Detection of Neurovascular Structures Using Injection Pressure in Blockade of Brachial Plexus in Rat

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Abstract

In the last few decades there has been a great development of regional anesthesia; all the postulates are defined and all the techniques of usage are perfected. However, like any other medical procedure, the block of brachial plexus carries a risk of certain unwanted complications, like possible intraneural and intravascular injections. The reason for great discrepancy between the injury of brachial plexus and other periphery nerves while performing the nerve blockade is the frequent usage of this block, but also the specific proximity of neurovascular structures in axilla.
The purpose of this work is to determine the values of pressures which appear in paraneural, intraneural and intravascular injection applications of local anesthetic, and to compare those values in order to avoid cases of intraneural and intravascular injections in clinical practice with consequential complications.
In experimental study there have been used 12 Wistar rats of both genders. After anesthesia with ether and midhumeral access to the neurovascular structures in axilla, the injection of 2% lidocain with epinephrine was performed with the help of automatic syringe charger. The needle was at first placed paraneural, and then also intraneural and intravascular. During every ap-

plication the pressure values were monitored using the manometer, and then they were analyzed by special software program. All paraneural injections resulted with the pressure between 13,96-27,92 kPa. The majority of intraneural injections were combined with the injection pressure greater than 69,8 kPa, while the intravascular injections were combined with injection pressure less than 6,98 kPa. Based on the available data it can be noticed that so far none of the methods of prevention from unwanted complications of regional anesthesia can insure the avoidance of intraneural and intravascular injection of local anesthetic. Based on our research it is obvious that the measuring of pressure during the nerve blockade is very important in order to decrease the risk of neurological and possible systematic complications. It is also clear that a small, mobile, and financially quite available apparatus for pressure measurement can help in differentiation between paraneural, intraneural and intravascular injection. Avoiding high injection pressure prevents from lodging the needle into intraneural space, while avoiding a very low injection pressure prevents from lodging the needle into intravascular space followed by consequential complications. The usage of this apparatus can find its application in other blockades of periphery nerves, and in other branches of medicine as well.
KEY WORDS: regional anesthesia, block of brachial plexus, intraneural injection, intravascular injection

Introduction

In the last few decades there has been a great development of regional anesthesia; all the postulates are defined and all the techniques of usage are perfected. The world trend of favoring various techniques of regional anesthesia is a result of the advantages that the regional anesthesia comes with, especially in comparison with the general anesthesia, like avoiding chemodynamical instability and lung complications and enabling faster mobilization and earlier release of the patients to their homes (1). One of the most frequently used techniques of regional anesthesia is the block of brachial plexus, which can be performed in all cases when the surgery is necessary on upper extremities or in therapy of postoperative pain (2). However, like any other medical procedure, the block of brachial plexus carries a risk of certain unwanted complications. To this also contributes the fact of specific anatomic proximity of neurovascular structures in axilla, which makes the branches of brachial plexus even more vulnerable (3). It is known, from the researches so far, that the unwanted complications during the nerve blockade can happen after unintentional intraneural or intravascular injection of local anesthetic in the surrounding neurovascular structures. Intraneural injections can be followed by the consequential paresis or the paralysis of certain nerve, while the intravascular injections of the local anesthetic can result in the appearance of the symptoms of toxicity of cardiovascular system or of central nervous system, with possible cardiac arrest, and even death. As prevention from intraneural injections and consequential complications today are in use two methods: the method of causing paresthesia or the method of using the stimulator of periphery nerve; however the injury can still occur, independent from the used techniques, even in the hands of the most experienced executer. In prevention from intravascular injection exists the method of aspiration before and during the application; but even the negative aspiration test does not always signify that the injection is placed out of artery or vein. The other possibility is the usage of epinephrine (addition to the local anesthetic) as a marker of intravascular injection. The reasoning behind this is that in 20 seconds after the injection the pulse is increasing up to 30% and this appearance can be a verification of intravascular injection. However, the epinephrine test also does not give enough security to exclude the intravascular injection (4,5). How to prevent mentioned complications are the themes that are most frequently discussed on the congresses of anesthesiologists.

Objective

The purpose of this work is to determine the values of pressures which appear in paraneural, intraneural and intravascular injection application of local anesthetic, and to compare those values in order to avoid cases of intraneural and intravascular injections in clinical practice with consequential complications. Purpose is also the standardization of the mentioned method.

Materials and Methods

In experimental study there have been used 12 Wistar rats of either sex. After anesthesia with ether and midhumeral access to the neurovascular structures in axilla (Figure 1.), with microscopic guidance, the injection of 2% lidocain with epinephrine was performed with the help of automatic syringe charger. The automatic syringe charger was set so that the speed of application is 3ml/min, and the volume of the injected solution is 4ml (Figure 2.). The needle, with the diameter of 26 G (Microlens) and under the angle of 45 degrees, was at first placed in close proximity to neurovascular structures (paraneural), and then into a nerve (n.medianus-intraneural) (Figure 3.) and into

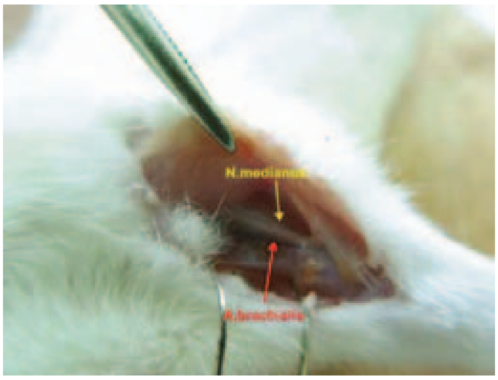


FIGURE 1. Midhumeral access to the neurovascular structures

FIGURE 2. Automatic syringe charger

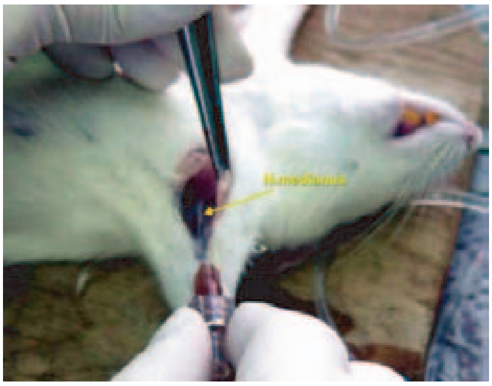


FIGURE 3. Application of local anesthetic into a n.medianu

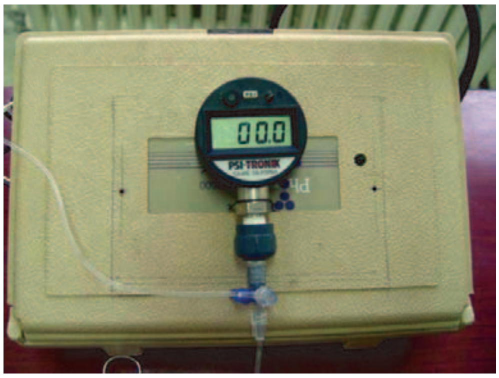
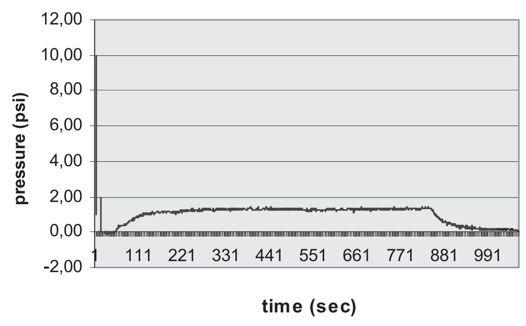


FIGURE 4. Manometer

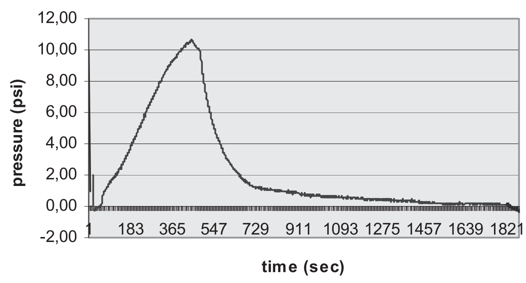
blood vessels of axilla (a. and v. axillaris- intravascular). During every application the pressure values were monitored (expressed in PSI; 1 PSI=6,98 kPa) using the manometer (PG 5000; PSI-Technologies Inc, Tulare, CA) (Figure 4.), that is connected to a computer with analogous digital converter (DAQ card 6023 National Instruments), and then they were analyzed by special software program - BioBench 1.2. National Instruments. BioBench program is designed for registration and analysis of data obtained in medical researches and is used for educational requirements as well. Using National Instruments for getting data, we can get data form any physiological type of linear voltage source. The program itself has the ability to use the obtained data and analyze it integrating the personal computer with physiological monitoring systems, and thus saves a great amount of time and money. Using the Bio Bench program we facilitated the registration, analysis and adequate evaluation of an enormous number of data which we got during our research.

Results

Generally speaking, all the injections were characterized by initial pressure, which was followed by a quite similar, but lower pressure in the remaining part of injecting. All paraneural injections resulted with the pressure between 13,96-27,92 kPa. The majority of intraneural injections were combined with the injection pressure greater than 69,8 kPa, while the intravascular injections were combined with injection pressure less than 6,98 kPa (Graphic 1, 2, 3). The average value of intraneural pressures was 86,552±13,262 kPa, in comparison to 25,128±3,49 kPa for paraneural injection and 7,0498±2,094 kPa for intravascular injection. Statistic analysis was executed using SPSS program - version 11.5. The test was used for determining significances during paraneural, intraneural and intravascular injections. The obtained results showed that p-value < 0,05, which is considered significant (intraneural-paraneural ap-



GRAPHIC 1. Example of intravascular injection

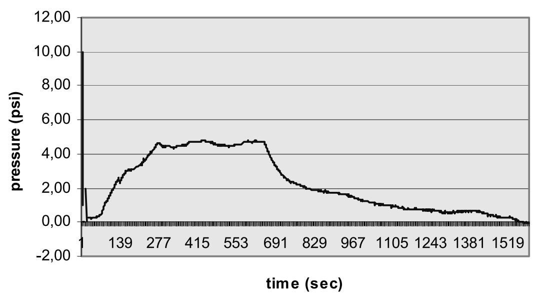


GRAPHIC 2. Example of intraneural injection

plication p<0,001; intravascular-intraneural application p<0,001; intravascular-paraneural application p<0,001).

Discussion

The incidence of permanent nerve damages during periphery nerve blocks varies between 0,02% and 0,04%, depending on the type of damage and the amount of time spent observing (6,7). The incidence of persistent neurological damage decreases with time. The proofs of neurological abnormality can be found in 19 % of patients in first 24 hours, then they are decreasing to 3-8% through 4-6 weeks, and in 1 year they are reduced to 1% (8). Cheney and his associates were investigating American Society of Anesthesiologist Closed Claims data base in order to determine the frequency of nerve damages based on filed claims. Out of 4.183 reviewed claims, 670 (16%) were because of the nerve damages that had some connection to anesthesia. The most frequent areas of damage were n. ulnaris (28%), brachial plexus (20%), lumbosacral nerve roots (16%) and spinal cord (13%)(9). Auroy and his associates made a prospective study grading the incidence and the characteristics of serious complications connected to regional anesthesia. Total of 103.730 techniques of regional anesthesia, including 71.053 of neuroaxial anesthesia, 21.278 periphery nerve blocks and 11.229 intravenous regional anesthesia, were carried out through a 5 month period. Neurological complications connected to techniques of regional anesthesia were present in 34 patients. Out of 34 neurological complications, 24 (70%) happened during spinal anesthesia, 6 (18%) during epidural anesthesia, and 4 (12%) during the blockade of periphery nerves. The additional complications that happened during the blockade of periphery nerves include the cardiac arrest (0,01%), death (0,005%), brain stroke (0,08%) and radiculopathy (0,02%) (10). Based on the available data it can be noticed that so



GRAPHIC 3. Example of paraneural injection

far none of the methods of prevention of unwanted complications of regional anesthesia can insure the avoidance of intraneural and intravascular injection of local anesthetic. There are many discussions about how to prevent intraneural injection and nerve damage coupled with periphery nerve block, and all debates are focused on two methods of nerve localization (paresthesia versus nerve stimulator). Many anesthesiologists intentionally cause paresthesia during the execution of periphery nerve blockade in order to reliably localize nerve structures. This partly emerged from an ancient saying «no paresthesia, no anesthesia» (11). Even though causing paresthesia can represent a direct trauma with needle and theoretically increased risk of neurological injury, there are no prospective clinical randomized studies that are able to definitely support or negate this (6, 7). Selander and associates reported a high incidence of nerve damages in patients that had parasthesia that was intentionally caused during the axillary block, in comparison to those patients on whom the perivascular technique was applied (2,8% versus 0,8%). Aurory and associates noticed that all cases of radiculopathy, after blockade of periphery nerve, were coupled either with paresthesia during the placement of the needle or with painful response to injection and they had the same topographic distribution like connected paresthesia (10). The researches that were mentioned earlier connect the technique of paresthesia with the detection of nerve that has perioperative nerve damage. However, other studies do not agree with this, believing that the results were obtained in animal studies in which the nerve damages happened under direct eye guidance (12). Moore pointed out that appropriately caused paresthesia does not indicate that the needle cut penetrated epineurium, that the nerve was pierced, nerve fibers cut off or that the intraneural injection has happened. He accentuated that there is no statistically significant published clinical data that indicates that a carefully performed paresthesia during a regional blockade results in temporary or permanent loss of nerve function. Researchers like Winchell and Pearce support Moore. Winchell and associates reported that the frequency of postoperative neurological injury in 854 patients with blockade of brachial plexus is only 0,36%. Out of these, 835 (98%) felt the paresthesia with consequential injection of local anesthetic (13,14). The concern comes out of the fact that paresthesia can be compromised in cases of sedated or anesthetized patients, because they are potentially exposed to unrecognizing of intraneural injection (15,16). In regard to the fact that causing paresthesia can be lessened for partially anesthetized nerve, for example in incompletely achieved anesthesia, then the supplementary block can theoretically increase the risk of nerve injury (17). This method is unacceptable for pediatric patients, because a child is not able to precisely report paresthesia or to distinguish it from other discomforts during the block execution. Children under 4 years of age distinguish pain with principle all or nothing «either it hurts or it doesn't». Does causing parasthesia present direct needle trauma, which increases the risk of nerve injury, still remains unknown. However today exists a tendency towards abandoning of this method in many centers. The usage of periphery nerve stimulator as a method for localization of periphery nerves has started in 1962 (18). The frequency of neurological complications with periphery nerve stimulator varies from 0% (19,20) to more than 8% (5). Some of the advantages of this method are described, including great success in the possibility of performing this procedure on sedated and uncooperative patients, avoiding vascular and neurological damages, and avoiding parasthesia insuring precise localization of the needle without real contact with the nerve (21,22,23). However, recent studies of Choyce and associates showed that this maybe isn't the case. In their study they explored the relation between subjective parasthesia and objective motor response, caused with periphery nerve simulator, in patients that had interscalene and axillary blockade (15,24). During the procedure the not insulin needle was entering all until the paresthesia was caused. In that moment the current of the nerve stimulator started to gradually increase until reaching the adequate motor response. It is interesting that after achieving paresthesia, for 25 % of the patients the current greater than 0,5 mA was needed for achieving manifesting motor response. The place of initial paresthesia matches the place of consequential motor response in 81% of the cases, indicating the inconsistency in provoking the motor response, in spite of the fact that the needle was probably close to the nerve. This concern is confirmed further by the reports of nerve damage after using low current (less than 0,5 mA) of periphery nerve stimulator and intramedullary injection during interscalene block of patients under general anesthesia (25). Stimulator with such low current is usually joined with paresthesia on injection, which can indicate possible intraneural placement of the needle. Therefore, the claim that the periphery nerve stimulator allows clinical staff to get close to nerve structures without a risk of mechanical trauma does not seem valid. It should be pointed out that the nerve stimulators used in blockade of periphery nerves quite vary in their characteristics, like stimulating frequencies, maximal production of voltage, duration of stimulus and their preciseness (26). Because of this the nerve stimulators undergo the tests of preciseness. Unfortunately, the majority of manufacturers make the tests using the current of 1.0 mA. It would be much more efficient if they would do these tests with clinically relevant current range from 0.1 to 0.5 mA. In the contemporary clinical practice there is no consensus about a technique or a method that reduces a risk from intraneural injection. The proximity of the brachial plexus to the vascular structures can contribute to intravascular injection of local anesthetic. Stan and others reported that the frequency of unintentional intravascular injection is 0,2% in 996 patients that had to undergo the axillary blockade, in spite of the negative test for aspiration (27). Intravascular complications were also noted during the interscalene block, where a deep insertion of a needle into interscalene groove can result with puncture or unwanted injection of local anesthetic into a.vertebralis, when local anesthetic gets directly to the brain (28). Unfortunately, the minimal quantities of local anesthetic (0,5 cm3) can cause extremely high concentrations of anesthetic in the central nervous system, which brings to a strong toxic response. Other, just as risky, vascular structures are a. carotis communis and v. jugularis externa (interscalenous block), a. and v. subclavia (supra or infra clavicle block) and a. and v. axillaris (axillary block). Similar complications due to intravascular injections were noted after giving the penicillin G to gluteal region, with consequential cardio respiratory arrest and death because of lung embolism caused by insoluble substances (29,30). One needs to be especially mindful of this because of frequent administration of penicillin into gluteal region, mainly to children, during the therapy of pharyngitis, impetigo or the infection of the middle ear. Clinical watchfulness, periodical aspiration, the usage of epinephrine as vascular marker, and continuous observation in search for symptoms and signals of toxicity of local anesthetic are presently the key variables for prevention from these complications, even though we should be mindful that even this technique is not absolutely dependable. One study on small animals showed that the intraneural injection can be joined with high injection pressure. The earlier studies carried out on rabbits showed that generally higher pressure (higher than 11psi) is needed in order to inject local anesthetic into intraneural space, in comparison to paraneural application (31). Anesthesiologists often rely on subjective estimate of abnormal resistance to injection during the performance of periphery nerve block, knowing that intraneural injection results with bigger resistance to injection. Hadžić and associates showed that the perception of the resistance can rather vary among the anesthesiologists and that this method is inconsistent and can be affected by different designs of needles (32). In the study that used dogs, Hadžić and associates showed that the intraneural injection into n.ischiadicus is joined with high injection pressure with consecutive persistent neurological deficit (33).

Conclusion

Based on our research it is obvious that the measuring of pressure during the nerve blockade is very important in order to decrease the risk of neurological and possible systematic complications. It is also clear that a small, mobile, and financially quite available apparatus for pressure measurement can help in differentiation between paraneural, intraneural and intravascular injection. Avoiding high injection pressure prevents from lodging the needle into intraneural space, while avoiding a very low injection pressure prevents from lodging the needle into intravascular space followed by consequential complications. The usage of this apparatus can find its application in other blockades of periphery nerves, and in other branches of medicine as well, for example in everyday practice of giving intramuscular injections of different medicines (antibiotics-penicillin, corticosteroids and similar) into gluteal or deltoid region, because the application into different tissues results with different values of injection pressures, which greatly depends on structure, compactness and extensibility of the tissue. The method of monitoring application pressure in detection of neurovascular structures is still in its developmental stage, and the clinical experience of its usage is limited. However this study shows that there exists a great potential in improvement of block performance resulting in better successfulness and lesser risk of lesions of nerves and blood vessels. In the near future the monitoring of injection pressure might exist in order to avoid intraneural injection and to more objectively document the procedure of periphery nerve block, and to analogously document the blood pressure. Applying these results to clinical practice, during periphery nerve blocks, the risk of unwanted complications can be reduced. It should be pointed out that none of the techniques can be a substitute to a good knowledge of anatomic relations.

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