0.3 mA ve 0.5 mA'lik Eşik Akımların Axiller Brakial Plexus Bloğu Üzerine Olan Etkileri

The Effects of 0.3 mA and 0.5 mA Threshold Currents on Axillary Brachial Plexus Block

Brakial Plexus Bloğu / Brachial Plexus Block

Halit Demir[1], Ayse Mizrak[1], Gunhan Karakurum[2], Unsal Oner[1]
[1]Department of Anesthesiology and Reanimation, [2]Orthopedic Sugery, Gaziantep University Medical Faculty, Gaziantep, Turkey.

Özet

Amaç

Periferik sinir stimülatörü ile sinir bloğu başarısı, optimal sinir lokalizasyonu ile arttırılabilir. Ancak bunun için hangi eşik akımın buna daha uygun olduğu açık değildir.

Gereç ve Yöntemler

Onsekiz-60 yaşları arasında 40 hasta bu randomize, çift kör çalışmaya alındı. Grup 1'de (n=20) ve grup 2'de (n=20) eşik akımlar sırasıyla 0.3 mA ve 0.5 mA idi. Totali 40 ml olan 150 mg levobupivakain (%0.5) ve 200 mg lidokain (%2) karışımı radial sinir etrafına enjekte edildi. Postoperatif duyusal ve motor blok süresi ve ilk analjezik ihtiyaç süresi ölçüldü.

Bulgular

Muskulokütaneusun duyusal ve motor blok başlayışı (sırasıyla p=0.01 ve p=0.004) median ve ulnar sinirin motor blok başlayışı (sırasıyla p=0.009 ve p=0.02) grup 1'de grup 2'ye göre istatistiksel olarak anlamlı bir şekilde düşüktü. Postoperatif duyusal ve motor blok süresi ile ilk analjezik ihtiyaç süresi grup 1'de grup 2'ye göre anlamlı bir şekilde uzundu (p=0.0001).

Sonuç

0.3 mA'lik akım 0.5 mA'lik akıma göre duyusal ve motor bloğun başlamasının kısalmasında, postoperatif duyusal ve motor bloğun ve ilk analjezik ihtiyacının uzamasında daha faydalıdır.

Anahtar Kelimeler

Aksiller-Brakial Pleksus Blok, Levobupivakain, Lidokain, Periferik Sinir Stimülatörü, Akım Eşiği (mA).

Abstract

Aim

The nerve block success by peripheral nerve stimulator may be increased by optimal nerve localization. However, it is not clear which current threshold is more suitable for this.

Material and Methods

Forty patients between 18-60 years of age were included in this randomized, double blind study. In group 1 (n=20) and group 2 (n=20), the thresholds of current were 0.3 mA and 0.5 mA respectively. The mixture of 150 mg of levobupivacaine (0.5%) and 200 mg of lidocaine (2%) in a total volume of 40 ml was injected around the radial nerve. The duration of postoperative sensory and motor block and the first analgesic requirement were measured.

Results

The onset of sensory and motor block of the musculocutaneus (p=0.01 and p=0.004 respectively) and the onset of motor block of the median and ulnar nerve (p=0.009 and p=0.02 respectively) were significantly shorter in group 1 than in group 2. The duration of postoperative sensory and motor block and the time to first analgesic requirement were significantly longer in group 1 than in group 2 (p=0.0001).

Conclusions

The 0.3 mA current is more beneficial than 0.5 mA current in shortening the onset of sensory and motor block, lengthening the postoperative sensory and motor block and the duration of first analgesic requirement.

Keywords

Axillary-Brachial Plexus Block, Levobupivacaine, Lidocaine, Peripheral Nerve Stimulator, Current Threshold (mA).

DOI: 10.4328/JCAM.342 Received: 13.08.2010 Accepted: 04.09.2010 Printed: 01.09.2011 J Clin Anal Med 2011;2(3):39-42
Corresponding Author: Ayse Mizrak, Gaziantep University Medical Faculty, Department of Anesthesiology and Reanimation, 27310 Sahinbey, Gaziantep, Turkey. E- mail: aysemizrak@mynet.com Fax: 00903423602244 Phone: +0905337181025

Introduction

Axillary block is the most common anesthetic technique used in hand and/or forearm operations [1-3]. In this study, the purpose is to shorten the latent period with the combination of a medium effective local anesthetic, of which effect starts early, and a slow and long effective local anesthetic [4-7]. In the studies, it was aimed to obtain a successful nerve block by providing a localization as good as possible [8]. The generally accepted view is that the minimum current strength for nerve stimulation must be 0.5 mA and below [9, 10]. There is a study showing the low block success rates in the nerve localization over 0.6-0.8 mA [11]. It is claimed that block development duration would get shorter and block success rate would increase in nerve localization below 0.5 mA [9]. In contrast to this view, it is suggested that pinpoint of the injection might contact the nerve at very low currents and cause nerve damage in nerve localization [12]. Rigaud et al.[13] reported that stimulating currents less than 0.5mA may contribute to intraneuronal injection. It is not a certain concept that threshold current should be below 0.5 mA and based on our experience, after the use of these two different threshold currents, block success results appear to be different as well. A study in which these two threshold currents are compared in detail during axillary block is not available in literature. Therefore, we aimed to compare the effects of 0.3 and 0.5 mA of threshold currents on sensorial and motor block onset, block duration, the first analgesic requirement duration, hemodynamic adverse effects and patient's and surgeon's satisfaction scores.

Materials and Methods

The study was planned after the ethical committee approval dated 28.04.2008 and numbered 04-2008/97 in Gaziantep University Medical Faculty, Department of Anesthesiology and Reanimation. The study was performed in accordance with the most recent version of the Helsinki Declaration. In our study, 40 orthopaedics and plastic surgery patients in American Anesthesiologists Association (ASA) I-II risk groups, aged between 18-60 and who were to undergo urgent elective right or left hand or arm surgery, were involved. The patients were informed in detail about the procedure to be carried out and consent forms regarding that they want to participate in the study were taken.

The patients with epilepsy, diabetes mellitus, impaired blood clotting and peripheral neuropathy, the patients with skin diseases such as scleroderma and Reynaud phenomenon, the cardiac patients (ischemic heart disease, arrhythmia) the pregnant and obese patients, patients who cannot be efficiently communicated with, patients with an infection on the regions of operation, alcohol or drug addicts, patients allergic to amid group local anesthetics, antipsychotic drug, clonidine, opioids and beta blocker users and patients who were taken to general anesthesia due to conditions preventing the abduction of the arm were excluded from the study. Patients were assigned to 1 of 2 study groups using the randomization chart posted on a wall; in Group 1 (n= 20) and Group 2 (n= 20), the thresholds of current used were 0.3 mA and 0.5 mA, respectively. They were given general anesthesia. The randomization continued until we reached 20 patients in each group. The patients were taken to the regional anesthesia application room in the operating theatre and they were monitored. Peripheral vascular access was opened with intravenous cannula (20 G) on the back of the nonoperated hand and 0.9% of NaCl solution was given with a pace of 5-7 ml/kg/hour. Half an hour before axillary block, all the patients were given 0.02 mg/kg of IV midazolam as standard for the purpose of premedication [14]. The patients were placed in the supine position for block. The arm was placed to 90º abduction and the forearm was put to 90º flexion and external rotation, with the back of the hand placed on the table and the forearm parallel to the long axis of the patient's body. The skin was infiltrated with 2 ml of 2% lidocaine on the artery fixed by the index finger and middle finger of the left hand. Injection access point was marked on the artery pulse. The cathode pole of the nerve stimulator was attached to the conductive end of the stimulator and the anode pole was attached to the ECG electrode on the region apart from the application region. The stimulator was first adjusted to 1.5 mA, 2 Hz frequency, 0.1 ms parameters. The injection was moved forward from the access point parallel to the artery with a 30º angle to the skin. The access to the axillary cover was recognized after feeling the fascia click while passing through the fascia. N. radialis, was searched via the twitch of the muscle to be sure that the local anesthetic could spread into the brachial plexus area for a successful block. At the beginning, peripheral nerve stimulator (PNS) was adjusted to 1.5 mA for all the nerves. Observing twitch when the current is at 0.3 mA in group 1 and at 0.5 mA in group 2 was accepted as the indicator of a successful localization and the local anesthetic solution was given to that region. If a patient was in the 0.5 mAmp, and had a brisk response at 0.5 mAmp, the current was then further reduced to find out the minimum current that would induce a motor response. Then the needle was manipulated so that there was a response at 0.5 mAmp, but no response at a lower current. For the radial nerve with nerve stimulator; nerve localization was done according to the response of extension in forearm, wrist, fingers and thumb supination. Stimupleks (® HNS 12,B.Braun Melsungen AG, Germany) was used as the peripheral nerve stimulator with isolated needle 22G, 100 mm. In the study, 150 mg of 0.5% levobupivacaine (Chirocaine®, 5 mg/ml, Abbott Lab, Turkey Nycomed Pharma AS NO-2418, Elverum Norway, 10 ml, 3 aliquots, total 30 ml in each bottle) and 200 mg of 2% lidocaine (Aritmal®, 20 mg/ml OSEL Pharmaceutical Industry and Trade Inc. Istanbul/Turkey, 5 ml, 2 aliquots, total 10 ml in each ampoule) were prepared as the local anesthetic (LA) solution for each patient. In Group 1 a mixture of 30 ml of 0.5% of levobupivacaine and 10 ml of 2% of lidocaine (total 40 ml) was injected slowly into the cover of the nerves belonging to plexus brachial, following the aspiration test when the current is at 0.3 mA. In Group 2 the same volume and mixture of LA was injected slowly into the cover of the nerves following the aspiration test when the current is at 0.5 mA. During the injection, it was checked whether the injection had intravascular emplacement by applying aspiration frequently. The rest of the local anesthetic solution was injected. Three minutes of compression was applied by hand in order to decrease the possibility of hematom.

We evaluated the block onset with pin-prick test and bromage scale, respectively before surgery has started. Pin-prick test was recorded by giving 0 point if the patient has pain, 1 point if the patient does not have sufficient loss of pain, 2 points if the patient does not have feel the pain at all. Bromage scale was recorded by giving 0 point if there is no loss of power in the arm and fingers, 1 point if motor power is less but the arm is moving, 2 points if the arm is not moving but the fingers are, 3 points if there is a total inactivity in the arm and fingers. If any adverse effects (numbness in the mouth and tongue, a feeling of metallic taste in the mouth, drowsiness, nausea, vomiting, hypotension,

hypertension, bradycardia, arrhythmia, tinnitus) were observed during the preoperative period, they were recorded.

The patients who needed additional analgesic during the operation were given fentanyl (50-150 µg according to VAS) and the pain was ceased. The patients in need of sedative were given midazolam and they were sedated. The total doses given to these patients were recorded. After the surgery was completed, the patients' sensory block recovery time, motor block recovery time and the first pain onset time were evaluated and recorded. The onset duration of pain was accepted and recorded as the duration from the block application to the period when VAS value is >3 at rest. The patient was told to put an intersecting mark on a horizontal line, which would show the level of his/her pain. The value was accepted as 0 if the patient had no pain and 10 if the pain was the worst pain ever to imagine. The patient and surgeon satisfaction regarding the anesthesia were investigated in postoperative period 24 hours later. The patient satisfaction was recorded by giving 0 point if the patient was not satisfied, 1 point if the patient was slightly satisfied, 2 points if the patient was satisfied and 3 points if the patient was very satisfied. The same points and procedure were employed to identify and record surgeon's satisfaction. All the evaluations and records were performed by a blinded observer who was different from the person who had performed the study.

Statistical Analysis

For the statistical evaluation of the findings obtained in the study, SPSS (Statistical Package for Social Sciences) for Windows 15.0 program (Chicago, USA) was used. While evaluating the study data, Mann-Whitney U test was used in comparing the quantitative data, in addition to defining statistical methods. As for the comparison of qualitative data, Kruskal Wallis test and Chi-Square test were used. The results were evaluated at 95% confidence interval, and significancy was evaluated at $p< 0.05$ level. The data were given as mean ± SD. We have not used a power calculation to calculate the sample size.

Results

There was not a significant difference between group 1 and group 2, regarding the operation durations, age, gender, weight, ASA classification and surgery types of the patients. No significant difference was found between the groups, in terms of the sedative (midazolam) and analgesic (fentanyl) requirement, patient and surgeon satisfaction (Table 1). The time when the first postoperative analgesic requirement appeared (when VAS score increased over 3) was statistically longer in group 1 than in group 2 (p= 0.0001, Table 1).

In group 1, the onset time of both sensory and motor block of musculocutaneous nerve (p= 0.001 and p= 0.004 respectively) and the onset of motor block of median and ulnar nerves were (p= 0.009 and p= 0.02 respectively) determined to be significantly shorter (Table 2A and 2B) than in group 2.

The recovery time of sensory and motor block for all nerves in group 1 was determined to be significantly longer than in group 2 (p= 0.0001, Table 3A and 3B).

No significant difference was found between the groups, regarding the preoperative MAP and HR during the postoperative period. In group 1 nausea in 1 patient, drowsiness in 1 patient and hypertension in 1 patient were observed. As for the 2nd group, drowsiness in 1 patient and a metallic taste in the mouth in 1 patient were observed as the adverse effects.

Table 1. Demographic Data, Types of Operations, Intraoperative Fentanyl and Midazolam Requirement, the Satisfaction of Patients and Surgeon and the Duration of Postoperative first Analgesic Need (VAS> 3).

	Group 1(n= 20)	*Group 2 (n= 20)*	*p*
The Duration of Operations (min)	49.7±42.3	65.5±36.1	NS
Age (years)	39.9 ± 16.6	33.6 ± 12.5	NS
Gender (F/M) (n)	9/11	8/12	NS
Weight (kg)	76.1 ± 81.7	72.2 ± 12.8	NS
ASA (I-II)	13/7	8/12	NS
The Type of Operations (Tendon release/ trigger finger)	15/5	!7/3	NS
Midazolam Requirement (mg)	0.8 ± 0.9	1.4± 0.9	NS
Fentanyl Requirement (µg) n (%)	30 ± 5.7 6(30%)	45± 5.4 9(45%)	NS
The Satisfaction of Patients	1.4±0.6	1.25±0.6	NS
The Satisfaction of Surgeon	1.4±0.6	1.35±0.5	NS
The Duration of Postoperative first Analgesic Need (VAS> 3) (Hours)	20.0±3.6*	12.7±4.4	0.0001*

n= 20, *p when compared with group 2. NS: Nonsignificant
Data was demonstrated as mean±SD or number (%).

Table 2a. The Onset Time of Sensory Block in the Groups.

	Group 1	*Group 2*	*p*
Ulnar Nerve (Min)	8.2 ± 6.6	8.6 ± 4.1	NS
Radial Nerve (Min)	10.3 ± 6.1	11.1 ± 10.7	NS
Median Nerve (Min)	9.4 ± 8.6	9.8 ± 3.9	NS
Musculocutaneus Nerve (Min)	11.6 ± 6.4*	22.4 ± 15.8	*0.01

Table 2b. The Onset Time of Motor Block in the Groups.

	Group 1	*Gorup 2*	*p*
Ulnar Nerve (Min)	9.1 ± 7.4	14.3 ± 9.0	*0.02
Radial Nerve (Min)	9.8 ± 6.7	13.3± 12.1	NS
Median Nerve (Min)	10.2 ± 7.0*	21.4 ± 19.0	*0.009
Musculocutaneus Nerve (Min)	13.0 ± 8.4*	27.9 ± 18.0	*0.004

n= 20, *p when compared with group 2. NS: Nonsignificant (>0.05)
Data was demonstrated as mean±SD.

Table 3a. The Recovery Times of Sensory and Motor Blocks in the Groups.

	Group 1	*Group 2*	*p*
Ulnar Nerve (Hr)	18.0 ± 2.7*	11.9 ± 4.2	*0.0001
Radial Nerve (Hr)	18.3 ± 2.6*	11.5 ± 4.0	*0.0001
Median Nerve (Hr)	18.0 ± 2.6*	11.1 ± 4.1	*0.0001
Musculocutaneus Nerve (Hr)	17.5 ± 2.6*	8.4 ± 3.9	*0.0001

Table 3b.

	Group 1	*Group 2*	*p*
Unlar Nerve (Hr)	17.7 ± 2.9*	11.0 ± 4.1	*0.0001
Radial Nerve (Hr)	17.9 ± 3.0*	10.6 ± 4.2	*0.0001
Median Nerve (Hr)	18.0 ± 2.5*	9.9 ± 4.2	*0.0001
Musculocutaneus Nerve ((Hr)	17.5 ± 2.8*	7.4 ± 3.9	*0.0001

n= 20, *p when compared with group 2. NS: Nonsignificant. Data was demonstrated as mean±SD.

Discussion

The 0.3 mA current provided shorter onset of sensory and motor block, longer postoperative sensory and motor block and the duration of first analgesic requirement than 0.5 mA current.

As surgery on the bone, nerve and extent of surgery make a difference on post operative pain, all the procedures were same.

The common view is that the required strength of current for nerve stimulator should be 0.5 mA and below [9, 10]. There is a study revealing the low block success rates in the nerve localization with the threshold current over 0.6-0.8 mA [11]. It is suggested that in the nerve localization under 0.5 mA, the block development time would get shorter and that block success rate would increase [9]. However, what exactly this threshold current should be is not stated. In our study, axillary block was applied by accepting 0.3 or 0.5 mA of threshold currents as reference. In group 1, the onset time of both sensory and motor block of musculocutaneous nerve and the onset of motor block of median and ulnar nerves determined to be significantly shorter.

The time when postoperative first analgesic requirement was seen (VAS> 3) was statistically longer in group 1 than in group 2. In our opinion, the reason for this is that at 0.5 mA stimulation, the local anesthetic was given when the injection point was not close enough to the target nerve. In the low current group since more of the local anesthetics remained near the nerves, the block onset time was shorter and the duration was longer than the high current group.

In the study regarding high doses of bupivacaine, levobupivacaine and ropivacaine (5mg/ml, 45 ml) they used in axillary BPB, Liisanatti et al. [15] determined the average block duration to be 19.3 hours, 19.5 hours,17.3 hours, respectively. Similarly in our study, the average block duration was determined to be 17.88 hours in group 1, and 10.18 hours in group 2, by using levobupivacaine (5 mg/ml, 30 ml) and lidocaine (20 mg/ml,10 ml) combination. In the study, sensory and motor block durations for all nerves were found to be significantly longer in group 1. The recovery time of sensory block and motor block for all nerves were found to be significantly longer in group 1 than in group 2. By determining 0.3 mA current threshold as the basis, it is seen that sensory and motor block durations extended, which means the block was more successful. However, they were found to be shorter compared to the block durations found by Liisanatti et al, [15]. The fact that the total volume of local anesthetic we used is lower and that the levobupivacaine volume in that concentration was much lower (30 ml) might be the reasons why the average block duration is much shorter compared to the results of Liisanatti et al. In other words, the duration of anesthetic effect may differ based on two factors, lidocaine when combined with bupivacaine, may compete with bupivacaine for the binding sites, by mass action this can lead to a shortened duration of effect. The other is the effect of the total mass of bupivacaine(or levobupivacaine) applied. More drug will provide a greater duration. Thus, the benefit of the lidocaine/levobupivacaine mixture may be faster onset, but shorter duration. In the study carried out by Chelly et al., lidocaine and bupivacaine were used as mixed and at the end of this study it was found that the brachial plexus block (BPB) applied was effective and reliable and that it would contribute to shorten the duration of hospital stay [16].

Carles et al. [11] stated that the failure rate was high in the cases which they performed by using 0.6-0.8 mA. According to Coulombs law, in low current stimulation, the closer the distance to the nerve, the higher is the success rate. Bachmann M. et al. [17] found out that an electrical current below 0.5 mA increases the success rate. However, nerve damage is the most important complication of regional anesthesia. Neurologic complications due to nerve stimulator use are stated as 0% in some studies [11, 18], and as 4-8% in some others [19, 20]. Urmey et al. [12] claimed that at very low currents in nerve localizations, the injection end could contact the nerve and cause nerve damage. Similarly, Robards et al.[21] demonstrated that low current stimulation contributed to a high incidence of intraneural needle placement in popliteal sciatic nerve block. However, the needle should be redirected if paresthesia occurs to avoid intraneural injection [22]. This method has the advantage that the patient cooperation is not required. In addition, injections of local anaesthetic agents can be placed more accurately [23]. In the present study, we had no paresthesia or pain by the patient experienced nerve block. Therefore, since it is more practical in application, observing the muscle move, even if it is minimal, while preventing the threshold current to fall below 0.3 mA, is very important in terms of high block success and having no neuronal damage. Similar to the current study, some studies have generally found that lower currents are associated with faster onset and better success rate. For example, Cuvillon et al. [24] have shown that using less than 0.5 mA is associated with better results. Despite the advantages to prevent these complications, it may have been impossible to use ultrasound because of the inability to use or inability to buy for its high price in certain centers. Robards et al. [25] experienced that pressure applied to an ultrasound transducer can occlude venous structures making negative aspiration misleading and unreliable for excluding intravascular needle placement. In addition, Sauter et al. [26] reported that in experienced hands, favorable results can be obtained when either nerve stimulation or ultrasound guidance is used.

In our study, there was not a significant difference between the groups, regarding the intraoperative MAP, HR, analgesic and sedative drug requirement, adverse effects and complications in the postoperative period. In the intraoperative 1st group, nausea in 1 patient, drowsiness in 1 patient and hypertension in 1 patient were observed. As for the second group, drowsiness in 1 patient and metallic taste in the mouth in 1 patient were seen. No other complications or systemic toxicity were observed during the preoperative and postoperative periods in our cases. Cox et al. [27] stated that there has been a distinct decrease from 0.2% to 0.01% in the incidence in systemic toxicity with local anesthetics during the last thirty years and they indicated that although systemic toxicity incidence in peripheral nerve blocks were at the highest level with 0.075%, the neural damage rate was at the lowest level with 0.019%.

Conclusions

Using 0.3 mA of threshold current in axillary brachial plexus block can be recommended since it extends postoperative analgesia and anesthesia times and delays the first postoperative analgesic requirement, which leads to an increase in success rate compared to 0.5 mA of threshold current, and it therefore can be used as a reference in axillary block.

References

1. Janzen PR, Vipond AJ, Bush DJ, Hopkins PM. A comparison of 1% prilocaine with 0.5% ropivacaine for outpatient-based surgery under axillary brachial plexus block. Anesth Analg 2001;93:187-91.
2. Martinez Navas A. [Complications of peripheral nerve blocks]. Rev Esp Anestesiol Reanim 2006;53:237-48.
3. Brockway MS, Wildsmith JA. Axillary brachial plexus block: method of choice? Br J Anaesth 1990;64:224-31.
4. Salazar CH, Espinosa W. Infraclavicular brachial plexus block: variation in approach and results in 360 cases. Reg Anesth Pain Med 1999;24:411-6.
5. Checcucci G, Allegra A, Bigazzi P, Gianesello L, Ceruso M, Gritti G. A new technique for regional anesthesia for arthroscopic shoulder surgery based on a suprascapular nerve block and an axillary nerve block: an evaluation of the first results. Arthroscopy 2008;24:689-96.
6. Gurkan Y, Hosten T, Solak M, Toker K. Lateral sagittal infraclavicular block: clinical experience in 380 patients. Acta Anaesthesiol Scand 2008;52:262-6.
7. Berry JS, Heindel L. Evaluation of lidocaine and tetracaine mixture in axillary brachial plexus block. Aana J 1999;67:329-34.
8. Barthram CN. Nerve stimulators for nerve location--are they all the same? A study of stimulator performance. Anaesthesia 1997;52:761-4.
9. De Andres J, Sala-Blanch X. Peripheral nerve stimulation in the practice of brachial plexus anesthesia: a review. Reg Anesth Pain Med 2001;26:478-83.
10. Benhamou D. Axillary plexus block using multiple nerve stimulation: a European view. Reg Anesth Pain Med 2001;26:495-8.
11. Carles M, Pulcini A, Macchi P, Duflos P, Raucoules-Aime M, Grimaud D. An evaluation of the brachial plexus block at the humeral canal using a neurostimulator (1417 patients): the efficacy, safety, and predictive criteria of failure. Anesth Analg 2001;92:194-8.
12. Urmey WF, Stanton J. Inability to consistently elicit a motor response following sensory paresthesia during interscalene block administration. Anesthesiology 2002;96:552-4.
13. Rigaud M, Filip P, Lirk P, Fuchs A, Gemes G, Hogan Q. Guidance of block needle insertion by electrical nerve stimulation: a pilot study of the resulting distribution of injected solution in dogs. Anesthesiology 2008;109:473-8.
14. Rawal N, Allvin R, Axelsson K, Hallén J, Ekbäck G, Ohlsson T, Amilon A. Patient-controlled regional analgesia (PCRA) at home: controlled comparison between bupivacaine and ropivacaine brachial plexus analgesia. Anesthesiology 2002;96:1290-6.
15. Liisanantti O, Luukkonen J, Rosenberg PH. High-dose bupivacaine, levobupivacaine and ropivacaine in axillary brachial plexus block. Acta Anaesthesiol Scand 2004;48:601-6.
16. Chelly JE, Greger J, Al Samsam T, Gebhard R, Masson M, Matuszczak M, Sciard D. Reduction of operating and recovery room times and overnight hospital stays with interscalene blocks as sole anesthetic technique for rotator cuff surgery. Minerva Anestesiol 2001;67:613-9.
17. Bachmann MB, Biscoping J, Hempelmann G. [Initial experiences with a novel nerve stimulator for use in axillary plexus anesthesia]. Reg Anaesth 1989;12:80-3.
18. Winnie AP. Does the transarterial technique of axillary block provide a higher success rate and a lower complication rate than a paresthesia technique? New evidence and old. Reg Anesth 1995;20:482-5.
19. Fanelli G, Casati A, Garancini P, Torri G. Nerve stimulator and multiple injection technique for upper and lower limb blockade: failure rate, patient acceptance, and neurologic complications. Study Group on Regional Anesthesia. Anesth Analg 1999;88:847-52.
20. Urban MK, Urquhart B. Evaluation of brachial plexus anesthesia for upper extremity surgery. Reg Anesth 1994;19:175-82.
21. Robards C, Hadzic A, Somasundaram L, Iwata T, Gadsden J, Xu D, et al. Intraneural injection with low-current stimulation during popliteal sciatic nerve block. Anesth Analg 2009;109:673-7.
22. Munir MA, Jaffar M. A further consideration on unsolicited paresthesias with nerve stimulator. Anesth Analg 2003;96:1529; author reply 1529.
23. Stark P, Watermann WF. [The use of nerve stimulators for nerve blocks (author's transl)]. Anaesthesist 1978;27:SPEC SECT 16-9.
24. Cuvillon P, Dion N, Deleuze M, Nouvellon E, Mahamat A, L'hermite J, et al. Comparison of 3 intensities of stimulation threshold for brachial plexus blocks at the midhumeral level: a prospective, double-blind, randomized study. Reg Anesth Pain Med 2009;34:296-300.
25. Robards C, Clendenen S, Greengrass R. Intravascular injection during ultrasound-guided axillary block: negative aspiration can be misleading. Anesth Analg 2008;107:1754-5.
26. Sauter AR, Dodgson MS, Stubhaug A, Halstensen AM, Klaastad O. Electrical nerve stimulation or ultrasound guidance for lateral sagittal infraclavicular blocks: a randomized, controlled, observer-blinded, comparative study. Anesth Analg 2008;106:1910-5.
27. Cox B, Durieux ME, Marcus MA. Toxicity of local anaesthetics. Best Pract Res Clin Anaesthesiol 2003;17:111-36.