Postoperative analgesia with intravenous fentanyl PCA vs epidural block after thoracoscopic pectus excavatum repair in children

D. Butkovic1*, S. Kralik1, M. Matolic1, M. Kralik2, S. Toljan1 and L. Radesic1

1Children’s Hospital Zagreb, Department of Anaesthesiology, Reanimatology and Intensive Care, Zagreb, Croatia. 2Clinical Hospital Centre Rebro, Clinical Institute of Diagnostic and Interventional Radiology, Zagreb, Croatia

*Corresponding author: Children’s Hospital Zagreb, Department of Anaesthesiology, Reanimatology and Intensive Care, Klaiceva 16, 10000 Zagreb, Croatia. E-mail: diana.butkovic1@zg.htnet.hr

Background. The aim of this prospective, randomized trial was to compare analgesia, sedation, and cardiopulmonary function in children after thoracoscopic surgery for pectus excavatum repair, using two types of analgesia—epidural block with bupivacaine plus fentanyl vs patient-controlled analgesia (PCA) with fentanyl.

Methods. Twenty-eight patients scheduled for thoracoscopic pectus excavatum surgery were randomly assigned to receive either thoracic epidural block or i.v. PCA for postoperative analgesia. Pain was assessed using a visual-analogue scale (VAS). The Ramsay sedation score, arterial pressure, ventilatory frequency, and heart rate were also measured, and blood gas analysis was performed regularly during the first 48 h after surgery.

Results. A significant decrease in the VAS pain score, Ramsay sedation score, heart rate ventilatory frequency, systolic and diastolic blood pressure, and $\text{P}_{\text{aCO}_2}$, and a significant increase in $\text{P}_{\text{aO}_2}$ and oxygen saturation were found over time. Patients in the PCA group had significantly higher $\text{P}_{\text{aCO}_2}$ values. In addition, a significantly slower decline of systolic blood pressure and heart rate, and faster recovery of $\text{P}_{\text{aCO}_2}$ were found in PCA patients than in patients with epidural block.

Conclusions. I.V. fentanyl PCA is as effective as thoracic epidural for postoperative analgesia in children after thoracoscopic pectus excavatum repair. Bearing in mind the possible complications of epidural catheterization in children, the use of fentanyl PCA is recommended.

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anaesthetics, can improve analgesia three-fold compared with local anaesthetics alone.\textsuperscript{13}

Fentanyl being a lipophilic opioid differs from morphine in epidural analgesia because of the limited rostral spread and is associated with less sedation and respiratory depression.\textsuperscript{12,13} Fentanyl is usually given as a continuous infusion because of its relatively short half-life. Fentanyl administered as a continuous infusion acts predominantly on supraspinal nociceptive pathways, producing non-segmental analgesia. Bolus administration of epidural fentanyl causes segmental analgesia, acting on the spinal level.\textsuperscript{12,13}

Epidural analgesia is, however, associated with spinal cord and nerve root lesions, high spinal blockade, significant systemic toxicity, epidural haematoma, and infections. Fortunately, such complications are rare.\textsuperscript{18}

Patient-controlled analgesia (PCA with or without a background infusion) is a well-established method of relieving postoperative pain in children as young as 5 yr old.\textsuperscript{19–21} PCA does, however, have major and minor adverse effects, such as nausea, vomiting, sedation, or respiratory depression. Hence, monitoring of respiratory function and level of sedation is mandatory.\textsuperscript{20}

The aim of this prospective, randomized study was to compare two types of postoperative analgesia, namely epidural block with bupivacaine plus fentanyl and PCA with fentanyl in terms of postoperative pain, sedation, arterial pressure, heart rate, ventilatory frequency, blood gases, and adverse effects in children undergoing the Nuss procedure for thoracoscopic pectus excavatum repair.

Methods

After obtaining the Hospital Ethics Committee’s approval and informed consent from the parents, 28 children (mean age 14.54 yr, range 8–19 yr) scheduled for thoracoscopic repair of pectus excavatum were randomly assigned to receive either epidural or PCA analgesia.

The exclusion criteria were NSAIDs use, coagulation disorders, allergy to local anaesthetics, American Society of Anaesthesiologists (ASA) grade more than III, inability to understand how to use the PCA device, and patients’ or parents’ objection to an epidural catheter.

All children were premedicated with midazolam 0.3 mg kg\textsuperscript{-1} orally. Before the induction of general anaesthesia, a thoracic epidural catheter was placed, an i.v. line was introduced, and bolus of 500 ml of isotonic saline given to each child in the epidural group. In most patients in the epidural group, a 20-gauge epidural catheter was inserted through an 18-gauge needle at the Th 7-8 or Th 8-9 intervertebral space using loss of resistance in the lateral position with non-invasive monitoring of arterial pressure, ECG, and pulse oxymetry. However, in small children, a catheter of 24-gauge was introduced through a 20-gauge needle. The catheter tip was advanced 2–3 cm into the epidural space.

A test dose of 0.1 ml kg\textsuperscript{-1} of 0.25% bupivacaine with 1:200.000 epinephrine was given. A cold sensitivity test was used to determine the extent of the block.

Patients in the PCA group were given i.v. line for postoperative PCA. The use of the PCA system was explained to the patients on two occasions, before and after the operation.

Anaesthesia was induced by midazolam 0.2 mg kg\textsuperscript{-1}, fentanyl 2 μg kg\textsuperscript{-1}, and rocuronium 0.8 mg kg\textsuperscript{-1}. After the trachea was intubated, anaesthesia was maintained with isoflurane (end-tidal concentration 0.8%) in oxygen–nitrous oxide ($F_{\text{IO2}}=0.5$). Additional fentanyl and rocuronium were administered at the discretion of the anaesthesiologist. Isotonic saline was used for intraoperative fluid maintenance.

A bolus of 0.125% bupivacaine and fentanyl was administered epidurally to patients in the epidural group before bar reversion, whereas children in the PCA group received i.v. additional bolus of fentanyl.

Postoperatively, patients were transferred to intensive care unit. In the epidural group, analgesia was maintained with bupivacaine 0.125% and fentanyl 2 μg ml\textsuperscript{-1} epidurally, with infusion rate of 0.15 ml kg\textsuperscript{-1} h\textsuperscript{-1}. In the PCA group, patients received basal infusion rate of 0.05 ml kg\textsuperscript{-1} h\textsuperscript{-1}, boluses of 0.1 ml kg\textsuperscript{-1}, and a lockout interval of 10 min. For the PCA, 1 mg of fentanyl was diluted in 500 ml of isotonic saline.

The intensity of pain was assessed at intervals during the first two postoperative days using a 10 point visual analogue scale (VAS) at 2, 4, 6, 12, 18, 24, 36, and 48 h postoperatively. The level of sedation was determined using the Ramsay sedation score (range from 1 to 6) at 2, 4, 6, 12, and 24 h postoperatively. Ventilatory frequency, heart rate, systolic and diastolic blood pressure, arterial blood oxygen saturation, and partial pressure of oxygen ($P_{\text{aO2}}$) and carbon dioxide ($P_{\text{aCO2}}$) were all measured at 2, 4, 6, 12, 18, and 24 h. Side-effects, such as pruritus, nausea, vomiting, and respiratory depression, were noted.

Statistical analysis was performed using SPSS software package for Windows, version 13.0. Normality of the distributions was tested by Kolmogorov–Smirnov test and homogeneity of variance was tested by Levene’s test. The Mann–Whitney test was used to determine the significance of difference between the groups. Any difference between frequencies was analysed by $\chi^2$ test. Fisher’s exact test was used when there was an expected frequency of less than 5. Main effects and interaction between factors were analysed by one-way within-subjects analysis of variance (ANOVA) and by two-way mixed ANOVA in repeated measures model. Sphericity assumption was tested by Mauchly’s test. Greenhouse–Geisser correction to the degrees of freedom and P-value was applied if no or mild violation of sphericity was present. If the violation was stronger, the more conservative Huynh–Feldt correction was used. The significance level used was 0.05.
Results

No significant differences in age, sex, body weight, ASA grade, and duration of surgery were found between two groups (P>0.05). The principal patients’ data are shown in Table 1. Preoperative pulmonary function tests, measured by spirometry, were normal in all patients, as were cardioiological findings (ultrasonography and ECG).

A decrease in VAS score was seen at every time-point relative to the previous measurement. The same was true for Ramsay sedation score, \( P_{\text{aco}_2} \), systolic and diastolic blood pressure, heart rate, and ventilatory frequency. The opposite was found for \( P_{\text{ao}_2} \) and oxygen saturation where there was increase in every successive measurement.

The one-way within-subjects ANOVA, done for all patients (data not shown) and separately for patients with different type of analgesia (Fig. 1), showed that there was significant effect of time elapsed after the surgery on all parameters (P<0.001).

Contrast analysis showed that the effects were linear for \( P_{\text{aco}_2} \) and \( P_{\text{ao}_2} \), but more complex than linear, with significant quadratic components, for Ramsay sedation score, systolic and diastolic blood pressure, heart rate, ventilatory frequency, and oxygen saturation. Furthermore, there were significant cubic and order four components for VAS score.

Two-way mixed model ANOVA analysis showed that there was a significant main effect of type of analgesia on \( P_{\text{aco}_2} \) (P=0.007), with PCA patients exhibiting on average 0.607 kPa higher values (Fig. 1n). No effect of type of analgesia was found on other parameters (VAS score, Ramsay sedation score, systolic and diastolic arterial blood pressure, heart rate, ventilatory frequency, \( P_{\text{ao}_2} \), and oxygen saturation, P=0.658, 0.602, 0.555, 0.647, 0.161, 0.755, 0.228, and 0.929, respectively).

However, there was a significant interaction between time of measurement and type of analgesia for systolic arterial blood pressure and \( P_{\text{aco}_2} \) (P=0.006 and 0.017, respectively) and moderate interaction for heart rate (P=0.036). This is due to the fact that PCA patients exhibited slower decline of elevated systolic blood pressure (Fig. 1n) and heart rate (Fig. 1c) and faster recovery of significantly higher \( P_{\text{aco}_2} \) (Fig. 1n) when compared with the patients with epidural analgesia.

Discussion

The present study suggests that the efficacy of postoperative analgesia after the thoracoscopic pectus excavatum repair in children does not differ between PCA with fentanyl and epidural infusion of fentanyl plus bupivacaine.

Neither an overall effect of type of analgesia on the VAS score nor an interaction between time of VAS score assessment and type of analgesia was seen. Likewise, there was no significant effect of type of analgesia on the Ramsay sedation score, implying that both analgesic regimes produced the same level of sedation.

Rawal reported that the risk of life-threatening respiratory depression in patients with i.v. PCA is approximately 0.9%. In our study, respiratory depression was evaluated by the ventilatory frequency and sedation scores as recommended by the European Society of Regional Anaesthesia. In the PCA group, postoperative \( P_{\text{aco}_2} \) values were found to be on average significantly higher compared with the epidural group. Nevertheless, the increased \( P_{\text{aco}_2} \) in the PCA group showed faster recovery towards initial values. These higher \( P_{\text{aco}_2} \) values could be attributed to: (i) the effect of opioids on respiration with an increase in baseline \( P_{\text{aco}_2} \) and blunting of \( P_{\text{aco}_2} \) response, which is supported by the finding of the same increase in ventilatory frequency in both groups and (ii) beneficial effects of thoracic epidural analgesia compared with the PCA on respiration, such as improved diaphragmatic function with earlier mobilization, as described in a study by Licker and colleagues.

Cardiovascular depression and hypotension due to local anaesthetic-induced negative inotropic effects in thoracic epidural analgesia were not seen in our study and the two groups did not differ in terms of systolic and diastolic blood pressure, or heart rate. However, patients in the epidural group showed faster decline in systolic blood pressure and heart rate than children in the PCA group.

A previous study reported an incidence of nausea and vomiting after epidural opioids of approximately 30%, compared with 87% during PCA. In our study, 29% (4/14) of the patients in the PCA group developed nausea, whereas 36% (5/14) of the children in the epidural group had nausea or pruritus. No significant difference in side-effects rate was found.

Kavanagh and colleagues have made a meta-analysis of current techniques for pain control after thoracic surgery. They compared the use of opioids, NSAIDs, ketamine, and regional analgesia. Their conclusion was that the combination of thoracic epidural local anaesthetics and

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patient data. Gender, ASA, and side-effects are given as frequencies (percentages), body weight and duration of surgery as mean (sd) (95% CI), and age as mean (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
<td><strong>PCA (n=14)</strong></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>10 (71.4%)</td>
</tr>
<tr>
<td>F</td>
<td>4 (28.6%)</td>
</tr>
<tr>
<td>Age, yr</td>
<td>14.54 (10–19)</td>
</tr>
<tr>
<td>Body weight, kg</td>
<td>56.93 (11.32)</td>
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<td>(50.39–63.46)</td>
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<td>ASA</td>
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<tr>
<td>I</td>
<td>2 (14.3%)</td>
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<tr>
<td>II</td>
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</tr>
<tr>
<td>III</td>
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<tr>
<td>Duration of surgery, min</td>
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<tr>
<td>(102.65–127.35)</td>
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</tr>
<tr>
<td>None</td>
<td>10 (71.4%)</td>
</tr>
<tr>
<td>Nausea</td>
<td>4 (28.6%)</td>
</tr>
<tr>
<td>Pruritus</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>4 (28.6%)</td>
</tr>
</tbody>
</table>
opioids can essentially abolish post-thoracotomy pain, but possible complications and cost–benefit issues have to be considered. McBride and colleagues investigated whether continuous epidural analgesia after pectus excavatum repair is as safe an alternative as high-dose narcotics in children. They found that the epidural analgesia eliminates the potential disadvantages of sedation and respiratory depression, both of which were associated with the use of high-dose narcotics. Cassady and colleagues compared continuous thoracic epidural analgesia with bupivacaine–fentanyl combination and PCA with morphine in adolescents undergoing posterior spinal fusion, and found them comparable in terms of effectiveness and safety. Bozkurt compared neuroendocrine response and analgesic efficacy of morphine-epidural and morphine-PCA in children after major genitourinary or lower abdominal surgery and found that both techniques provided sufficient pain relief and attenuation of the hormonal response. Lejus and colleagues evaluated epidural analgesia with bupivacaine and fentanyl in 348 children, and found excellent pain control in 86% of patients, with only mild complications (nausea, vomiting, pruritus, and urinary retention) in a minority of patients. Bloch and colleagues compared an i.v. infusion tramadol with epidural morphine for post-thoracotomy pain in adults, and concluded that thoracic epidural analgesia may result in earlier recovery of respiratory function, but the procedure was not without risk. Their study suggests that postoperative infusion of tramadol, on the basis of pain scores, analgesic requirements, and respiratory variables, is at least as effective as thoracic epidural morphine.

In conclusion, PCA with fentanyl is as effective as epidural block with bupivacaine and fentanyl in postoperative pain control and recovery of children after thoracoscopic surgery for pectus excavatum repair. Bearing in mind the possible complications of thoracic epidural catheter placement in children, the results of the present study support the usage of fentanyl PCA over epidural block.

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