<th>Motor blockade*</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Median Range</td>
<td>Median Range</td>
</tr>
<tr>
<td>5</td>
<td>T9 T7-10</td>
<td>2 1-3</td>
</tr>
<tr>
<td>15</td>
<td>T5 T2-8</td>
<td>1 1-2</td>
</tr>
<tr>
<td>30</td>
<td>T3 T2-5</td>
<td>1 1-2</td>
</tr>
<tr>
<td>60</td>
<td>T5.5 T4-7</td>
<td>1 1-2</td>
</tr>
</tbody>
</table>

Doppler signal was used. Blood flow \( (\dot{Q}) \) was calculated according to the formula \( \dot{Q} = V \cdot A / \cos 45^\circ \), where \( V \) = blood velocity and \( A \) = vessel area. The blood flow values were related to the weight of the fetus at delivery and expressed in ml min\(^{-1}\) kg\(^{-1}\). The waveform of the maximum velocity curves recorded from the fetal aorta was analysed by computer (ABC 806, Luxor, Motala, Sweden), and characterized by the pulsatility index (PI) [6] and rising slope (RS) [7] (fig. 1). Blood flow calculations and waveform analysis were based on Doppler traces of at least 10 s duration obtained under steady-state conditions without breathing or gross movement of the fetus.

Immediately after completion of measurements, the mother was transferred to the operating theatre. Oxygen 4 litre min\(^{-1}\) was administered via nasal cannulae. Dixyrazine (a phenothiazine with a piperazine side-chain) 10 mg was given i.v. after delivery to prevent nausea. As the induction–delivery interval was prolonged by the taking of fetal blood flow measurements, 2 % lignocaine with adrenaline 12.5 μg ml\(^{-1}\), was administered via the extradural catheter after delivery, when necessary. Midazolam 2.5–5 mg was given i.v. after delivery if sedation was required.

The condition of the newborn was evaluated by estimating cord blood pH and Apgar score. All women were interviewed on the second day after operation and any postoperative complications noted.

The results were analysed statistically using the \( t \) test for paired observations, \( P < 0.05 \) being considered significant.

**RESULTS**

Spread of the spinal anaesthesia is presented in table I.

**Duration of the spinal anaesthesia.** Supplementary extradural analgesia was administered on average 82 (SD 6) min after the induction of the spinal anaesthesia in 10 women. Their mean induction–delivery interval was 72 (8) min. The mean induction–delivery interval for the five women not requiring additional extradural analgesia was 60 (12) min.

**Supplementary medication.** Before delivery all women received an infusion of ephedrine to maintain systolic arterial pressure, the mean (SD) dose being 37.2 (12.6) mg given during 42 (14) min after the induction of spinal anaesthesia. After delivery, all women received dixyrazine 10 mg to prevent nausea; nonetheless, five women developed nausea and received another mean dose of dixyrazine 9 (2.2) mg. Eight women who wanted sedation after delivery received a mean dose of midazolam 3.3 (1.2) mg.

**Maternal effects** are given in table II. During spinal anaesthesia, no incidents of hypotension (systolic arterial pressure less than 90 mm Hg) were recorded. One woman developed spinal headache on the first day after operation, and was successfully treated with an extradural blood patch on the fourth day after operation. At the postoperative interview all women declared themselves content with the spinal anaesthesia.

**TABLE II. Maternal circulatory variables (mean (SD)) before, 15 and 30 min after induction of spinal anaesthesia**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>15 min</th>
<th>30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (beat min(^{-1}))</td>
<td>86.2 (2.7)</td>
<td>90.5 (3.0)</td>
<td>89.3 (3.1)</td>
</tr>
<tr>
<td>Systolic arterial pressure (mm Hg)</td>
<td>121.3 (2.4)</td>
<td>119.3 (2.5)</td>
<td>119.3 (2.6)</td>
</tr>
<tr>
<td>Diastolic arterial pressure (mm Hg)</td>
<td>74.7 (2.6)</td>
<td>69.3 (2.7)</td>
<td>69.0 (2.2)</td>
</tr>
</tbody>
</table>

\( P = 0.017 \quad P = 0.006 \)
Effects on the fetus are given in table III.

Neonatal variables. The mean (SD) umbilical venous and arterial pH were 7.29 (0.07) and 7.23 (0.09), respectively. All newborns had Apgar scores of ≥9 at 1 and 5 min. One newborn developed icterus and was treated at the neonatal unit for 2 days.

DISCUSSION

Spinal anaesthesia is easily administered, has a rapid onset of action, high success rate and gives profound blockade. This applies also when the spinal block is applied for obstetric analgesia. Moreover, owing to the small amounts of local anaesthetic used, placental transfer and fetal uptake of the drug used are negligible. The duration of block is limited, however, and may be shorter than that of surgery. As the measurements of fetal blood flow increased the induction-delivery interval, the mothers in the present study were prepared in advance for supplementary extradural block should the spinal block wear off before the completion of surgery. Ten of the fifteen women required this additional extradural block.

Spinal anaesthesia is more commonly accompanied by arterial hypotension, with consequent risk to the fetus [8-10]. Preventive measures such as prehydration and left uterine displacement may reduce this figure slightly [11,12]. Kang, Abouleish and Caritis [13], adding ephedrine infusion to the regimen of prehydration and left uterine displacement, found that maternal arterial pressure could be kept close to pre-anaesthetic values. In the present study, where a 2-litre preload and ephedrine infusion were used, the maternal circulation remained essentially unchanged after the induction of spinal anaesthesia and no hypotensive episodes occurred. On the other hand, vaso-pressors may cause impairment of uterine blood flow [14,15]. Ephedrine, however, does not affect uterine blood flow in pregnant sheep [16] nor placental blood flow in women [17]. Ephedrine is transferred across the human placenta and fetal tachycardia has been reported by Wright and colleagues [18]. A certain fetal uptake of ephedrine in the present study is implied by our finding of an increased fetal heart rate 30 min after induction of spinal anaesthesia.

Because of the high incidence of hypotension during spinal anaesthesia, it is our belief that spinal anaesthesia should be combined with a fluid preload and an infusion of ephedrine. In this study we wished to examine the possible effects of this technique (using spinal anaesthesia, preload and ephedrine infusion) on the fetal circulation with the non-invasive Doppler ultrasound technique. In our opinion it would have been unethical to use a control group of patients who did not receive ephedrine. In this study, each woman and
fetus served as their own controls comparing the maternal and fetal haemodynamics before and after the regimen used. It would have been possible to measure fetal blood flow before and after preloading, after the start of the ephedrine infusion and, finally, after induction of the spinal anaesthesia. However, as the measurements of volume blood flow take some time, this would have been inconvenient to the patients, the effect of the preload might have been lessened and the amount of ephedrine required for maintenance of maternal normotension would probably have been increased.

The estimation of fetal blood flow and analysis of the blood velocity waveform by means of a combined ultrasound and Doppler technique [4] is now an established method of evaluating fetal status in utero. The validity and reproducibility of the technique has been studied both in vitro [19] and in vivo [20]. It allows for the very early detection of impending fetal asphyxia and has certain advantages over cardiotocography in this respect [21,22]. The technique has also been applied in studies of the effects on fetal circulation of drugs commonly used in pregnancy and labour [23–25]. In a previous study, we used the method for the study of fetal blood flow during extradural anaesthesia [2].

There have been no reports of studies on fetal circulation during spinal anaesthesia. Placental blood flow during spinal anaesthesia was studied by Jouppila and colleagues [12], who found no change in placental blood flow despite significant decreases in mean systolic and diastolic arterial pressures; they concluded that pre-loading with 1.5–2.0 litre of crystalloid, combined with infusion of ephedrine 50 mg in Ringer’s solution 500 ml if systolic arterial pressure decreased, could prevent decrease in placental blood flow despite a moderate decrease in maternal arterial pressure. In the present investigation, fetal aortic and umbilical vein blood flow remained unchanged during spinal anaesthesia when maternal arterial pressure was kept stable by prehydration and an infusion of ephedrine. Rising slope (RS) of the maximum velocity waveform in the descending aorta was shown, in animal experiments, to reflect myocardial contractility [26]; in the present study RS remained unchanged both in the aorta and in the umbilical artery. The pulsatility index (PI), which is said to mirror the impedance of the arterial vascular bed distal to the site of measurement [7,27] was moderately reduced, both in the fetal aorta and in the umbilical artery. The decrease in PI in the aorta could not be explained by the known slight decrease in PI seen with increasing fetal heart rate [5]; in the umbilical artery fetal heart rate does not affect the values of PI [28,29]. Thus this decrease in PI suggests that there was a real decrease in the placental vascular resistance. This decrease might reflect effects of the sympathetic block of the spinal anaesthesia or of the regimen used (preload, ephedrine infusion and spinal anaesthesia) on the myometrial and placental vascular bed.

We conclude that spinal anaesthesia, in combination with prehydration and an infusion of ephedrine, caused minor changes in maternal diastolic arterial pressure, fetal heart rate and pulsatility index of the fetal aortic and umbilical blood velocity, but gave rise to no harmful effects on the fetal circulation.

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REFERENCES


