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A new neurostimulator guided technique of rectus sheath block: study of feasibility and local anesthetic spread in children

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Abstract

Background: Rectus sheath block (RSB) is a valuable regional technique for abdominal wall midline analgesia. It can be used for a variety of surgical procedures such as midline laparotomy, umbilical and paraumbilical hernia repair, and laparoscopic surgery. Not all operating theatres, especially in low income countries, are equipped with ultrasound (US) scanners for carrying out US guided regional blocks. In cases of total absence of objective control, neurostimulator (NS) guided technique of RSB can be useful. The aim of the study was to assess the feasibility of performing NS guided RSB.

Methods: US guided RSB with NS was performed on patients in group 1. NS guided RSB was performed on patients in group 2. US scanning of block area and clinical efficacy assessment were performed in group 2.

Results: In group 1 in all cases of US guided RSB with NS, needle entry into the rectus abdominis muscle resulted in its contractions and needle contact with the posterior sheath resulted in cessation of these contractions. In group 2 optimal spread of local anesthetic was achieved in 86 cases (74.14%), and suboptimal spread in 30 cases (25.86%) of NS guided RSB. There were no cases of non-optimal local anesthetic spread. In all cases NS guided RSB had high clinical efficacy (there was no motor response to incision and no need for fentanyl administration).

Conclusions: Rectus sheath block can be performed under neurostimulator guidance. Neurostimulator guided rectus sheath block results in optimal or suboptimal local anesthetic spread. Clinical efficacy of neurostimulator guided rectus sheath block is high.

The trial is registered as ACTRN12618000553279 (http://www.ANZCTR.org.au/ACTRN12618000553279.aspx).

Key words: regional anesthesia, rectus sheath block, neurostimulator guidance, children.

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There is an opinion that regional anesthesia should be used in pediatric anesthesiology whenever it is possible [1]. Adult patients can benefit from regional anesthesia too [2]. Data from scientific literature show that peripheral regional blocks can offer more safety and at least the same efficacy in selected patients compared to epidural and spinal anesthesia [3].

Rectus sheath block (RSB) was first described by Schleich in 1899 for muscle relaxation and analgesia of the abdominal wall midline in adults, but later it became less popular due to the introduction of muscle relaxants in anesthesia practice [4]. In 1996 Ferguson *et al*. suggested using RSB for analgesia in umbilical hernia repair in children [5]. Nowadays there is new interest in this block because of progress in minimally invasive, fast track and day case surgery [6]. This block is based on the innervation anatomy of the abdominal wall midline. It is innervated by the anterior primary rami of T7–L1 spinal nerves, i.e. by terminal branches of T7–T12 and the iliohypogastric nerve. After leaving the intervertebral foramina the intercostal nerves run between the internal intercostal muscle and the innermost intercostal muscle and after that between the internal oblique muscle and transversus abdominis muscle. Subcostal and iliohypogastric nerves run between the iliopsoas muscle and quadratus lumborum muscle and then between the internal oblique muscle and transversus abdominis muscle. After that all these nerves penetrate the transversus abdominis muscle aponeurosis, posterior part of rectus sheath, rectus abdominis muscle, anterior part of rectus sheath and end in the skin of the midline of the abdomen with two terminal cutaneous branches (medial and lateral) [7].

Therefore, administration of local anesthetic solution into the potential space between the rectus abdominis muscle and posterior sheath can block innervation of the abdominal midline. Local anesthetic solution can spread along the posterior rectus abdominis muscle sheath cranially and caudally, as tendinous intersections of this muscle are not attached to the posterior sheath [8]. So, depending on local anesthetic volume, the area of anesthesia of the abdominal midline can expand above and below the injection site. For anesthesia of the abdominal wall midline RSB must be performed bilaterally.

RSB can be used for analgesia in cases of umbilical, paraumbilical and epigastric hernia surgery [9], for somatic analgesia in laparotomy surgery when epidural anesthesia is contraindicated [10] and for midline trocar sites analgesia in laparoscopic surgery [11]. There are published data about RSB use for paraumbilical analgesia in patients with cardiovascular compromise, when neuraxial anesthesia was risky or contraindicated [9].

RSB may be performed as a single shot technique or with posterior rectus sheath space catheterization for continuous analgesia of the abdominal wall midline [12].

Usually RSB is performed with ultrasound (US) guidance [8]. Blind RSB technique has been described and used earlier as well [13]. Blind regional blocks can be dangerous and are associated with higher failure rates compared to techniques with objective methods of needle position identification [14]. Cases of failed RSB may be due to incorrect needle placement and local anesthetic spread as well as due to anatomical variability of terminal branches of T7–L1 nerves, as the anterior cutaneous branches of the nerves can be formed before the rectus sheath and in this case do not penetrate the posterior rectus sheath [15].

In low-income countries and countries with low financing of the health industry, such as Ukraine, not every operating theatre is equipped with a US scanner. Thus, we consider it reasonable to search for alternative objective methods of needle tip position identification in peripheral regional blocks of the abdominal wall.

TABLE 1. Demographic data of children in group 1

Age, months (median (25; 75 quartile))	62.50 (30.00; 80.00)
Male/Female	7/3
Body mass, kg (median (25; 75 quartile))	22.10 (14.20; 26.18)

Our hypothesis was based on the experience of peripheral nerve block practice under neurostimulator (NS) guidance, particularly in cases of deep blocks and/or when block technique is related to the needle passing through muscle (e.g. paravertebral block or transgluteal sciatic nerve block). When performing the block the needle passing through the muscle causes its electrostimulation and is often accompanied by its contractions. After the needle has passed through the muscle the contractions stop. We assumed that when performing RSB with the needle attached to the NS, its entry into the rectus abdominis muscle will cause its contractions, and after the needle tip has come out of the muscle these contractions will stop. Cessation of rectus abdominis muscle contractions can serve as a sign of needle tip position between the muscle and its posterior sheath, i.e. of the correct needle tip position for RSB.

NS guided RSB has not been described in the literature.

METHODS

The study was designed as an open-label nonrandomized clinical trial. It was approved by the Lviv Regional Children's Hospital Ethics Committee (Protocol #1, dated January 27, 2016, chairperson O. Burda, MD, PhD, Reference number 1-1-2016). Prior to enrollment informed consent was obtained from parents for participation of their children in the study. Inclusion criteria consisted of: (1) elective umbilical or paraumbilical hernia surgery, (2) age more than one year, (3) ASA status 1 or 2, and (4) parental consent for regional anesthesia and study participation.

Intravenous induction in general anesthesia was administered to all children (propofol bolus 2.5–3 mg kg^{-1} followed by infusion 6 mg kg^{-1} h^{-1}) and a laryngeal mask airway was placed. Then local anesthesia of the skin in RSB injection sites was performed (lidocaine 1% 1–2 mL per side). RSB was performed with bupivacaine 0.25% 0.3 mL kg^{-1} per side according to the techniques described below.

In the first part of the study for verification of our hypothesis we performed US guided bilateral RSB in 10 children (group 1, demographic data shown in Table 1) using a 5-10 MHz linear-array probe (SonoSite Titan; SonoSite Inc., Washington, USA, long axis, in-plane) with an insulated needle attached to the NS (Stimuplex A, 21G, 50 mm and Stimuplex HNS 12 respectively, B. Braun, Melsungen, Germany) with the following settings: current 5 mA (to increase probability of direct muscle stimulation we set high current), impulse time 0.3 ms, impulse frequency 2 Hz. During the blockade, we observed the needle path and local anesthetic spread and registered the beginning and cessation of rectus abdominis muscle twitches.

In the second part of our study we performed NS guided bilateral RSB in 58 children (group 2, demographic data shown in Table 2) with US assessment of block area after doing the blockade. The needle was positioned 3–5 cm cranially from the surgery site in the parasagittal plane and passed in a caudal and dorsal direction at a 45° angle. The needle bevel was set parallel to the rectus sheath. When rectus abdominis muscle twitches started we considered that the insulated needle bevel entered the muscle. When muscle twitches disappeared, we considered that the needle bevel reached the posterior rectus sheath. At this moment an aspiration test was performed and local anesthetic was injected (volume and dose of local anesthetic were the same as in the first part of our study). After the bilateral RSB was done we verified the local anesthetic spread pattern with US scanning. According to US scanning results all NS guided RSB were divided into 3 groups as follows: optimal spread (local anesthetic solution is between the rectus abdominis muscle and posterior rectus sheath), suboptimal spread (most of the local anesthetic solution is between the rectus abdominis muscle and posterior rectus sheath, infiltration of the rectus abdominis muscle with local anesthetic is evident) and non-optimal spread (local anesthetic solution is in the rectus abdominis muscle tissue, there is no or minimal local anesthetic between the rectus abdominis muscle and posterior rectus sheath).

We also assessed clinical efficacy of NS guided RSB by means of registration of motor response to incision and the need for fentanyl administration according to hemodynamic variables.

Statistical analysis

Statistical analysis was performed using Open Source Epidemiologic Statistics for Public Health (http://www.openepi.com/) and G*Power 3.1 (http://www.gpower.hhu.de/) software. The χ^2 test for more than 2 groups (R by C table) was used to calculate the significance of differences among groups and post hoc power analysis of study was performed.

RESULTS

In the first part of the study we determined that in all cases of needle entry into the rectus abdominis muscle, contractions of this muscle in response to NS were registered. These contractions were observed on the US scanner screen and visually. At the moment of needle contact with the posterior rectus sheath the contractions stopped. In all 20 cases of "double" (US and NS) guided RSB optimal local anesthetic spread was registered.

In the second part of the study we performed 116 NS guided RSB in 58 children. In all cases rectus abdominis muscle contractions in response to NS were visually observed. US scanning of the blockade area after NS guided RSB showed that optimal local anesthetic spread was registered in 86 RSB (74.14%) and suboptimal local anesthetic spread in 30 RSB (25.86%). There were no cases of non-optimal local anesthetic spread. Study results are shown in Table 3.

Post hoc power analysis showed that the achieved power of our study (1 – β-error probability) was 0.999791–1.0.

Examples of optimal and suboptimal local anesthetic spread are shown in Figures 1 and 2.

TABLE 2. Demographic data of children in group 2

Age, months (median (25; 75 quartile))	34.50 (21.75, 52.00)
Male/Female	41/17
Body mass, kg (median (25; 75 quartile))	16.35 (14.23, 21.23)

TABLE 3. Local anesthetic solution spread after neurostimulator-guided rectus sheath block (RSB)

	O	SO	NO	
RSB number (%)	86 (74.14)	30 (25.86)	0 (0)	χ^2 square = 147.8 $P < 0.0000001$

O – optimal, SO – suboptimal, NO – non-optimal

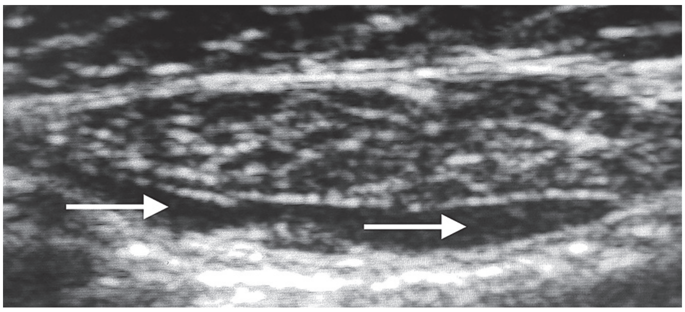

FIGURE 1. Example of optimal local anesthetic spread. Thick arrows – local anesthetic spread between rectus abdominis muscle and posterior part of its sheath

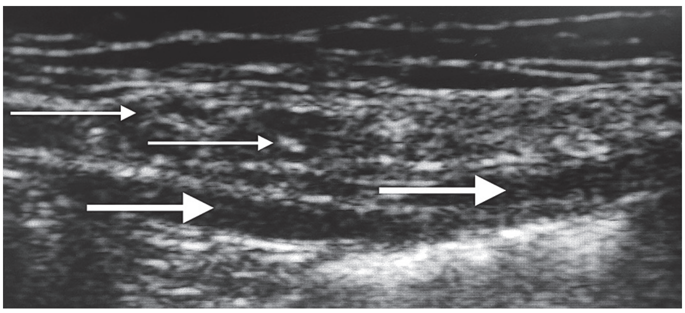

FIGURE 2. Example of suboptimal local anesthetic spread. Thick arrows – local anesthetic spread between rectus abdominis muscle and posterior part of its sheath. Thin arrows – intramuscular local anesthetic spread

Assessment of clinical efficacy of NS guided RSB showed that in all cases surgical analgesia was achieved. None of the children demonstrated a motor response to incision. None of the children needed fentanyl administration either.

We did not observe any adverse events or complications during or after NS guided RSB.

DISCUSSION

Our study showed that in most cases NS guided RSB ensured optimal spread of local anesthetic. Alternatively, one can say that in all cases NS guided RSB produced optimal or suboptimal spread of local anesthetic. It can be speculated that in all cases of NS guided RSB the local anesthetic solution (the entire volume or most of it) was deposited between the rectus abdominis muscle and posterior rectus sheath and this was the background to produce effective RSB. Additionally, the results of our study showed that NS guidance can be an acceptable method of needle tip position identification between the rectus abdominis muscle and its posterior sheath.

Assessment of clinical efficacy of NS guided RSB showed that a sufficient level of surgical analgesia was achieved in 100% of cases, which allowed surgery to be performed without opioid administration. This means that effective RSB is possible even with suboptimal local anesthetic spread. This phenomenon may be due to the fact that the major amount of local anesthetic was deposited in the correct anatomical space, i.e. effective blockade was produced with less than the calculated volume of local anesthetic. US guided RSB with small volumes of local anesthetic such as 0.1 ml kg^{-1} bilaterally was described by Willschke *et al*. [16]. In addition, blockade of nerves in the body of the rectus abdominis muscle could contribute to anterior abdominal wall analgesia. The success rate of US guided RSB is about 53.3–100% with its maximum in children and minimum in adults with high body mass index [16, 17]. As NS guided RSB has not been described yet, there is no comparison of NS guided and US guided RSB efficacy in the literature. Also, there are no data on blind RSB efficacy compared to US guided and NS guided techniques, but Willschke *et al*. [16] showed the possibility to lower the amount of local anesthetic in US guided RSB compared to blind technique in children.

In the context of safety in the review of Abrahams *et al*. [8] it is mentioned that US guidance is the preferred method to perform RSB and ilioinguinal/iliohypogastric nerve blocks. On the other hand, safety improvement due to US guidance in regional anesthesia has been demonstrated only for prevention of postoperative neurologic symptoms, vascular puncture, local anesthetic systemic toxicity and hemidiaphragmatic paresis [18]. Moreover, Polaner *et al*. [19] in an epidemiologic study of regional anesthesia safety in children report none of the adverse events and complications of RSB regardless of whether US guided or blind techniques were used.

We do not deny the importance of US visualization in regional anesthesia, though we consider that in the settings of total absence of objective methods of needle position identification NS guidance can be an acceptable technique for RSB.

CONCLUSIONS

Rectus sheath block can be performed under neurostimulator guidance. Neurostimulator guided rectus sheath block results in optimal or suboptimal local anesthetic spread. Clinical efficacy of neurostimulator guided rectus sheath block is high.

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