ARTYKUŁ ORYGINALNY/ORIGINAL PAPER
Otrzymano/Submitted: 01.07.2015 • Zaakceptowano/Accepted: 08.09.2015

Intermittent thoracic epidural administration of bupivacaine-morphine versus intravenous infusion of morphine after thoracic surgery in children and adolescents

Lucyna Tomaszek[1], Waldemar Tomalak[2], Ryszard Gajdosz[3], Joachim Buchwald[1]

[1] Department of Thoracic Surgery, Physiopathology of Respiratory System, Institute for Tuberculosis and Lung Diseases, Pediatric Division, Rabka-Zdrój, Poland

[2] Department of Physiopathology of Respiratory System, Institute for Tuberculosis and Lung Diseases, Pediatric Division, Rabka-Zdrój, Poland

[3] Faculty of Health Sciences, Jagiellonian University Medical College, Krakow, Poland

Abstract

Background. Pain management after thoracic surgery in children may be generally provided by either intravenous opioids or regional anaesthetic techniques. Thoracic epidural analgesia with a combination of local anaesthetics and opioids is an effective method of pain relief. However, this type of analgesia can cause life-threatening complications and nurses need to be able to identify these and provide safe care for patients. ***Objectives.*** The aim of this study was, (1) to compare the effectiveness and side effects of intermittent epidural doses of bupivacaine + morphine to intravenous infusion of morphine in children and adolescents after thoracic surgery, and (2) to assess if an epidural analgesia could be provided safely by nurse anaesthetists. ***Material and methods.*** This prospective, observational study was performed on children 7-18 years old. Postoperative analgesia was achieved with either intermittent epidural doses of bupivacaine + morphine (the study group, n = 75), or intravenous infusion of morphine (the control group, n = 70). ***Results.*** Pain scores, heart rate and blood pressure values in the postoperative period were significantly lower in the study group. No significant differences regarding the frequency of postoperative side effects such as nausea, vomiting, itching, and urinary retention between both groups were observed. In the study group some complication occurred in relation to administering of the drugs to epidural space such as muscle tremors, paresthesia, and vascular penetration of the catheter. ***Conclusions.*** After thoracic surgery in children and adolescents, epidural analgesia with bupivacaine and morphine administered in repeated doses is more effective than a continuous intravenous infusion of morphine. Nurse anaesthetists, under medical supervision, can safely provide thoracic epidural analgesia with intermittent doses. *Anestezjologia i Ratownictwo 2015; 9: 260-268.*

Keywords: bupivacaine, morphine, analgesia, adverse events, nurses' role, pediatric

Introduction

Pediatric thoracosurgical patients constitute a very diverse population with regard to age, body weight and the type of pathology [1]. Surgical treatment is always associated with extensive injury to the muscles, ribs and peripheral nerves and is a cause of intensive postoperative pain that is amplified by normal breathing and the presence of drainage tubes in the thoracic cavity. Inefficiently treated pain, especially in the early postoperative stages, leads to changes in breathing patterns (shallow breathing) and inefficient sputum evacuation from the airways, which in turn may lead to atelectasis and pneumonia [2]. Postoperative pain and other

postoperative complications have a negative influence on the psyche of the child and may also cause negative emotions towards the medical staff and discontent of the patient and his or her parents/guardians.

Therefore, analgesia is the most important element of postoperative care and requires carefully planned actions to minimize the consequences of nociception. Based on the literature, we know that pain management after thoracic surgery in children may be generally provided by either intravenous opioids or regional anaesthetic techniques [3]. Thoracic epidural analgesia with a combination of local anaesthetics (LA) and opioids is an effective method of pain relief [4]. However, this type of analgesia can cause life-threatening complications and nurses need to be able to identify these and provide safe care for patients [5-8].

The aim of this study was, (1) to compare the effectiveness and side effects of intermittent epidural bolus of bupivacaine + morphine to intravenous infusion of morphine in children and adolescents after thoracosurgical intervention, and (2) to assess if an epidural analgesia could be provided safely by nurse anaesthetists.

Material and methods

The study was approved by the Ethics Committee of the Institute for TBC & Lung Diseases (decision: KE 40/2009; 08.04.2009). This prospective, observational study was performed on children 7-18 years old. The patients included in the study were children of physical status I-II, according to the American Society of Anesthesiologists (ASA), and were scheduled for thoracotomy or a modified Ravitch procedure. Informed consent was obtained from the patients' parent or guardians, and the child also agreed to participate. The exclusion criteria were metastatic disease, lack of communication and no postoperative drainage.

The study group consisted of children receiving epidural analgesia, while the patients from the control group received intravenous analgesia (figure 1).

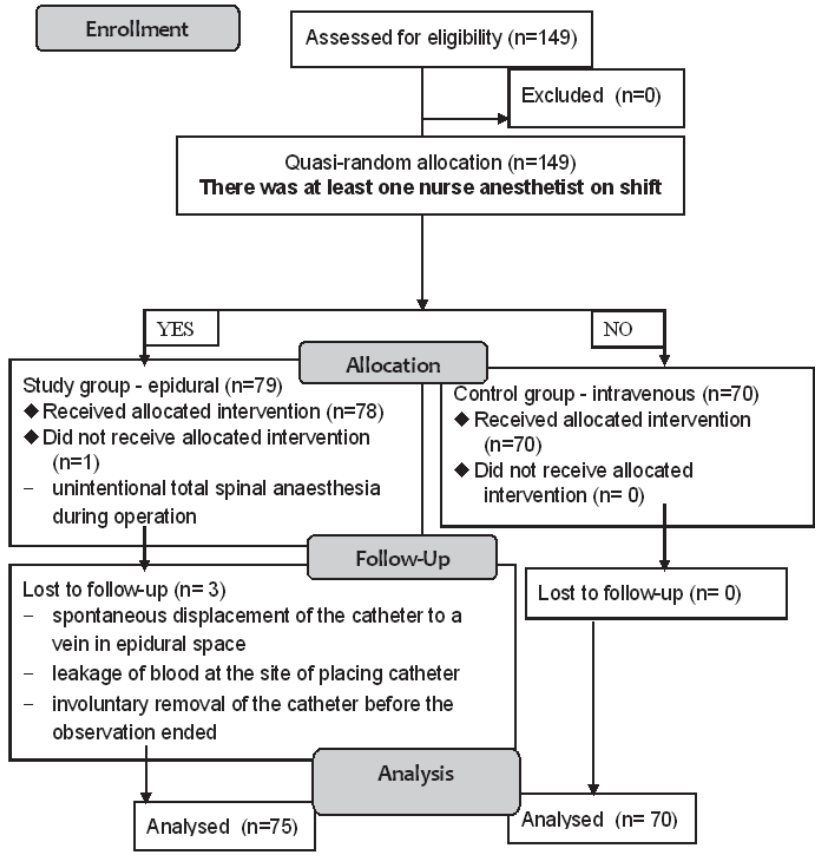

Figure 1. Number of patients assessed, enrolled and allocated to the study

The patients received the oral premedication midazolam 0.2-0.5 kg^{-1} 30-60 minutes before surgery. After arriving into the operating room, the patients were monitored by electrocardiography, pulse oximetry and non-invasive blood pressure measurements. Peripheral *i.v.* access was secured, and before the induction of the anaesthesia, the children were given ondansetron 0.1 mg kg^{-1} (a maximum of 4 mg). Fentanyl 1-5 μg kg^{-1}, thiopentone 5 mg kg^{-1} and pancuronium or vecuronium 0.1 mg kg^{-1} were administered for the anaesthesia induction. The anaesthesia was maintained with nitrous oxide/oxygen using a tracheal tube. Neuromuscular blockade was maintained with pancuronium or vecuronium. Blood pressure (BP), heart rate (HR), respiratory rate (RR), oxygen saturation and end-tidal CO_2 were continuously monitored.

The children who qualified for the epidural anaesthesia were placed in a left lateral position after intubation. A gauge 20 epidural catheter was inserted up to 3-4 cm in the cephalic direction through an 18-gauge Tuohy needle by an anaesthetist. A thoracic catheter was placed in the Th5-Th7 interspace by a midline approach using the loss of resistance technique. The unsuccessful identification of the epidural space in the desired level resulted in approaching the epidural space in the neighboring levels (Th4-Th5, Th7-Th8 interspace).

For intraoperative analgesia, 0.5% bupivacaine (max. 2 mg kg^{-1}) was used in the study group. Then (after 90 min), a mixture of 0.25% bupivacaine and morphine was administered. The single dose of the mixture was calculated based on the Bromage formula [9], which had been tested in a pilot group and was then locally modified as follows: *1.2 ml x 10 segments + 0.1 ml/segment for each 10 cm of height above 120 cm* but not more than 20 ml. In the cases of inadequate epidural analgesia (as indicated by an increase in pulse rate and blood pressure) at the skin incision site made by the surgeon, fentanyl 1-5 μg kg^{-1} was administered intravenously. In the control group, intraoperative analgesia was achieved using intermittent intravenous doses of 1-5 μg kg^{-1} fentanyl injected every 20-30 minutes.

At the end of the operation, the patients were given either metamizol 50 mg kg^{-1} (a maximum of 2.5 g), for the children ≥ 15 years old, or paracetamol 20-30 mg kg^{-1}, for the children < 15 years old, in combination with antiemetic (metoclopramide 0.1-0.2 mg kg^{-1}). After the surgery, the patients were extubated and transferred to the postoperative intensive care unit, where the analgesic treatment continued.

In the study group, the postoperative analgesia consisted of a solution of bupivacaine 2.5 mg/mL + morphine 0.1 mg/mL. The volume of a single dose was calculated according to the equation cited above. The first dose was administered 4 hours after the last dose was administered in the operation room and the doses following occurred in 8 hours intervals. In the control group, a continuous infusion of morphine was started at a rate of 0.04–0.06 mg $kg^{-1}hour^{-1}$.

Pain intensity was measured in dynamic conditions (figure 2). The Prince Henry Hospital pain score (PHH, range 0-3) and the Numerical Rating Scale (NRS, range 0-10) were used [10].

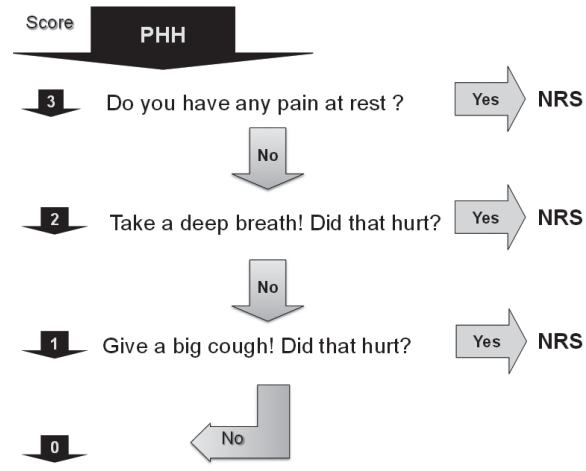

Figure 2. Pain intensity in dynamic conditions using the Prince Henry Hospital pain score (PHH, range 0-3) and the Numerical Rating Scale (NRS, range 0-10) according to PHH scheme

The nurses monitored the patients' pain at 1, 2, 4, 11 and 24 h. The therapeutic goal of the pain control was a pain level of 2/10 at rest and 3/10 during deep breathing and coughing using the NRS.

The nurses modified analgesia in cases of inadequate pain control (NRS > 2/10 at rest, NRS > 3/10 during deep breathing and cough). In the study group, the children received an additional 2-6 ml of 0.25% bupivacaine + morphine (the total volume of the drugs administered in the operating room and during the postoperative period could not exceed 20 ml). In the control group, a bolus of morphine (1-2 mg) was used and/or the infusion rate of morphine was increased

by 10-30%. Additionally, both of the groups received non-opioid analgesics (*i.v.* paracetamol 20-30 mg kg^{-1}, max. 3-4 g /day^{-1} and/or *i.v.* metamizol 50 mg kg^{-1}, max. 5 g/day^{-1}).

At the same time the pain intensity was managed, the sedation levels were controlled according to the Ramsay scale [11]. A sedation level 4/5 was considered as over-treatment and was an indication for reducing analgesics (a decrease in the infusion rate of morphine by 10-30% and subsequently decreasing the doses of bupivacaine + morphine by 2 ml).

In addition, hemodynamic parameters (BP and HR), oxygen saturation and any adverse effects were recorded. In the study group, the degree of motor blockade was assessed every 4 h using the Bromage scale [5].

After 24 h of observation, all of the patients were asked to rank their satisfaction according to the following scale: 2 = unsatisfactory; 3 = satisfactory; 4 = good; 5 = very good.

In order to promote patient safety, the nurses were trained in areas of pain assessment and management and to assess possible complications and how to deal with them.

- *Statistical analyses*

The initial sample size estimation was performed basing on a pilot study (the study group n = 9 and the control group n = 9; there were 45 observations of pain intensity in each group). Assuming a power of 90%, it was calculated that 68 patients in each group were required to find a significant difference in pain intensity.

To evaluate the efficacy of analgesia we have compared pain intensity, number of doses of non-opioid analgesics, frequency of the modification of analgesia, quality of analgesia judged by the patients in both groups. The safety was assessed through registering systolic/diastolic blood pressure, heart rate, the depth of sedation, number and quality of side effects of used analgesic treatment.

Table I. Demographic and baseline clinical data (* p significant difference; values are expressed as median and Q25-Q75 or number and percentage)

Parameter		Study group (N = 75)	Control group (N = 70)	Statistical test	P value
Ages [y]		14 (12-16)	13 (10-15)	*Mann-Whitney U-test*	0.064
Height [cm]		170 (159-177)	161,5 (147-174)		*0.002**
Body weight [kg]		54 (46-51)	48 (38-57)		*0.033**
BMI [kg/m^2]		18,1 (17,1-20)	18,2 (16,6-20)		*0.828*
Before induction	Heart rate (beat min^{-1})	99 (84-110)	102 (90-116)		*0.094*
	Systolic blood pressure [mmHg]	120 (110-130)	112 (106-120)		*0.053*
	Diastolic blood pressure [mmHg]	78 (69-80)	70 (62-80)		*0.075*
Gender [%]	Female	19 (25,3%)	19 (27,1%)	*Chi²*	*0.804*
	Male	56 (74,7%)	51 (72,9%)		
ASA [%]	I	70 (93,3%)	64 (91,4%)		*0.665*
	II	5 (6,7%)	6 (8,6%)		
Surgical type	Thoracotomy	20 (26,7%)	32 (45,7%)		*0.017**
	Ravitch	55 (73,3%)	38 (54,3%)		
Drainage	One	67 (89,3%)	55 (78,6%)		0.076
	Two	8 (10,7%)	15 (21,4%)		
Duration of surgery [min]		135 (115-163)	141 9120-177)	*Mann-Whitney U-test*	*0.441*
Duration of anaesthesia [min]		180 (155-205)	173 (152-203)		*0.399*
Extubation time [min]		8 (5-10)	7 (5-10)		*0.615*

Statistical analyses were performed based on procedures available in Statistica 10. Quantitative variables were presented using median and upper and lower quartile or mean ± SD (in case of normal data distribution). Normality of the system was checked tested using the Shapiro-Wilk test. The values of the qualitative variable were represented by the absolute values and percentage. To compare quantitative variables the Mann-Whitney U-test was used. Qualitative data were analyzed with Chi-square test or the Fisher's exact test. A p value less than 0.05 was considered significant.

Results

Among the 149 patients enrolled into the study, 145 (97.3%) finished it successfully. Four patients from the epidural group were excluded because of complications and thus, required continuous intravenous analgesia (figure 1).

The final analysis was performed using the results from the 145 patients. Significant differences were observed (table I) between the groups with respect to body height and weight and the chosen operative techniques.

Epidural thoracic block was always done with the patient under general anaesthesia. The median approach to the epidural block was used in 145 patients (100%). Sixty-two patients (82.7%) required only a single attempt, 10 patients (13.3%) required 2 attempts, in 3 patients (4%) three attempts were made. The intervertebral spaces accessed were from Th4-Th5 to Th7-Th8; Th5-Th6 was the most frequent, being used in 49 patients (65.3%), followed by Th6-Th7 in 24 patients (32%).

In the study group, the mean dose of 0.25% bupivacaine in a single bolus (16.2 ml) was 0.75 mg kg^{-1}, whereas, the mean daily dose of bupivacaine (48.8 ml) was 2.3 mg kg^{-1} day^{-1}. The mean dosage of morphine was 4.8 mg (0.09 mg kg^{-1} day^{-1}). The analgesia was not sufficient in 32 (42.7%) cases, and thus, they also received a bupivacaine + morphine solution (3,9 ± 0,9 ml on average 85 min after the last dose of LA administered in the operating room).

In the control group, the mean usage of morphine was 0.87 mg kg^{-1} day^{-1}.

There was no difference between the doses of non-opioid drugs used in both of the groups (difference between median 1 *vs.* 2, p = 0.324; Fisher's exact test).

The children in the study group felt less intensive pain according to PHH pain score (figure 3) than the control group children. The median NRS scores were significantly lower during deep breathing (figure 4) and coughing (figure 5) in the study group. The type of surgical access did not influence the pain intensity (p = 0,346, Mann-Whitney U-test).

There were no statistically significant differences in the Ramsay scores or in the distribution of the scores between the two groups (p = 0.516; Fisher's exact test). In both groups, there were 725 observations, and 630 (86.9%) observations were scored Ramsay = 2 (children were co-operative and oriented),

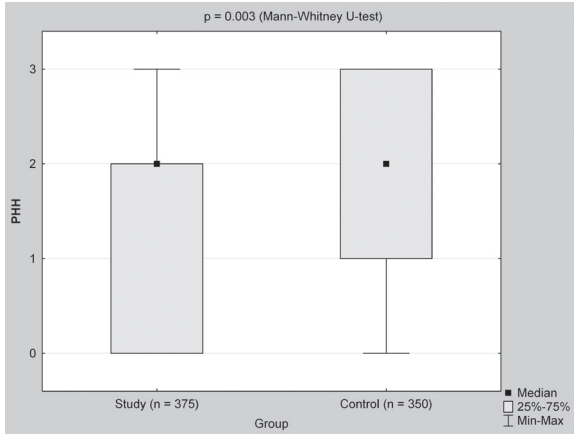

Figure 3. Median PHH (Prince Henry Hospital pain score, range 0-3) during the first 24 h after the operation

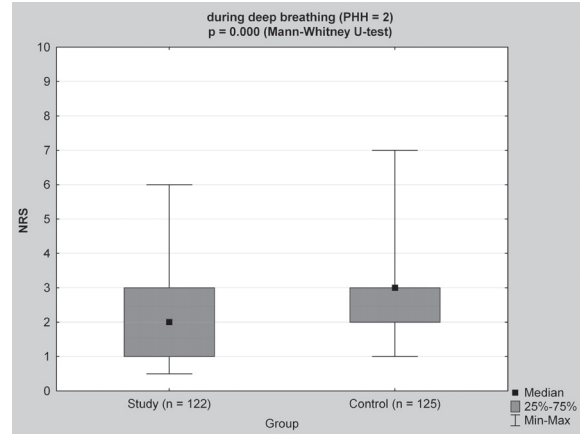

Figure 4. Median NRS (Numerical Rating Scale, range 0-10) scores during deep breathing (Prince Henry Hospital pain score, PHH = 2) - the first 24 h after the operation

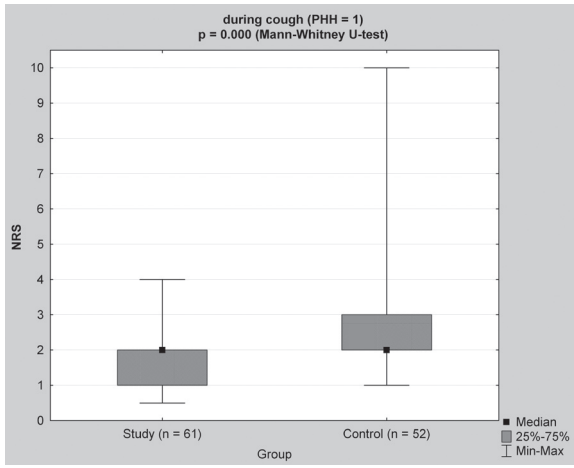

Figure 5. Median NRS (Numerical Rating Scale, range 0-10) scores during cough (Prince Henry Hospital pain score, PHH = 1) - the first 24 h after the operation

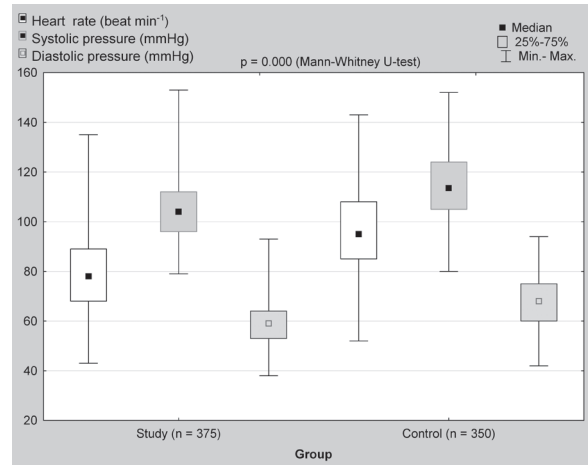

Figure 6. Median values of heart rate, and systolic blood pressure, and diastolic blood pressure

87 (12%) observations were scored Ramsay = 3 and 8 (1.1%) were Ramsay = 4.

During the postoperative period, significantly lower median HR values and systolic and diastolic blood pressures were noted in the study group compared to the control group (figure 6). The side effects in the study group, including nausea, vomiting, itching, urinary retention and others, are presented in table II and were not significantly different from those in the control group. In the study group, some complications occurred in relation the administration of the drugs into the epidural space. Paresthesia was noted in 6 (8%) of the patients, and muscle trembling was reported in 3 (4%) of the patients.

An evaluation of the postoperative analgesia was performed 24 hours after extubation. The nurse asked the patients to take into account, not only the efficacy of the pain relieving, but also any accompanying side effects. The median of the patients satisfaction score was higher in the children receiving the epidural analgesia (median 5) compared with those receiving the intravenous analgesia (median 4); (figure 7).

Table II. Frequency of side effects in the postoperative period (values are expressed as number and percentage)

Side effect		Study group (N = 75)		Control group (N = 70)		Statistical test	P value
Nausea and vomiting	Nausea	9	(12%)	9	(12,8%)	*Chi* ²	*0,373*
	Vomiting ≤ 2 episodes	11	(14.7%)	9	(12.8%)		
	Vomiting > 2 episodes	9	(12%)	3	(4.3%)		
Itching		13	(17.3%)	8	(11.4%)		0.313
Urine retention		6	(8%)	3	(4.3%)	Fisher's exact test	0.496
Oxygen saturation < 94%		6	(8%)	7	(10%)	*Chi* ²	*0.674*
Body temperature ≥ 38° C		23	(30.7%)	29	(41.4%)		*0.177*
Reduction of systolic blood pressure by 20-25% compared to preoperative levels at least once a day		7	(9.3%)	4	(5.7%)		*0.411*

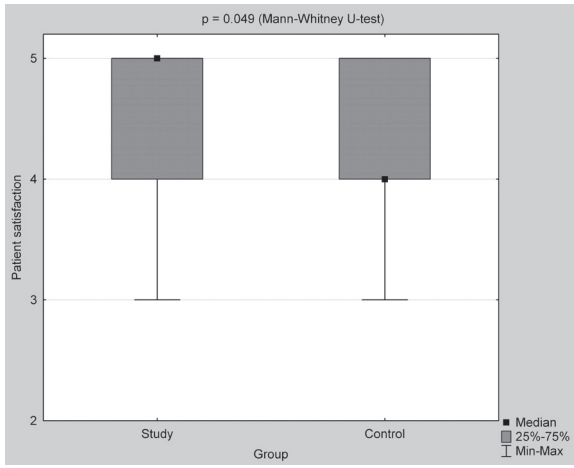

Figure 7. Patients satisfaction (2 = unsatisfactory, 3 = satisfactory, 4 = good, 5 = very good; children participating in the study group n = 75 and control group n = 70)

Discussion

Postoperative pain management should be characterized by high efficacy and safety standards. The efficacy of epidural analgesia depends on the quantity and the concentration of LA and the opioid type. In the pediatric setting, the most commonly used drug for local anaesthesia is bupivacaine because of its widespread availability and long lasting activity effect.

In our study, bupivacaine was used at concentrations of 0.25-0.5%. The higher concentration was administered before surgical intervention mainly to obtain motor blockade and to induce pre-emptive analgesia. The lower concentration (0.25%) was used as therapy for the postoperative pain, as this lower dose stops the sensation of pain without impacting motor function, which gives the patient the opportunity to move and to begin active rehabilitation as well as breathing exercises [12].

Ingelmo et al. [13], in their randomized, double-blind, controlled trial, observed that 0.25% bupivacaine had clinical advantages over 0.2% bupivacaine for pediatric epidural anaesthesia. In our earlier study, the use of pure bupivacaine, at a concentration of 0.25%, in children > 7 years old was sufficient to maintain anaesthesia for 4 hours. Adding morphine to bupivacaine significantly improved the quality of the analgesia, causing a 2-fold decrease in the demand for LA and a 4-fold decrease in the need for additional analgesic drugs, and moreover, it increased the time of analgesia to 8 hours [1].

We calculated the appropriate doses for bupivacaine in our patients using a modified Bromage equation. A mean dose of 0.25% bupivacaine in a single bolus was four times less than the maximum recommended dose; whereas, the mean daily dose of bupivacaine was five times less than the maximal permissible dose [12].

Epidural analgesia with LA-opioid combinations has been shown to be better than an intravenous analgesia with opioids [14]. In our study, the difference in analgesia was evident both while the patients were at rest and during breathing and coughing maneuvers (dynamic pain relief). The thoracic epidural analgesia group showed lower pain scores compared with patients receiving an intravenous infusion of morphine. In the control group, despite worse analgesia, the nurses had to modify the treatment 4 times more frequently according to the pain and sedation assessment (a bolus of morphine and an increase/decrease in the infusion rate of morphine). We did not observe significant differences between the groups with regard to the number of doses of non-opioid analgesics.

In children, the insertion of catheters in the thoracic epidural space is not performed routinely because of concerns related to potential complications [6,15-17]. An analysis of the results of two prospective studies in the UK and Ireland, designed to evaluate the safety of epidural and intravenous analgesia [17,18], showed that the risk of serious complications (the lack of recovery during the year) is comparable and is 1: 10000. Epidural analgesia was accompanied by more potential complications diagnosed in due course and not having any undesirable consequences for health (1: 233 *vs.* 1: 631) [17]. These were errors associated with the supply of drugs, topical infections, postpuncture headaches, transient peripheral nerve injuries and total spinal anaesthesia [18]. On the other hand, the techniques associated with the intravenous infusion of opioids were associated with a higher incidence of major complications requiring additional treatment interventions or changes in regimen (1: 383 *vs.* 1: 1100). The main problems were respiratory depression, nausea and vomiting, pruritus and urinary retention [17].

According to Ecoffey at al., complications of epidural analgesia are rare and mostly occur early in the operating theater [15]. In our study, inadvertent spinal anaesthesia was recognized in a 13-year old child who had an insertion of a thoracic catheter prior to an opera-

tion of pleural empyema. According to the other reports [15,18], total spinal anaesthesia is characterized by the stability of the circulatory system, widely dilated pupils and by the lack of back breath during recovery from general anaesthesia. The boy required mechanical ventilation for 150 minutes. It is difficult to assess whether the catheter was inserted intrathecally (aspiration of cerebrospinal fluid was negative) or whether it moved there spontaneously or if LA was diffusing through the damaged dura mater (five attempts were made to insert the epidural catheter – there was no obvious dural tap).

Not only is the moment of catheter implantation related to the risk of complications, but also the administration of drugs into the epidural space. In our clinic, where the research was being carried out, the drugs were administered only by nurse anaesthetists, according to a standard obligatory procedure (according to the procedure the administration of drugs to the epidural space that is valid in the Clinic). Before applying a dose of anaesthetics, HR, BP and saturation were monitored, and aspiration through the catheter was performed to exclude the presence of cerebrospinal fluid or blood. Next, a test dose of 3-4 ml of a bupivacaine-morphine mixture was given, and again the vital parameters were measured and motor blockade was evaluated using the Bromage scale. When there were no signs of spinal anaesthesia and no toxic symptoms, 5 minutes later the rest of the analgesic mixture was slowly administered. Such precaution is necessary, as the correctly placed catheter may migrate to the blood vessel as well as to the intrathecal space [6]. In our work we recorded a single case of migration of a catheter into a blood vessel in a 16-year-old boy after plastic surgery of funnel chest. The nurse, before administering by epidural way another (third) dose of bupivacaine and morphine, aspired blood to catheter. The complication was the indication for catheter removal and intravenous follow-up treatment. An accidental intravascular injection of LA could cause dramatic complications, such as seizures or cardiac arrhythmias [15,16].

A distinct problem that has to be discussed is the occurrence of muscle tremors and paresthesia during treatment, which was mentioned by Wood et al. [19]. In our study, muscle tremors occurred once in 3 patients. Those patients received 0.25% bupivacaine with morphine in bolus at dose of 0.6-0.7–1 mg kg^{-1}. The doses of LA were much lower than the permissible dose, thus it is possible that the cause of the muscle tremors was from the LA absorbing to quickly into the systemic circulation. In our study, paresthesia occurred in 6 patients and was characterized by numbness and sensory disorders of the upper limbs, sometimes just the hand. The symptoms appeared immediately after administration of the drug and vanished spontaneously.

Based on the literature [4, 20] and from our own experience, nausea and vomiting are the most frequently occurring side effects reported by patients during the postoperative period. In total, 12.4% of patients felt nausea and 22.1% of children vomited, which in the majority of the cases were single episodes (13.8%). The side effects occurred more frequently in the older children (13-18 yrs.) than in the younger children ($p = 0.011$; Chi^2 test).

Another common side effect of analgesia is itching [19]. In our study, complications related mainly to the face. In 6.2% of the cases, the symptoms were annoying and were alleviated by an oral supply of promethazine.

Urinary retention was a problem for 26.9% of the patients and occurred with a similar frequency in both of the groups. Pharmacological provocation (neostigmine) proved to be ineffective in 9 of the children. In these cases, a catheter was introduced into the bladder.

This study showed that nurse anaesthetists could provide thoracic epidural analgesia with intermittent doses efficiently and safely. Nursing care for children receiving epidural analgesia focused on safely administering prescribed medications, achieving optimal pain relief and identifying and managing any adverse reactions or complications. It is worth emphasizing that the nurses have a fairly large autonomy in the modification of the treatment. They modified the doses depending on the results in pain and sedation on the basis of general medical orders contained in the individual order cards and guidelines contained in the standard treatment of pain, which was developed for the needs of hospitalized patients in the ward thoracic surgery (a division with "Pain-Free Hospital" certificate). This allowed to reduce the time from the onset of pain in the patient to the administration of an analgesic.

Conclusions

After thoracic surgery in children and adolescents, epidural analgesia with bupivacaine and morphine administered in repeated doses is more effective than a continuous intravenous infusion of morphine. Nurse anaesthetists, under medical supervision, can safely provide thoracic epidural analgesia with intermittent doses.

Acknowledgments

The authors wish to thank the nursing and surgical staff of Thoracic Surgery Clinic, Institute of Lung Diseases and Tuberculosis in Rabka; Dr Jacek Młodkowski for postoperative pain management protocol.

Conflict of interest

None

Correspondence address:
Lucyna Tomaszek
Dept. Thoracic Surgery, Institute for Tuberculosis and Lung Diseases, Pediatric Div.
3b, J. Rudnik Str., 34-700 Rabka, Poland
☎ (+48 18) 267 60 60 (243)
ltomaszek@igrabka.edu.pl

References

1. Tomaszek L, Młodkowski J, Gajdosz R. Paediatric epidural analgesia with "top-up" doses: evaluation of its effectiveness and side effects. Pol J Cardio-Thoracic Surg. 2011;4:509-15.
2. Hughes R, Gao F. Pain control for thoracotomy. Contin Educ Anaesth Crit Care Pain. 2005;5:56-60.
3. Golianu B, Hammer GB. Pain management for pediatric thoracic surgery. Curr Opin Anesthesiol. 2005;18:13-21.
4. Walaszczyk M, Knapik P, Misiołek H, Korlacki W. Epidural and opioid analgesia following the Nuss procedure. Med Sci Monit. 2011;17:PH81-86.
5. Weetman C, Allison W. Use of epidural analgesia in post-operative pain management. Nurs Stand. 2006;20:54-64.
6. Chumbley G, Thomas S. Care of the patient receiving epidural analgesia. Nurs Stand. 2010;25:35-40.
7. Pasero C, Eksterowicz N, Primeau M, Cowley C. Registered nurse management and monitoring of analgesia by catheter techniques: position statement. Pain Manag Nurs. 2007;8:48-54.
8. Bird A, Wallis M. Nursing knowledge and assessment skills in the management of patients receiving analgesia via epidural infusion. J Adv Nurs. 2002;40:522-31.
9. Bromage PR. Epidural Analgesia. Philadelphia: WB Saunders, 1978.
10. Torda TA, Hann P, Mills G, De Leon G, Penman D. Comparison of extradural fentanyl, bupivacaine and two fentanyl-bupivacaine mixtures of pain relief after abdominal surgery. Br J Anaesth. 1995;74:35-40.
11. Hader CF. Epidural analgesia in the critically ill. Nursing 2007. Crit Care. 2007;2:20-30.
12. Verghese ST, Hannallah RS. Acute pain management in children. J Pain Res. 2010;3:105-23.
13. Ingelmo P, Locatelli BG, Frawley G, Knottenbelt G, Favarato M, Spotti A, et al. The optimum initial pediatric epidural bolus: a comparison of four local anesthetic solutions. Paediatr Anaesth. 2007;17:1166-75.
14. Wu CL, Cohen SR, Richman JM, Rowlingson AJ, Courpas GE, Cheung K, et al. Efficacy of postoperative patient-controlled and continuous infusion epidural analgesia versus intravenous patient-controlled analgesia with opioids: a meta-analysis. Anesthesiology. 2005;103:1079-88.
15. Ecoffey C, Lacroix F, Giaufre E, Orliaguet G, Courrèges P; Association des Anesthésistes Réanimateurs Pédiatriques d'Expression Française (ADARPEF). Epidemiology and morbidity of regional anaesthesia in children: a follow-up one-year prospective survey of the French-Language Society of Paediatric Anaesthesiologists (ADARPEF). Pediatr Anesth. 2010;20:1061-9.
16. Giaufré E, Dalens B, Gombert A. Epidemiology and morbidity of regional anesthesia in children: a one-year prospective survey of the French-Language Society of Pediatric Anesthesiologists. Anesth Analg. 1996;83:904-9\12.
17. Morton NS, Errera A. APA national audit of pediatric opioid infusion. Pediatr Anesth 2010;20:119-125.
18. Llewellyn N, Moriarty A. The national pediatric epidural audit. Pediatr Anesth. 2007;17:520-33.
19. Wood CE, Goresky GV, Klassen KA, Kuwahara B, Neil SG. Complication of continuous epidural infusions for postoperative analgesia in children. Can J Anaesth. 1994;41:613-20.
20. Williams DG, Howard RF. Epidural analgesia in children. A survey of current opinions and practices amongst UK paediatric anaesthetists. Paediatr Anaesth. 2003;13:769-76.