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Original Article

Ropivacaine/Fentanyl vs. Bupivacaine/Fentanyl for Pain Control in Children after Thoracic Surgery: A Randomized Study

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A R T I C L E I N F O

A B S T R A C T

Background: Although bupivacaine remains a standard local anesthetic for postoperative epidural infusions in pediatric patients, it is increasingly being replaced with ropivacaine by many anesthesiologists. Ropivacaine is associated with less risk for cardiac and central nervous system toxicity.
Aims: The purpose of this study was to compare analgesic efficacy and adverse events of postoperative epidural analgesia with ropivacaine/fentanyl versus bupivacaine/fentanyl in children after the Ravitch procedure and thoracotomy.
Design: This was a prospective randomized controlled study.
Settings: This study was conducted at the Department of Thoracic Surgery of the Institute of Tuberculosis and Lung Diseases in Rabka Zdroj, Poland.
Participants/Subjects: 94 patients undergoing elective thoracic surgery.
Methods: Patients aged 7-17 years were randomly allocated into a ropivacaine 0.2% (RF, n = 45) or bupivacaine 0.125% (BF, n = 45) group; 1 mL of each analgesic solution contained 5 μg fentanyl. All patients received acetaminophen and nonsteroidal anti-inflammatory drugs. Nurses assessed pain intensity and incidence of adverse events over 72 hours after surgery and modified analgesia if patient pain intensity was greater than 2 out of 10.
Results: There was no statistically significant difference in median pain scores and incidence of adverse events between the RF group and the BF group. The analgesia was excellent (median pain intensity scores at rest, during deep breathing, and when coughing was less than 1 out of 10 in all patients). Adverse events included incidents of desaturation (64/90), nausea (18/90), vomiting (31/90), pruritus (12/90), urinary retention (2/90), paresthesia (11/90), anisocoria (2/90), and Horner syndrome (2/90).
Conclusions: Thoracic epidural analgesia using an RF and BF solution resulted in similar pain relief and adverse event profiles.
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Given the high efficacy, but also risk of adverse events, epidural analgesia should be used only in patients after very painful operations, such as open thoracic surgery (Moriarty, 2012). Thoracic surgeries include the modified Ravitch procedure, which is used to treat pigeon and funnel chest (Patvardhan & Martinez, 2016), and thoracotomy, which is applied in the surgery of pathologic conditions located in the lungs, pleura, and mediastinum (Kolettas et al., 2015). Surgical treatment is associated with extensive injury to the muscles, ribs, and peripheral nerves and is a cause of intensive postoperative pain >7 out of 10 on the Numeric Rating Scale and a duration longer than 3 days (Misiołek et al., 2014).

Thoracic epidurals represented only 3% of all central blocks (Ecoffey, Lacroix, Giaufre, Orliaguet, & Courrèges, 2010) and 6% of all epidural blocks (Lejus et al., 2001). This is based on the administration of local anesthetic drugs or an analgesic mixture containing local anesthetic drugs and opioids (Brasher et al., 2014; Tomaszek, Młodkowski, & Gajdosz, 2011; Walaszczyk et al., 2018) through a catheter placed in the epidural space.

Although bupivacaine remains a standard local anesthetic for postoperative epidural infusions in pediatric patients, it is increasingly being replaced with ropivacaine by many anesthesiologists

(Lejus et al., 2001, Siddiqui, Tse, Paul, Fitzgerald, & Teh, 2016; Walaszczyk et al., 2018). Ropivacaine is associated with less risk for cardiac (bradycardia, arrhythmias) and central nervous system (paresthesia, convulsions) toxicity and has less propensity for motor block (Kuthiala & Chaudhary, 2011). The symptoms of systemic toxicity of these drugs result from their high concentration in the blood as a result of rapid absorption, overdose, or unintentional intravascular administration (Christie, Picard, & Weinberg, 2015); there are cases of spontaneous catheter displacement into the blood vessel in the epidural space (Strandness, Wiktor, Varadarajan, & Weisman, 2015; Taenzer, Clark, & Kovarik, 2010).

Although the coadministration of local anesthetic and fentanyl provides additional analgesia, it poses a risk of nausea, vomiting, urinary retention, pruritus, excessive sedation, and respiratory depression (Chou et al., 2016, Youssef et al., 2014). To ensure the safety of patients receiving epidural analgesia, in Poland only anesthesiologist nurses (Kusza et al., 2012)—that is, those who have completed a qualification course or specialization in anesthesiology and intensive care (Tomaszek & Dębska, 2018)—are authorized to administer drugs through a catheter introduced into the epidural space. These nurses can temporarily modify the dose of an analgesic in the range ordered by the doctor (Tomaszek, Tomalak, Gajdosz, & Buchwald, 2015) and assess the patient for signs and symptoms of complications associated with the use of epidural analgesia.

Until now, in clinical practice we have used bupivacaine 0.125% with fentanyl 5 μg/mL for the treatment of postoperative pain after the Ravitch procedure or thoracotomy. In Poland, bupivacaine is much less expensive than ropivacaine.

In view of the considerations, the aim of this study was to compare the analgesic efficacy and adverse events of postoperative epidural analgesia with ropivacaine/fentanyl versus bupivacaine/fentanyl in children after the Ravitch procedure and thoracotomy.

Methods

After obtaining approval from the Institution Ethical Committee (Decision No. KB-2/2015) and the informed written consent of either the patients (from the age of 16) or their legal guardians, 94 patients were enrolled in the study. The study was carried out according to the ethical principles of the Declaration of Helsinki. This study was registered with ClinicalTrials.gov (Identifier: NCT03444636).

Trial Design

The study was designed as an interventional randomized controlled trial with 1:1 parallel assignment to the intervention (ropivacaine/fentanyl analgesia, RF group) and control arms (bupivacaine/fentanyl analgesia, BF group). No important changes were made to the methods after the trial began.

Eligibility Criteria for Participants

All patients aged 7-17 years undergoing elective thoracic surgery (thoracotomy or Ravitch procedure) and being managed with continuous thoracic epidural analgesia were included in this study.

Exclusion criteria were an American Society of Anesthesiologists physical status >3, history of chronic pain or preoperative opioid use, oncologic treatment, impaired verbal communication, removal of epidural catheter <24 hours postoperatively, and lack of postoperative chest drainage.

Settings of Data Collection

This study was conducted at the Department of Thoracic Surgery of the Institute of Tuberculosis and Lung Diseases in Rabka Zdroj, Poland. Thoracic surgery and the preceding anesthetic procedures were performed by the same team of surgeons and anesthesiologists. Usually one anesthesiologist nurse provided postoperative care to two patients in the intensive postoperative care unit.

Recruitment and Random Allocation

Patients were recruited from March 2015 to December 2016. A randomization list (simple randomization), which was generated by the study manager on a computer, was the basis for assigning patients to the RF group or BF group. The list was prepared before recruitment to the study and was printed out and handed to the anesthesiologist nurse (the study nurse) responsible for assigning patients to individual groups. Each time before operation (usually the day before surgery), the study nurse informed the patient and/or his or her legal guardian about the nursing care to be provided before and after surgery, with emphasis on the correct assessment of pain intensity and the principles of ensuring the patient's safety. The nurse also informed the anesthesiologist who qualified the patient for the procedure about the order of assigning to the groups. After obtaining from the patient and/or his or her legal guardian the informed consent to participate in the clinical trial, the anesthesiologist was responsible for implementing the proper treatment procedure in accordance with the applicable research protocol. The participant, care provider, investigator, and outcomes assessor were not blinded for control or intervention conditions.

Thoracic Epidural

All patients underwent standardized, combined epidural-general anesthesia (Table 1). An epidural catheter was inserted into the anaesthetized patients by a physician specialized in anesthesiology and intensive care. Patients for thoracic epidural placement were positioned in the left lateral decubitus position. A 24-gauge (for children up to 10 years old) or 20-gauge catheter was inserted up to 3-4 centimeters in the cephalic direction through a 20-gauge or 18-gauge Tuohy needle, respectively. Then it was tunneled laterally from the initial puncture.

A catheter was placed in the Th4 and Th7 interspace by a midline approach using the loss of resistance technique. Unsuccessful identification of the epidural space within the desired level resulted in approaching the epidural space in the neighboring levels (from the Th7 to Th10 interspace).

The site of catheter insertion was secured with a transparent breathable dressing. The catheter tip was protected with an antibacterial filter and combined with a latex-free and hypoallergenic foam pad attached to the skin of the patient.

To avoid administration of the wrong medication, a yellow label with the word "epidural" was attached to an epidural catheter, extension tubes for infusion lines, and a syringe with the drug. In addition, the syringe and extension tubes for infusion lines were yellow.

Epidural infusion was prepared by nurses according to procedure. Each time before connecting the syringe to the drug, the catheter was aspirated. The presence of blood or cerebrospinal fluid in the catheter was an absolute contraindication to the administration of the drug. Nurses modified analgesia mainly according to pain intensity and sedation scores (Table 1).

Table 1
Preoperative, Intraoperative, and Postoperative Management for Patients Undergoing Thoracic Surgery

Procedure	Drug	Dosage	Route of Administration
Premedication	Midazolam hydrochloride	0.2-0.5 mg/kg (30-60 minutes before surgery)	Oral
Antiemetic prophylaxis	Ondansetron hydrochloride	0.1 mg/kg up to 4 mg	Intravenous
Preemptive analgesia	Acetaminophen	15 mg/kg	
	Ibuprofen (children up to 14 years old)	10 mg/kg	Rectal
	Ketoprofen (children older than 14 years)	1 mg/kg	Intravenous
Induction of anesthesia	Fentanyl	1-5 μg/kg	
	Propofol	3-5 mg/kg	
	Rocuronium bromide (children up to 10 years old)	1 mg/kg	
	Pancuronium bromide (children older than 10 years)	0.1 mg/kg	
Maintenance of anesthesia	Desflurane	8-10 vol% in an oxygen/air mixture	Respiratory
Intraoperative analgesia	2% lidocaine	2 mg/kg	Epidural
	After 15 minutes		
	1% ropivacaine (RF group)	1-3 mg/kg	
	0.5% bupivacaine (BF group)	0.5-1 mg/kg	
	After 60 minutes		
	0.2% ropivacaine with fentanyl 5 μg/mL (RF group)	With flow rate of 0.1 mL/kg per hour	
	0.125% bupivacaine with fentanyl 5 μg/mL (BF group)		
Postoperative analgesia[*]	0.2% ropivacaine with fentanyl 5 μg/mL (RF group)		
	0.125% bupivacaine with fentanyl 5 μg/mL (BF group)		
	Acetaminophen	Every 6 hours; maximum 60 mg/kg daily	Intravenous
	Ibuprofen (children up to 14 years old)	Every 8 hours; up to 30 mg/kg daily	Oral, rectal
	Ketoprofen (children older than 14 years)	1 mg/kg; maximum 200 mg daily	Intravenous
	Dipyrone (rescue drug)	20 mg/kg; maximum 2.5 g daily	
Antiemetic treatment[†]	Ondansetron hydrochloride	0.1 mg/kg up to 4 mg	
	Metoclopramide hydrochloride	0.1-0.2 mg/kg	
	Dexamethasone	0.15 mg/kg up to 5 mg	

RF = epidural infusion of ropivacaine 0.2% with fentanyl; BF = epidural infusion of bupivacaine 0.125% with fentanyl.

[*] If patient pain intensity was greater than 2 out of 10 at rest, during deep breathing, and when coughing, the flow rate of the epidural analgesic mixture was increased by 10%-30%, and/or this mixture was administered in a bolus (half-hourly dose), and/or dipyrone was given intravenously. Sedation scores of 3-4 or 5 were an indication of a decrease in the infusion rate by 10%-30% or a stop in analgesic infusion, respectively.

[†] Antiemetic treatment for patients with postoperative nausea and vomiting.

Patient Monitoring

All patients were monitored using noninvasive equipment in the postoperative intensive care unit while receiving epidural analgesia. Clinical observations, such as hemodynamic parameters (blood pressure, heart rate), respiratory rate, oxygen saturation, and temperature, were monitored continuously and recorded hourly.

Pain intensity, sedation levels, and motor blockade were controlled on the first postoperative day, for the first 4 hours, every hour, then at least every 4 hours, and from the second postoperative day, at least 4 times a day. These parameters were also assessed 30 minutes after the administration of an additional analgesic.

Pain intensity was measured using the Numeric Rating Scale (range: 0-10) (Manworren & Stinson, 2016) and the three-step method (Tomaszek, 2012): at rest, during deep breathing, and when coughing (Fig. 1). The mean pain score was calculated for each patient over the 72-hour study period. The therapeutic goal of pain control was a pain level of 2 out of 10 when coughing.

The degree of motor block of lower limbs was assessed bilaterally using the Bromage scale (0 = none: full flexion of knees and feet; 1 = partial: just able to move knees; 2 = almost complete: able to move feet only; 3 = complete: unable to move knees or feet) (Weetman & Allison, 2006).

Sedation was controlled according to a sedation scale (1 = patient anxious, agitated; 2 = patient cooperative, oriented,
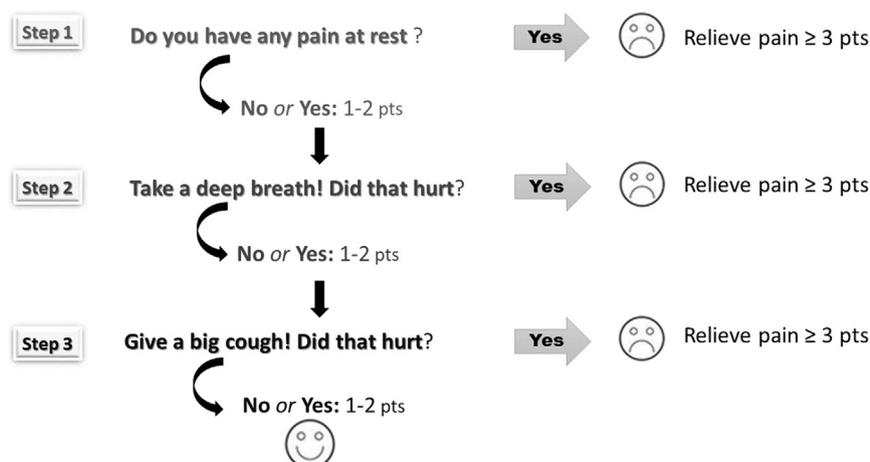
Figure 1. The three-step pain assessment method (pain assessment range: 0-10 points [pts]; therapeutic goal of pain relief: 0-2 pts during coughing).

tranquil; 3 = patient asleep, easy to wake up; 4 = patient asleep, difficult to wake up; 5 = patient asleep, does not respond to painful stimulus). The therapeutic goal was a sedation score of 2.

Data Collection

Data collection included demographic information; type of surgery; American Society of Anesthesiologists (ASA) physical status classification; duration of anesthesia; duration of epidural analgesia; thoracic epidural catheter placement (approach, attempt); duration of oxygen therapy, pain intensity scores; hemodynamic parameters (heart rate and blood pressure [systolic, diastolic]); and adverse events.

Adverse events included nausea, vomiting, urinary retention, incidence of hypotension (requiring ephedrine treatment), incidence of bradycardia and tachycardia (a heart rate 20% higher or lower than the baseline value), incidence of oxygen desaturation (<94% for 4 minutes, monitoring with pulse oximetry), sedation score ≥3, respiratory depression (requiring opioid reversal with naloxone), paresthesia, and others.

Outcomes

The primary outcome measurements were pain intensity scores and incidences of adverse events between 0 and 72 hours postoperatively. Secondary outcome measures included sedation, hemodynamic parameters, and motor blockade.

Statistical Methods

All continuous data are presented as a median and upper and lower quartile because the distribution differed from the norm. The assumption of normality was checked using the Shapiro-Wilk test.

Differences between the two independent groups were assessed using the Mann-Whitney U test. Categorical data were reported as number and percentage. Cross-group differences between categorical variables were examined using the χ^2 or Fisher's exact test. Statistical analysis was performed by using the Statistica 12 program (StatSoft, Krakow, Poland). The significance level was set at 0.05.

Sample Size

The outcomes of the pilot study were used to determine the size of the minimal sample. The authors of the study analyzed the differences between the RF group (n = 10) and BF group (n = 10) in terms of mean pain results obtained while resting (M1 = 0.7; M2 = 0.4), breathing deeply (M1 = 0.5; M2 = 0.2), and coughing (M1 = 0.9; M2 = 0.6).

If we accepted the value of standard deviation at 0.5 and α value at .05 for mean pain results obtained while resting, 45 patients were needed in each group to detect a considerable difference with 80% power.

If for both groups we accepted an α of .05 and standard deviation of 0.3 for mean pain results obtained while deep breathing, at least 23 patients were necessary in each group to detect a difference with 90% power.

If for both groups we accepted standard deviation of 0.5 and α of .05 for mean pain results obtained when coughing, at least 45 patients were necessary in each group to detect a difference with 80% power.

Results

Of the 94 patients enrolled in the study, four patients (4.2%) were dropped from analysis. The final analysis included data of 45 patients in the RF group and 45 patients in the BF group (Fig. 2). The
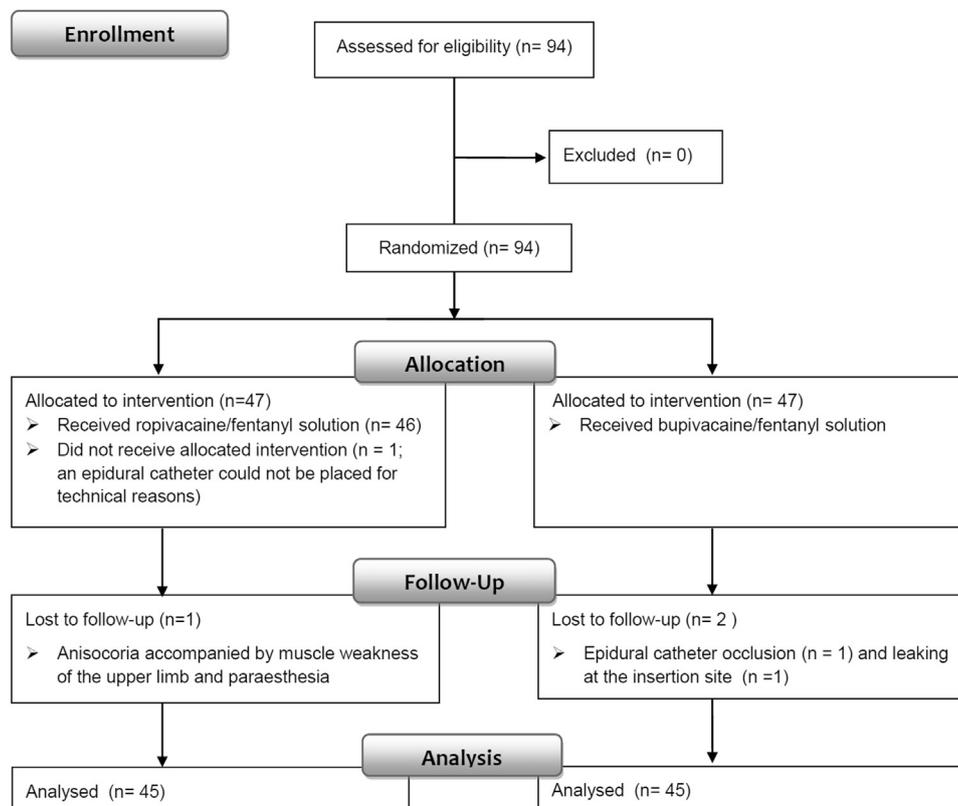

Figure 2. Flow diagram of patient enrollment.

demographic data were comparable between the groups with respect to age, height, weight, and gender. The median age of patients was 14 (10-15) years old. The median height and weight were 166 (135-175) centimeters and 51 (30-55) kilograms, respectively. The majority of participants were male (72.2%). The study groups did not differ significantly in terms of hemodynamic parameters before induction of anesthesia (heart rate, systolic blood pressure, and diastolic blood pressure), ASA scores, duration of anesthesia and surgery, duration of epidural analgesia and oxygen therapy, or type of surgical procedure. A total of 86.7% of patients were assigned to ASA class I; only 3.3% of patients were ASA class III. A deformity of the anterior wall of the chest was the most common reason for surgery (63.3%). The median duration of thoracic epidural was 71 (50-90) hours. All patients received oxygen postoperatively through the nasal cannula with a flow of 1-2 L/min (median 31 [19-48] hours). The exact demographic and clinical characteristics are shown in Table 2.

Thoracic Epidural Catheter Placement

All thoracic epidural catheters were placed with the median approach. Twelve catheters (13.3%) were inserted at the Th4-Th5 nerve root level, 41 (45.5%) at Th5-Th6, 34 (37.8%) at Th6-Th7, and three (3.3%) lower than Th7. Sixty-five patients (72.2%) required only a single attempt, 21 (23.3%) required two attempts, and four (4.4%) required three attempts. Three children (3.2%) had a vascular puncture during the procedure. In one patient (1/94), it was impossible to insert the catheter because of the difficulty in identifying the epidural space.

Assessment of Pain and Modification of Analgesia

The medians of postoperative pain intensity at rest (0.5 vs. 0.4), during deep breathing (0.3 vs. 0.3), and when coughing (0.6 vs. 0.6) were comparable between the RF group and the BF group (Fig. 3). The analgesia was excellent.

Over the whole period of observation, the nurses modified analgesia 499 times (91.1%) according to pain intensity and 49 times (8.9%) according to sedation scores by increasing or decreasing the flow rate of the epidural analgesic mixture (319 times, 58.2%), administering a bolus of the epidural analgesic mixture (90 times, 16.4%), or giving intravenous dipyrone (139 times, 25.4%). Analgesia was modified more often on the first postoperative day (296 times, 54.1%) than on the second day (157 times, 28.6%) or the third day (95 times, 17.3%). The total number of nurse interventions related to modification of analgesia in every patient was similar (median 6 [4-7] vs. 6 [3-8]; Z = 0.540; p = .588). A positive correlation was found between the total number of interventions and postoperative pain at rest (R = 0.30, t = 2.976, p = .003), during deep breathing (R = 0.25, t = 2.396, p = .018), and when coughing (R = 0.25, t = 2.429, p = .017).

Assessment of Hemodynamic Parameters

There was no statistically significant difference in median heart rate (81 [74-94] vs. 79 [74-90] beats per minute; Z = −0.738; p = .460), systolic blood pressure (103 [100-110] vs. 105 [101-110] mm Hg; Z = 0.633; p = .526), and diastolic blood pressure (60 [54-62] vs. 58 [56-61] mm Hg; Z = −0.540; p = .588) between the RF and BF groups.

Assessment of Sedation

Overall, 2,031 sedation scores were obtained. A total of 98.2% of the observations (n = 1,995) received a score of 2 (patient cooperative, oriented, tranquil), and 1.8% of the observations (n = 36) received a score of 3 (patient asleep, easy to wake up). There was no statistically significant difference in the proportions of patients with a sedation score of 3 between the RF and BF groups (Table 3).

Assessment of Adverse Events

Any adverse events during postoperative pain therapy are summarized in Table 3. Mild incidents of oxygen desaturation (90%-93%) were recognized 208 times, and severe (up to 86%) 10 times. The median incident of oxygen desaturation was higher in patients

Table 2
Demographic and Clinical Data of RF and BF Group

Variable	RF (n = 45)	BF (n = 45)	RF vs. BF
Age (years)	14 (9-15)	14 (11-15)	Z = 0.367; p = .713
Body height (cm)	166 (131-174)	167 (146-175)	Z = 0.213; p = .830
Body weight (kg)	51 (26-59)	51 (40-54)	Z = −0.145; p = .884
Sex			
Girls	13 (28.9%)	12 (26.7%)	χ² = 0.055; p = .813
Boys	32 (71.1%)	33 (73.3%)	
Before induction			
Heart rate (beats/min)	98 (90-110)	92 (84-110)	Z = −0.819; p = .412
Systolic blood pressure (mm Hg)	120 (110-130)	115 (110-120)	Z = −1.028; p = .303
Diastolic blood pressure (mm Hg)	70 (60-75)	60 (60-70)	Z = −1.436; p = .150
ASA			
1	40 (88.9%)	38 (84.4%)	χ² = 0.502; p = .777
2	4 (8.9%)	5 (11.1%)	
3	1 (2.2%)	2 (4.4%)	
Type of surgery			
Ravitch*	25 (55.6%)	32 (71.1%)	χ² = 2.344; p = .125
Thoracotomy†	20 (44.4%)	13 (28.9%)	
Duration of anesthesia (min)	190 (165-215)	200 (170-225)	Z = 1.162; p = .245
Duration of surgery (min)	130 (110-145)	130 (105-165)	Z = 0.258; p = .796
Duration of epidural analgesia (hour)	72 (63-96)	70 (50-90)	Z = −1.355; p = .175
Duration of oxygen therapy (hour)	28 (19-44)	34 (23-48)	Z = 0.762; p = .445

RF = epidural infusion of ropivacaine 0.2% with fentanyl; BF = epidural infusion of bupivacaine 0.125% with fentanyl; ASA = American Society of Anaesthesiologists.
Results presented as medians (upper and lower quartile) or numbers (percentages).
* Pigeon chest (n = 10), funnel chest (n = 47).
† Pulmonary sequestration (n = 2), lobectomy (n = 9), segmentectomy (n = 9), bilobectomy (n = 1), pneumonectomy (n = 1), enucleation of the tumor/cyst (n = 5), decortication for empyema (n = 6).
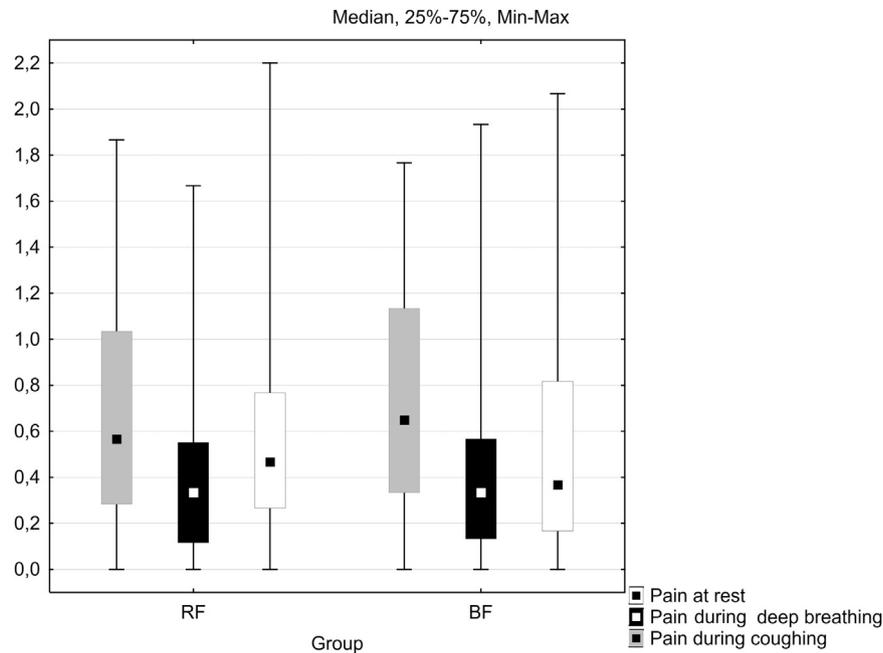
Figure 3. Postoperative pain intensity at rest, during deep breathing, and when coughing. RF = ropivacaine/fentanyl group; BF = bupivacaine/fentanyl group.

after a thoracotomy than after the Ravitch procedure (1 [0.3-1.3] vs. 0.3 [0-0.7]; Z = −2.167; p = .030). A strong positive correlation was found between the mean episodes of oxygen desaturation and oxygen supplementation in the postoperative period (R = 0.65; t = 8.071; p < .001).

Urinary retention was a problem for 24 out of 90 patients (26.7%). Pharmacologic provocation (neostigmine) was ineffective in only two of the patients. In these cases, a urinary catheter was introduced.

Paresthesia occurred in 11 children (12.2%) and was characterized by numbness and sensory disorders of the upper limbs. The symptoms were mild and vanished spontaneously.

Apart from this, the three patients who underwent the Ravitch procedure suffered from a difference of pupils (left pupil smaller than the right) postoperatively. In all patients, the catheter was introduced at the Th6-Th7 level. A 14-year-old boy manifested left-sided miosis accompanied by muscle weakness of the left upper limb and paresthesia. Despite a gradual reduction in the flow of ropivacaine and fentanyl (from 4 mL to 3 mL, 2 mL, and then 1 mL), the symptoms did not subside. After 12 hours of infusion, the doctor decided to remove the catheter from the epidural space. All these adverse reactions resolved up to 3 hours after cessation of analgesia.

The boy was excluded from further analysis because he did not meet the inclusion criteria. In the other two patients, a 10-year-old girl and a 16-year-old boy, epidural analgesia was continued for 29 hours and 47 hours, respectively. The left eye returned to normal within a few hours after removal of the catheter.

Furthermore, syndrome was detected in two cases. Approximately 48 hours postoperatively, a 17-year-old boy (weight 62 kilograms, ASA I) undergoing a left thoracotomy and receiving a ropivacaine/fentanyl infusion at a rate of 6 mL/hr (two attempts were required to place the epidural catheter into Th5-Th6) experienced weakness of the upper left limb. Left ptosis, miosis, and enophthalmos were noticed. The boy was cooperative, oriented, and tranquil at all times. The epidural infusion was continued for a total of 148 hours. The analgesia was excellent (median pain scores when coughing 0.6/10). After removing the epidural catheter, the left eye returned to normal, and the boy was discharged home without any untoward sequelae.

Horner syndrome was also recorded in a 12-year-old boy (weight 54 kilograms, ASA II) who underwent the Ravitch procedure. Because of a vascular puncture, two attempts were required to insert the epidural catheter into the epidural space (Th6-Th7). The patient received a continuous epidural infusion

Table 3
Adverse Events in Children and Adolescents Treated with a Thoracic Epidural Catheter

Variable	RF (n = 45)	BF (n = 45)	RF vs. BF
Nausea	8 (17.8)	10 (22.2)	$\chi^2 = 0.069$; $p = .792$
Vomiting*	16 (33.3)	15 (35.6)	$\chi^2 = 0.049$; $p = .824$
Pruritus	5 (11.1)	7 (15.6)	$\chi^2 = 0.096$; $p = .757$
Urinary retention			
Pharmacologic provocation	9 (20.0)	15 (33.3)	$\chi^2 = 2.079$; $p = .353$
Urinary catheter	1 (2.2)	1 (2.2)	
Incidence of desaturation[†]	35 (77.8)	29 (64.4)	$\chi^2 = 1.947$; $p = .162$
Sedation score of 3	9 (20%)	12 (27%)	$\chi^2 = 0.559$, $p = .454$
Paresthesia	7 (15.6)	4 (8.9)	$\chi^2 = 0.414$; $p = .521$
Anisocoria and Horner syndrome	2 (4.4)	2 (4.4)	$\chi^2 = 0.261$; $p = 1.000$

RF = epidural infusion of ropivacaine 0.2% with fentanyl; BF = epidural infusion of bupivacaine 0.125% with fentanyl.
* Children experienced one episode of vomiting, only four patients from RF group and three patients from BF group vomited twice in postoperative day 1.
[†] At least once in postoperative period.

of 0.125% bupivacaine + fentanyl with a flow rate of 5 mL/hr. Approximately 8 hours postoperatively, the boy developed left-sided ptosis and miosis. The patient had no other motor or sensory dysfunction (median pain scores when coughing 0.2/10). After decreasing the infusion to 3 mL/hr, Horner syndrome was resolved. The epidural infusion was continued for a total of 90 hours with no further problems.

Respiratory depression, hypotension, bradycardia, arrhythmias, infections, and drug errors were not found in any of the groups. No patients recorded an inadvertent motor blockade (Bromage score $\geq$ 1).

Discussion

Our study found that the epidural infusion of ropivacaine/fentanyl provided almost identical pain relief as with bupivacaine/fentanyl. Any adverse events were minor and easily reversible. Nursing care for patients focused on safely administering analgesia, achieving optimal pain control, and identifying adverse events early and managing them properly.

In our study, median pain intensity scores at rest, during deep breathing, and when coughing were less than 1 out of 10 in all patients, which indicates the high efficacy of analgesia. Baidya et al. (2012) reported that a continuous epidural infusion of bupivacaine 0.1% and 1 μg/mL fentanyl was able to provide adequate analgesia in 87.5% of children undergoing thoracic or upper abdominal surgery. Schnabel et al. (2015) reported higher pain scores among German children after thoracic surgery. The median pain score during movement was 4 out of 10 in the first 3 postoperative days. Differences in pain intensity in patients from Poland and Germany might be explained by the fact that children from Germany received a different analgesic mixture (bupivacaine 0.175% or ropivacaine 0.2% combined with sufentanil), and the therapeutic goal for pain was 3 out of 10 (in our study it was 2 out of 10).

We found that the occurrence of adverse events, such as incidents of oxygen desaturation, nausea and vomiting, pruritus, urinary retention, paresthesia, anisocoria, and Horner syndrome, were similar in both groups.

During the postoperative period, oxygen therapy was used, and desaturation was identified in 71.1% of the patients. Our results confirm the observations of Powell et al. (Powell, Menon, & Jones, 1996) that patients who have undergone a thoracotomy and are receiving opioids are at risk of hypoxemia and need oxygen supplementation postoperatively.

A distinct problem associated with epidural analgesia was the occurrence of postoperative nausea (20%) and vomiting (34.4%), despite the use of an antiemetic prophylaxis. However, it should be emphasized that in most cases vomiting was occasional and occurred mainly on the first postoperative day. In the study conducted by Walaszczyk et al. (2018), in pediatric patients receiving thoracic epidural ropivacaine 0.1% or bupivacaine 0.0625% mixed with 6 μg/mL fentanyl after the Nuss procedure, the incidence of nausea (7.4%) and vomiting (2.1%) was lower than in our study. Unfortunately, because of the different interpretation of pain measurement results, it is impossible to compare the degree of pain relief between our study and the works of the quoted authors.

During epidural infusion, urinary retention requiring a urinary catheter developed in only two of our patients. If the children had difficulty in urinating up to 6 hours after surgery, we then used a pharmacologic provocation with neostigmine, which was effective in 92% of cases. Anticipating this complication, some anesthesiologists catheterize the urinary bladder before surgery (Baidya et al., 2012).

The administration of opioids to the epidural space may be the cause of pruritus (Chaudhary et al., 2013) as a result of the release of histamine from mast cells or the activation of central μ-opioid receptors (Weetman & Allison, 2006). Pruritus most often affects the face, chest, and abdomen, is somewhat severe, and in most patients does not require treatment, which is confirmed by our study. Among the 12 patients (13.3%) suffering from pruritus, only two required oral administration of promethazine hydrochloride. Baidya et al. (2012) noted only one case (2.5%) of pruritus, which resolved spontaneously. The low incidence of pruritus in the cited research may be explained by the administered dose of epidural fentanyl, which was smaller than in our study.

Left Horner syndrome was also documented after thoracic epidural analgesia in two of our patients (2.2%). The mechanism of Horner syndrome is a cephalic spread of the local anesthetic solution (Aronson et al., 2000; Valois, Ranger, & Raghavendran, 2006). This occurs as a result of the blockade of sympathetic fibers supplying the eye and facial area (Jadon, 2014). This complication has been reported in children, with an incidence of 0.3%-2.6%, and did not result in untoward sequelae (Ecoffey et al., 2010; Valois et al., 2006; Zadra & Giusti, 2000). Despite the occurrence of Horner syndrome, we continued analgesia by the epidural route, similar to Valois et al. (2006), Aronson et al. (2000), and Zadra and Giusti (2000), providing an accurate observation of the patient's vital signs and neurologic function. Furthermore, three of our patients had anisocoria, with the left pupil smaller than the right. Schnabel et al. (2015) noticed that two children (0.3%) treated with a thoracic epidural catheter also suffered from a difference of pupils. The mechanism of this complication is probably the same as in the case of Horner syndrome.

We have reported no symptoms of infection caused by the presence of an epidural catheter or drug error (Wong et al., 2013). Certainly, this is because nurses followed the rules of asepsis when preparing and administering drugs to the epidural space and properly cared for the catheter site, and because of the short period of analgesia administration (Sethna et al., 2010). In turn, careful labeling of the catheter and equipment used for the epidural administration reduced the risk of potential mistakes while administering drugs through this route (Grissinger, 2012).

Limitations

There are several limitations in this study. First, we did not use any tools to assess the severity of nausea. Second, because we did not have a postoperative nausea and vomiting treatment algorithm, each doctor used medication according to personal preferences. Third, there are no data allowing us to accurately assess, for example, how many hours after the end of analgesia it took for the symptoms of Horner syndrome to subside.

Implications for Clinical Practice

A continuous thoracic epidural infusion of ropivacaine or bupivacaine with fentanyl is an efficient and safe method of pain control in children and adolescents after thoracic surgery.

The modification of postoperative epidural analgesia by a nurse based on the three-step pain assessment method and early identification and proper management of adverse events are a key to effective and well-tolerated epidural analgesia. The three-step pain assessment method forces nurses to perform the pain assessment under dynamic conditions and undertake interventions to relieve pain >2 out of 10. At the same time, this way of assessing pain "protects" the patient from additional suffering because it does not allow for the pain evaluation during deep breathing, for instance, when the patient experiences moderate to severe pain at rest. On the first postoperative day, patients require more frequent interventions to relieve pain than on other days, and therefore more frequent pain assessment is necessary. In addition to the standard monitoring,

including the evaluation of vital signs, sedation, and motor blockade of the lower limbs, it is recommended to observe the pupil width and the appearance of the eyeballs (miosis and enophthalmos) because of the possible blockade of sympathetic fibers supplying the eye and facial area manifested as anisocoria or Horner syndrome.

Good cooperation of doctors and nurses is one of the crucial components of effective and safe pain control. Nurses can modify analgesia and manage of adverse events within the scope of the doctor's order and the guidelines available in the hospital. It is important that the medical recommendation for each patient contains the minimum and maximum analgesic dosage, a "rescue drug" in case of breakthrough pain, antiemetic treatment in case of nausea and vomiting, pharmacologic provocation in case of urinary retention, and precise data on the use of supplemental oxygen and other interventions. Then, without a necessity to contact the doctor, the nurse can give the appropriate medication, which shortens the time from the onset of pain or the appearance of side effects until they are resolved.

Conclusions

Continuous thoracic epidural ropivacaine 0.2% combined with 5.0 μg/mL fentanyl provided adequate pain relief similar to bupivacaine 0.125% with 5.0 μg/mL fentanyl in children after the Ravitch procedure and thoracotomy. The effectiveness of analgesia depended on the number of nursing interventions undertaken to relieve pain. Any adverse events were minor and easily reversible.

Acknowledgments

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