Spinal Anesthesia with an Indwelling Catheter Reduces the Stress Response in Pediatric Open Heart Surgery

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Background: Extreme stress and inflammatory responses to open heart surgery are associated with increased morbidity and mortality. Based on both animal and adult human data, it was hypothesized that spinal anesthesia would be more effective at attenuating these responses than conventional high dose intravenous opioid techniques in infants and young children undergoing open heart surgery.

Methods: A prospective randomized controlled clinical trial was performed in 60 children aged up to 24 months undergoing open heart surgery. Patients were randomly assigned to receive either high-dose intravenous opioid or high-dose intravenous opioid plus spinal anesthesia. Spinal anesthesia was administered via an indwelling intrathecal catheter.

Results: Spinal anesthesia significantly reduced the stress responses as measured by plasma norepinephrine and epinephrine concentrations (both \( P < 0.05 \)). Spinal anesthesia reduced plasma lactate concentrations (\( P < 0.05 \)), but increased fluid requirements during the first postoperative day (\( P < 0.05 \)). There were no differences in other cardiovascular parameters.

Conclusions: Continuous spinal anesthesia reduces stress responses in infants and young children undergoing cardiac surgery with cardiopulmonary bypass more effectively than high-dose intravenous opioids alone.

INFANTS and children undergoing cardiac surgery mount a substantial stress response, and in neonates, this has been shown to be associated with adverse outcome. High-dose intravenous opioid techniques can reduce or even eliminate these responses to nonbypass surgery, but they remain substantial during and after cardiopulmonary bypass (CPB), even when large doses of opioids are used. Nevertheless, partial suppression with opioids can improve markers of myocardial damage in adults and reduce morbidity and mortality in neonates. CPB is also associated with a profound inflammatory response that is in part related to the stress response. Both \textit{in vitro} and \textit{in vivo} studies have demonstrated that catecholamines increase the expression of proinflammatory cytokines such as interleukin (IL)-6, and high serum concentrations of IL-6 have been correlated with increased morbidity after CPB in infants and children. Therefore, techniques that can improve the control of stress, and hence indirectly inflammation, have the potential to improve outcome in pediatric cardiac surgery with CPB.

There are strong indications from the adult literature that both epidural and spinal techniques may confer advantages in terms of hemodynamic response, stress response, myocardial damage, and markers of postoperative recovery. Animal data has shown that the use of high spinal local anesthesia delivered to fetal lambs before bypass is better than other systemic techniques at improving survival. Two recent retrospective reports have described the use of regional techniques in pediatric cardiac surgery and have suggested an outcome benefit, but expert commentaries have indicated that these are not techniques that should be adopted without careful objective measurement of risk versus benefit. We have developed a regional technique using a spinal catheter that is inserted before surgery, which provides high spinal anesthesia during surgery and continuous regional analgesia in the postoperative period. In what we believe to be the first prospective comparative evaluation of regional anesthesia with an indwelling intrathecal catheter for pediatric cardiac surgery, we have evaluated this technique against high-dose intravenous opioid anesthesia in a randomized controlled trial in infants and children aged up to 2 yr undergoing open heart surgery to determine whether it provides more effective control of the stress response.

Materials and Methods

Patients and Samples

This trial was conducted after institutional review committee approval (United Bristol Healthcare Trust, Bristol, United Kingdom). Children aged up to 2 yr, undergoing elective cardiac surgery with CPB, were enrolled in the study after informed written parental consent. Patients were randomly assigned by sealed envelope to receive either spinal or opioid anesthesia.

Patients were excluded if they had known spinal or motor developmental abnormalities or were pre-stressed (e.g., ventilated or receiving inotropic support). Children
receiving anticoagulants or with thrombocytopenia were excluded to minimize risk of peridural hematoma.

Blood samples were drawn after induction of anesthesia, at removal of the cross clamp, and 30 min, 2 h, 6 h, and 24 h later. Samples on bypass were taken from the venous side of the CPB circuit, and all other samples were taken from an indwelling arterial catheter. Samples were collected into ice-chilled, pyrogen-free bottles containing EDTA or lithium heparin and were spun immediately at 2,500g, 4°C, for 15 min before being stored in aliquots in pyrogen-free containers at −80°C until batch analysis.

**Anesthetic Regimens**

In both groups, anesthesia was induced in the anesthetic room adjacent to theater using either sevoflurane (1–4%) or intravenous midazolam. Patients had full vital sign monitoring during induction. Pancuronium bromide (0.2 mg/kg) was administered to facilitate intubation. Anesthesia was maintained using isoflurane (0–1%). Fentanyl was administered as a bolus of 5 µg/kg intravenously, and an infusion commenced at a rate of 25 µg·kg⁻¹·h⁻¹. After 1 h, the infusion was slowed to a rate of 10 µg·kg⁻¹·h⁻¹. All patients were given gentamicin (4 mg/kg), fluclodaxilin (30 mg/kg), and dexamethasone (0.5 mg/kg) before the start of surgery.

In the spinal group, a 22-gauge Sprotte spinal needle was introduced at the fourth lumbar interspace, with the side port directed cranially. When a clear flow of cerebrospinal fluid was obtained, a 28-gauge spinal catheter was introduced a short distance (1–2 cm) into the subarachnoid space. The patient was transferred to the operating room, and the spinal catheter was loaded with a bolus of 20 µg/kg preservative-free morphine before the start of surgery.

Midazolam (0.5 mg/kg) and pancuronium bromide (0.2 mg/kg) were added to the pump prime in both groups. On starting bypass, the patients randomly assigned to spinal anesthesia received an intrathecal bupivacaine bolus (0.5 ml/kg of 0.25%), and the fentanyl infusion was discontinued. A further dose of intrathecal bupivacaine (0.2 ml/kg of 0.25%) was given during rewarming. Patients randomly assigned to opioid anesthesia continued with a fentanyl infusion throughout bypass and before decannulation.

In the spinal group, postoperative analgesia consisted of an intrathecal infusion via the spinal catheter of a solution containing 0.125% bupivacaine and 30 µg/ml morphine run at a fixed rate of 0.1 ml/h (125 µg·kg⁻¹·h⁻¹ bupivacaine and 3 µg·kg⁻¹·h⁻¹ morphine). Spinal catheters were retained for 24–48 h postoperatively and were removed when normal coagulation and platelet count had been confirmed. Postoperative analgesia in the opioid group was provided by an intravenous morphine infusion (10–40 µg·kg⁻¹·h⁻¹) according to unit protocols. Intravenous midazolam (0–300 µg·kg⁻¹·h⁻¹) was given to both groups for sedation as required. Any additional fluids (above intravenous maintenance) were given according to the standard unit practice, based on hemodynamic variables and clinical assessment, by the physician intensivists who were independent (but not blinded to the group allocation).

**Analytical Procedures**

Catecholamines were extracted from plasma using an alumina-based technique with 3,4-dihydroxybenzylamine (ESA Analytical, Ltd., Aylesbury, United Kingdom) as an internal standard. Extract concentrations of norepinephrine and epinephrine were determined using high-performance liquid chromatography with electrochemical detection using a Luna 3-µm C-18 150 × 4.6-mm column (Phenomenex Ltd., Macclesfield, United Kingdom). Mobile phase composition was 20 mM sodium dihydrogen phosphate, 900 mg/l octanesulfonic acid, and 2 mg/l ethylenediaminetetraacetic acid (Sigma Aldrich, Poole, UK) in double-distilled water, with 8% acetonitrile and 8% methanol (BDH, Poole, United Kingdom). After mixing, the pH was adjusted to 3.71 with 10% orthophosphoric acid (Sigma Aldrich). High-performance liquid chromatography calibration was performed using commercial standards (ESA Analytical, Ltd.).

Plasma cytokines IL-6, IL-8, and IL-10 and tumor necrosis factor α were measured using commercial kits according to the manufacturer’s instructions (Amersham Biosciences UK Ltd., Little Chalfont, United Kingdom). Plasma cortisol was measured using a commercial chemiluminescent assay (Diagnostic Products Corp. Ltd., Llanberis, United Kingdom).

**Statistical Analysis**

This was performed on an intention to treat basis using StatView® personal computing package (SAS Institute Inc, Cary, NC). Catecholamine, lactate, and cytokine data were normalized by logarithmic transformation for analysis. Intragroup analysis was performed by the use of paired t tests with Bonferroni correction. Intergroup analysis was performed using unpaired t tests with Bonferroni correction, chi-square tests with Fisher correction, and Mann–Whitney tests as appropriate. Intergroup analyses of time series data were performed using repeated-measures analysis of variance. Statistical significance was taken as a P value of less than 0.05. The sample size chosen gave a 90% chance of detecting a 50% reduction in plasma noradrenaline concentrations significant at the 0.05 level based on previously published data. A much
larger sample size would be required to compare the efficacy of the technique in relation to clinical outcomes.

Results

Clinical Parameters

Sixty patients were recruited, 30 in each intervention group. The groups were similar in preoperative diagnosis, patient demographics, and operative characteristics (tables 1 and 2). Times to extubation did not differ significantly between the groups. One patient who failed extubation and was found to have a residual ventricular septal defect necessitating reoperation within the first 24 h was excluded from the extubation time analysis.

There were no differences between anesthetic techniques in postoperative inotrope requirements during the first 12 h as assessed by inotrope score, a score that provides a weighted score of inotrope requirements according to clinical potency. There were no significant differences in postoperative heart rate or blood pressure (figs. 1A and B, respectively). Although day 1 postoperative fluid requirements were greater in the spinal group (median, 24.4 vs. 11.7 ml/kg; \( P = 0.019 \)), urine output and blood loss were similar (table 2).

We achieved a high-level blockade intraoperatively as was evident by the observation of dilated pupils in the spinal group. This blockade regressed rapidly in the postoperative period, although three patients had transient pupillary asymmetry at admission to the intensive care unit. The spinal technique was associated with satisfactory postoperative analgesia, with only a single patient having the spinal infusion replaced by intravenous opiates at 10 h postoperatively. There were no failed intrathecal catheter insertions. A minimal cerebrospinal fluid leak was observed in the majority of patients with spinal catheters and was sufficient to necessitate dressing change in three patients. All leaks resolved with the removal of the intrathecal catheter.

Plasma Catecholamines and Cortisol

Plasma norepinephrine concentrations (fig. 2A) increased from baseline in the intravenous opioid group, being significantly higher by 30 min after cross clamp removal (\( P < 0.0001 \)) and peaking at 2 h after cross clamp removal (\( P = 0.0008 \)). In contrast, in the spinal group, plasma norepinephrine concentrations decreased initially and did not increase significantly until 2 h after cross clamp removal (\( P = 0.005 \)). Plasma norepinephrine concentrations were significantly lower in the spinal group at cross clamp removal and 30 min later (\( P =

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Table 1. Patient Operations

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Spinal</th>
<th>Intravenous</th>
</tr>
</thead>
<tbody>
<tr>
<td>VSD closure</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>VSD closure and mitral valve repair</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>ASD closure</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>ASD closure and pulmonary valve dilatation</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>ASD and VSD closure</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>VSD closure and pulmonary artery reconstruction</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>VSD closure and relief of pulmonary stenosis</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Complete repair of tetralogy of Fallot</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Arterial switch</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Arterial switch and VSD closure</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Atrioventricular canal repair</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Truncus arteriosus repair</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Repair of double outlet right ventricle</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Atrioventricular valve repair</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Closure of aortopulmonary window</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Aortic valvotomy</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Repair of partial atriocventricular canal</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Glenn shunt, pulmonary valve repair, and right</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ventricular muscle resection</td>
<td>Total</td>
<td>30</td>
</tr>
</tbody>
</table>

Distribution of surgical procedures by anesthetic technique.

ASD = atrioseptal defect; VSD = ventriculoseptal defect.

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Table 2. Patient Characteristics and Outcome

<table>
<thead>
<tr>
<th></th>
<th>Spinal</th>
<th>Intravenous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>IQR</td>
</tr>
<tr>
<td>Weight</td>
<td>5.85</td>
<td>(4.3–8.2)</td>
</tr>
<tr>
<td>Age in days</td>
<td>179</td>
<td>(78–315)</td>
</tr>
<tr>
<td>Male sex</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>Trisomy 21</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Bypass time, min</td>
<td>71</td>
<td>(52–112)</td>
</tr>
<tr>
<td>Cross clamp time, min</td>
<td>42</td>
<td>(31–65)</td>
</tr>
<tr>
<td>Time to extubation, days</td>
<td>1.08</td>
<td>(0.8–1.9)</td>
</tr>
<tr>
<td>Mean inotrope score, first 12 h</td>
<td>5.85</td>
<td>(5.0–10.0)</td>
</tr>
<tr>
<td>Fluid bolus, ml/kg on day 1</td>
<td>24.4</td>
<td>(14.8–35)</td>
</tr>
<tr>
<td>Blood loss, ml/kg on day 1</td>
<td>8.8</td>
<td>(6.1–13.8)</td>
</tr>
<tr>
<td>Urine output, ml/kg on day 1</td>
<td>26.5</td>
<td>(19.6–37.8)</td>
</tr>
</tbody>
</table>

Patient characteristics and outcome by anesthetic intervention.

* \( P < 0.05 \).

IQR = interquartile range.
0.0014 and $P = 0.0051$, respectively). Overall plasma norepinephrine concentrations were significantly lower in the spinal group ($n = 59$; $P = 0.0085$, repeated-measures analysis of variance).

Plasma epinephrine (fig. 2B) concentrations increased significantly in the opioid group at cross clamp removal and 30 min later ($P = 0.0038$ and $P = 0.0095$, respectively). There was no significant change in plasma epinephrine from baseline in the spinal group at any time point. Plasma epinephrine concentrations were significantly lower in the spinal than the intravenous opioid group at cross clamp removal ($P = 0.0033$). Overall plasma epinephrine concentrations were significantly lower in the spinal group ($n = 59$; $P = 0.0173$, repeated-measures analysis of variance).

Plasma cortisol (fig. 2C) decreased after induction of anesthesia in both groups, reaching significance at cross clamp removal in the spinal group ($P = 0.0001$) and at 30 min after cross clamp removal in the opioid group ($P < 0.0001$). Plasma concentrations continued to decrease postoperatively in both groups and remained significantly lower until 6 h after cross clamp removal ($P < 0.005$ at all points). Plasma cortisol returned to baseline in the spinal group at 24 h after cross clamp removal but remained suppressed in the intravenous opioid group ($P = 0.007$). There were no significant differences between the groups at any time point or overall.

**Lactate**

Lactate concentrations (fig. 3) increased in both groups after commencement of CPB. Repeated-measures analysis of variance analysis indicated a significant group effect, with lower plasma lactate concentrations in the spinal group ($n = 60$; $P = 0.049$).

**Inflammatory Markers**

Plasma IL-6 (fig. 4A) increased significantly at 2 h after cross clamp removal ($P = 0.0001$) in both groups and...
remained increased throughout the duration of the study. Plasma IL-8 (fig. 4B) and IL-10 (fig. 4C) concentrations increased significantly in both groups, peaking at 2 h after cross clamp removal, and then remained increased throughout the study. There was no group effect. Tumor necrosis factor $\alpha$ was measured in the first 20 patients, but there was no detectable increase with surgery in either group. This was in accord with previous reports, and further analysis was discontinued.

Although there were no significant differences found between the mean values of IL-6 between the groups, the distributions of plasma IL-6 at 24 h differed significantly between the groups ($P = 0.034$), with greater variability in the intravenous opioid group (fig. 4D).

**Adverse Events**

There was one death in the study. A 2.6-kg infant with type II truncus arteriosus (spinal group), with a regurgitant truncal valve, died 72 days postoperatively. Postoperatively, he was found to have severe pulmonary stenosis distal to the conduit, causing right ventricular failure. It was unrelied by insertion of bilateral pulmonary arterial stents. He eventually died of peritonitis and systemic sepsis, having never been extubated. One infant, who had undergone a repair of tetralogy of Fallot (spinal group), had development of hypotension and sepsis on the third postoperative day secondary to thrombosis of the middle colic artery. His hemodynamics on bypass and in the early postoperative phase were unremarkable, but he subsequently had development of restrictive right ventricular physiology. After laparotomy, he was neurologically abnormal. Magnetic resonance imaging of his brain and spine showed a normal spinal cord but ischemic changes in his basal ganglia. He was discharged home, with residual neurologic impairment. Neither of these patients had uncontrolled vasodilation either on bypass or during the early postoperative phase. These cases were discussed thoroughly at the routine multidisciplinary mortality and morbidity meeting.

**Discussion**

This is the first study showing that spinal anesthesia is more effective than intravenous opioid anesthesia at controlling the stress response to CPB in pediatric patients undergoing cardiac surgery. Spinal anesthesia can effectively eliminate the intraoperative increase in
plasma norepinephrine and epinephrine during the critical period of myocardial ischemia and reperfusion as well as providing adequate postoperative analgesia.

The continued popularity of high-dose opioid techniques in pediatric cardiac surgery is based on studies that have demonstrated moderation of hemodynamic and stress responses with improved postoperative recovery and reduced mortality compared with lower doses. However, although opioids can effectively eliminate stress responses to nonbypass surgery, even very large doses of opioids do not suppress the increases in cortisol and catecholamines associated with pediatric CPB. High-dose opioid techniques are often avoided in simple cardiac procedures to facilitate early extubation. We chose to use high-dose opioids to determine the added effects on spinal anesthesia on the stress response against the current best-case stress-controlling technique. However, spinal anesthesia has a relatively short duration and can provide conditions for early extubation in suitable patients. The extubation times in this study reflect the current policy of the attending physicians rather than delayed recovery after anesthesia. The postoperative intrathecal spinal infusion did not seem to delay extubation: Patients who had been extubated after surgery continued on this analgesic regimen until discharge from the pediatric intensive care unit or routine removal between 24 and 48 h postoperatively. We have shown that central neuraxial blockade offers an alternative approach to control of stress responses to CPB.

There is good evidence that increased sympathetic activity and the effects of increased endogenous catecholamines are harmful to the postischemic heart. Adult studies have demonstrated that thoracic epidural anesthesia can reduce plasma catecholamines and limit both myocardial ischemia and damage after cardiac surgery. Adult studies of high spinal anesthesia for cardiac surgery have shown increased cardiac index and reduced systemic and pulmonary vascular resistance compared with opioid techniques, but at the expense of lower systemic blood pressure and increased vasoconstrictor requirements. We chose not to administer drugs via the spinal catheter until aortic cannulation to facilitate treatment of hypotension, but in contrast to adult studies, we have observed no differences in heart rate, blood pressure, or inotrope requirements between the groups. This is in keeping with previous pediatric studies of high spinal anesthesia in cardiac surgery, demonstrating that younger children have minimal reduction in blood pressure even after extensive sympathetic blockade. However, the spinal group did receive more bolus fluid, based on observed clinical parameters, in the first 24 h after surgery (median, 15 ml/kg), suggesting some consequence of prolonged spinal block. Overall, these results show that spinal anesthesia can be used in this age group even in those with cardiovascular compromise. Furthermore, plasma lactate, a factor previously linked to increased morbidity and mortality in pediatric cardiac surgery, was lower in the spinal group. This could be due to either improved cardiac output or enhanced peripheral perfusion and suggests a potential benefit from spinal anesthesia, especially in high-risk patients.

An inappropriate or exaggerated inflammatory response is thought to be responsible for much of the tissue damage associated with cardiac surgery on CPB. It is therefore noteworthy that concentrations of IL-6, a proinflammatory cytokine with negative inotropic effects, were attenuated in both treatment groups. This pattern of IL-6 response was similar in terms of timing and magnitude to that published in a recent randomized controlled pediatric study in which methylprednisolone was administered 4 h before surgery. This early treatment was associated not only with delayed and suppressed increase of IL-6, but also with improved clinical outcome. The rises in IL-8 and IL-10 concentrations observed were also similar to those seen in other studies and our results show that their responses were unaffected by anesthetic technique. The similar pattern of cytokine response in both our treatment groups suggests that steroid administration on induction of anesthesia may confer similar benefits to 4-h preoperative administration. Cortisol remained suppressed in both groups up to 6 h after CPB, a likely effect of the use of dexamethasone, in contrast to other pediatric studies where steroids have not been used. This overrode any possible effect of anesthetic intervention.

The heart is a major source of IL-6 production after CPB, and animal in vitro studies have demonstrated that increased catecholamine concentrations are associated with increased cardiac production of IL-6. The reduced variation in the spinal group may be due to inhibition of a synergic relation between IL-6 production and catecholamines. Further studies are under way to further investigate the production and regulation of this potent proinflammatory cytokine.

There are potential drawbacks in applying regional techniques to major cardiac surgery: Single-dose spinal anesthesia with local anesthetic agents has a relatively short duration of effect, and although single-dose epidurals last longer, they do not control stress responses as effectively. Spinal and epidural morphine can provide longer lasting analgesia but have limited effects on the stress responses. The use of a spinal catheter offers the possibility of an incremental and controlled administration of local anesthesia during surgery while allowing postoperative analgesia through a continuous infusion. Epidural catheterization immediately before open heart surgery remains controversial because of the possibility of a “bloody tap” and the theoretical risk of uncontrolled epidural bleeding or the formation of an epidural hematoma after full heparinization. We chose spinal anesthesia with a catheter because it produces a
more potent neuraxial block than epidural anesthesia, and it can be placed with a fine needle below the lower limit of the spinal cord. However, the risk of epidural hematoma formation remains, although this has been estimated to be low. The most frequently quoted figure is approximately 1 in 220,000 in adult series, although there remains insufficient published data to confirm these estimates in infants and children. Much larger prospective randomized controlled trials comparing intrathecal techniques with general anesthesia are required before safety can be assured.

Another potential issue of this technique is the use of spinal catheters and the risk of cauda equina syndrome, which resulted in withdrawal of micro-spinal catheters in the United States. Although lignocaine at clinically available doses can be neurotoxic, bupivacaine at concentrations of 0.5% or less is not. Other factors that have been considered as causative include high cumulative dose of local anesthetic and local pooling of drug around the sacral nerves. Since these early reports, continuous spinal anesthesia has been reintroduced in many centers, although in pediatrics, we believe this report is only the second description in the peer-reviewed literature. The key issues that have been advocated to ensure safety have been the use of bupivacaine rather than lidocaine, limiting the concentration of drug, limiting the total drug dose, and placement of the catheter to a limited amount within the subarachnoid space to reduce the possibility of pooling. In our study, we believe that all these major safeguards were achieved and that dosing, concentration, and catheter placement were based on the available knowledge in this area.

It was important that our control group reflected current best practice in terms of perioperative opioid and steroid management. Our prebypass fentanyl regimen was based on previous data, which have demonstrated adequate hemodynamic and stress reduction in this group of patients. Once on bypass, we increased the infusion rate in the opioid group to 15 μg·kg⁻¹·h⁻¹ to maintain adequate plasma concentrations. The results in the control group indicate plasma catecholamine concentrations similar to those seen in other studies using high-dose opioids, implying that the differences in stress response in the control group were a result of limitations of opioid technique rather than inadequate dosing.

We had considered blinding the study by the use of a sham catheter in the intravenous opioid group, as described previously, but in this study, it was infeasible because our postoperative protocol included observation of the catheter insertion site for signs of bleeding or excessive cerebrospinal fluid leak. Given the lack of blinding, the possibility that treatment may have been influenced by the presence of a spinal catheter must be acknowledged. Laboratory analysis of specimens was blinded to the intervention performed.

In summary, this study demonstrates that the use of a combined high spinal and intravenous opioid technique controls sympathetic responses to CPB and improves plasma lactate a marker associated with adverse outcome, compared with intravenous opioids alone. High spinal anesthesia may offer advantages over conventional high-dose intravenous opioid anesthesia in the management of infants and young children undergoing CPB.

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References