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RESEARCH ARTICLE

EFFECT OF SYRINGE SIZE ON OPENING INJECTION PRESSURES

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ABSTRACT

***Introduction*:** High opening injection pressure (> 15 psi) can detect needle - nerve contact. However, the reliability of injection pressure monitoring to detect needle – nerve or impingement may be affected by syringe size. We hypothesized that monitoring of opening injection pressure (the pressure at which injectate is detected by US) is affected by the size of the syringe used for injection. ***Methods*:** After Ethics Commitee approval, 22 gauge 50 mm needles were inserted under US to contact the C5, C6 and C7 nerve roots of fresh human cadavers. Hand-held injections were made using 3 different syringe sizes (5, 10, 20 mL) at a rate commensurate with typical clinical practice. Injections were made bilaterally at each of the above nerve roots. Opening injection pressure data were aquired with an in-line digital pressure recorder using a 60 mL syringe (10ml/min), and injection halted when spread was detected. ***Results*:** A total of 48 injection measurements were made. The peak (opening) pressures at which injection commenced in two cadavers were 30.50 psi and 34.07 psi with 5 mL syringe, 29.20 psi and 34.95 psi for 10 mL syringe, 26.03 psi and 29.42 psi for 20 mL syringe, all han-held injection. In automated pump injection 60 mL syringe was used, and maximum achieved pressures were 23.42 psi and 34.03 psi. Opening injection pressures were similar regarless of syringe size (p>0.05). ***Conclusion*:** The size of the syringe commonly used in clinical practice of peripheral nerve blockade did not significantly affect the monitoring of the open injection pressure. All injection with the needle – nerve contact resulted in injetion pressure > 20 psi, regardless of syringe size or method of injection. Our findings ate thus consistent with the fluid mechaminc described by Pascal's Law, where pressure exerted anywhere in a confined incompressible fluid system is transmited equally throughout until the opening pressure is reached and injection begins.

INTRODUCTION

In order for a peripheral nerve blockade procedure to be successfully performed with a local anesthetic, needle has to be located close enough to the targeted nerve. However, if the injection passes through the epineurium or worse if it comes within the fascicle it can result in a nerve injury and a permanent neurological deficit (Patil *et al.,* 2015). There are different methods involved in detection of nerve structures during peripheral nerve blockade, such as paresthesia, ultrasound, abnormal resistence to injection during the performance of nerve blockade and nerve stimulators. Previous studies showed that high injection pressure (>75 kPa) is associated with high risk of intrafascicular injection and low injection pressure (<28 kPa) indicate extraneural injectinon. Hence, the monitoring of the value of injection pressure is one of the reliable methods for avoiding intraneural injection (Hadzic *et al.,* 2002; Hasanbegovic *et al.,* 2012; Selander *et al.,* 1979). Syringe selection is mostly based upon the volume of medication to be administered and the desired pressure flow. Volumes are usually measured in centimeters (cc) or milliliters (mL). Both types of measurements are equivalent in volume. A 1 cc syringe is the same as a 1 mL syringe. Large volumes of medication require larger syringe sizes. Lower pressure flows also require larger syringe sizes. The purpose of this work is to determine the possible differences in values of opening pressure in peripheral nerve blockade using different size syringes during hand-held injection and automated pump injections.

METHODS

The present study was conducted on two fresh frozen human cadavers, after approval of Ethnics Commitee of the Medical Faculty University of Sarajevo. Under ultasound control, we inserted 22 G, 50 mm needles (Stimuplex-A, B Braun, Inc) bilaterally on to the C5, C6 and C7 nerve roots. 2% lidocaine (Bosnalijek, Sarajevo) was used as injectate. For application we used three different syringe sizes, as follows: 5 ml, 10 ml, 20 ml. Injection were hand-held at a rate commensurate with typical clinical practice. In fourth group we used 60 ml syringe with the speed of 10ml/min. The data of achieved pressures during application were registered using an in-line digital pressure recorder. For injection with 60 ml syringe we used automated pump injection. The application stopped when the spread was recorded. Statistical analyses were performed by using SPSS program, version 11.5. Maximum pressure values during intraneural injection were compared by using paired t-test. A P value < 0.05 was considered to be significant.

RESULTS

A total of 48 injections measurements were made, 12 for each group using different size syringe. Generally speaking, all injections were characterized by small increase of pressure in the beginning of application (first 10-15 seconds), resulting in maximum pressure, which was then followed by significantly lower pressure, when the further application was stoped. The peak pressures at which injection commenced are displayed in the table (Table 1). There are no statisticaly significant differences in opening pressure values using different syringe size (p>0.05) and there is no statisticaly significant differences in opening pressure values using different method of application (p>0.05) (Figure 1, 2, 3, 4).

Table 1. Opening pressure peak values

	Hand-held injections			Automated Pump Injection
Syringe size	5cc (n=12)	10cc (n=12)	20cc (n=12)	60cc (n=12)
Cadaver 1	30.50	29.20	26.03	23.42
Cadaver 2	34.07	34.95	29.42	34.03

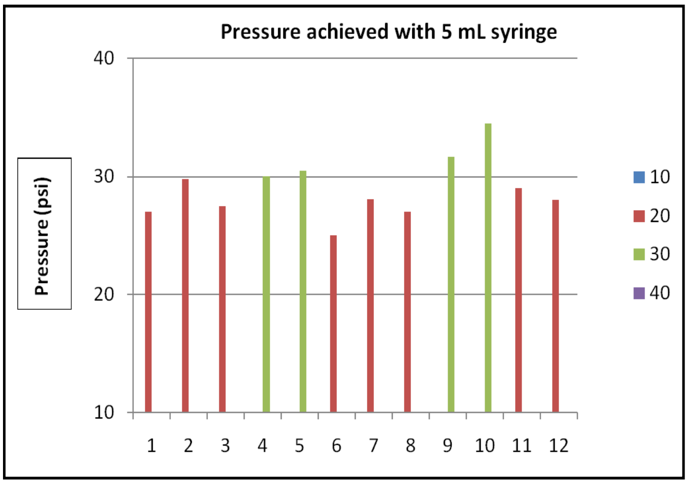

Figure 1. Pressures achieved during application with 5 mL syringe

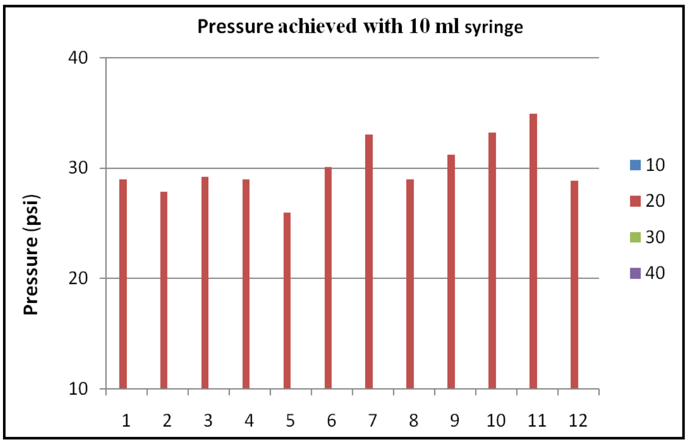

Figure 2.Pressures achieved during application with 10 mL syringe

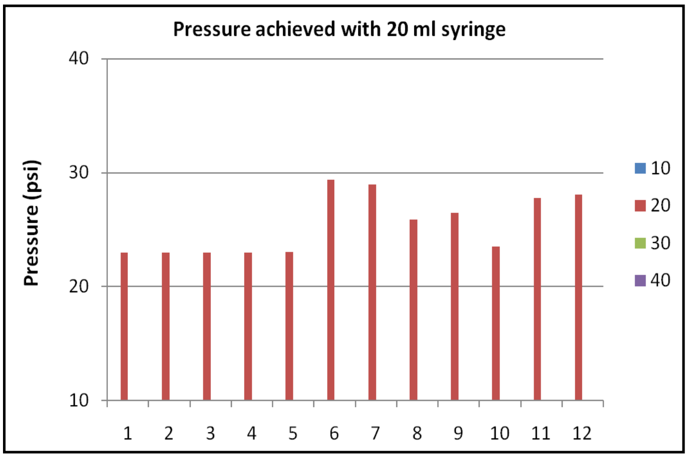

Figure 3. Pressures achieved during application with 20 mL syringe

DISCUSSION

Peripheral nerve block with LA is a common practice in providing pain control for a wide range of surgical procedures and pain syndromes. Inadvertent intrafascicular injection of an local anaesthetic can generate a variety of nerve injuries, some of which may result in long term disability (Auroy *et al.,* 2002). Nerve injury is considered to be multifactorial in nature. Factors such as needle type and size, site of insertion, type and dose of medication injected (toxicity) affect degree of nerve injury according to various studies (Auroy *et al.,* 2002; Whitlock *et al.,* 2010; Mackinnon *et al.,* 1982). In general, most drugs caused nerve injury when injected intrafascicularly, and, in contrast extrafascicular injections produced little to no damage (Mackinnon *et al.,* 1982; Sala-Blach *et al.,* 2009). Damage may be minimal or may result in severe axonal and myelin degeneration, depending on the agent injected and dose of the drug used (Mackinnon *et al.,* 1982; Gentilli *et al.,* 1980). Unfortunately, the mechanism by which unintented intraneural injection causes nerve injury is not well understood. The overwhelming clinical experience is that correctly placed local anesthetics carry a very low risk of neve injury. However, all local anesthetics are potentially neurotoxic if used in high concentrations or if applied to nerves for aprolonged period of time (Selander, 1993). Under normal conditions, an injected bolus of local anesthetic reaches a pressure equilibrium with the surronding tissues. At this point, diffusion into the tissues occurs, interstinal fluid rapidly dilutes the local anesthetic, and the concentration is futher decreased by systemic absorbtion.

In current clinical practice, there is no consensus on techniques or methods to reduce the risk of intraneural injection. This produced the need for development of objective monitoring and reliable prevention of intraneural injection and consecutive neurological injuries. There are many discussions about how to prevent intraneural injection and nerve injury coombined with peripheral nerve blok, and all these discussions are focused on the methods of nerve localization. And yet, there is no evidence that one method is safer than the other because neurological sequels follow all availabe methods (Moore, 1953; Selander *et al.,* 1979; McClain and Finucane, 1987). Results from previous studies showed that detection of pressure during peripheral nerve blocks is unique as a nerve localizing technique in terms of being able to avoid needle-nerve contact and potentially prevent direct trauma to nerves (Hasanbegovic *et al.,* 2006). Also the injection of local anesthetic into sciatic nerve of a dog resulted in high application pressure (Hadzic *et al.,* 2002; Kapur *et al.,* 2007).

In our study we tried to determine if there is a significant differences in pressure values using syringe of different size. Our results showed that the size of syringe commonly used in clinical practice of peripheral nerve blocks did not significantly affect the monitoring of the open injection pressure. In our study all injection had injection-nerve conntact and they all resulted in pressure greater than 20 psi, regardless of syringe size. Also, our results showed that there is no significat differences in values of opening pressure using the different method of injection, meaning hand-held injetion or automated pump injection. An earlier study performed in rabbits has suggested that generally a greater presure (i.e. ≥11 psi) is required to inject solutions intraneurally than perineurally (Selander and Sjostrand, 1978). Indeed, in our study all intraneural injecrion resulted in pressure greater than 20 psi. Our findings are thus consistent with the fluid mechanics described by Pascal's Law, that states that pressure at a point has infinite direction, and thus a pressure change at any point in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere (Bloomfield and Louis, 2006). The pressure at a point in a fluid at rest is the same in all directions; the pressure would be the same on all planes passing through a specific point. According to Pascal's Law, in a hydraulic system a pressure exerted on a piston produces an equal increase in pressure on another piston in the system. If the second piston has an area 10 times that of the first, the force on the second piston is 10 times greater, though the pressure is the same as that on the first piston. This effect is exemplified by the hydraulic press, based on Pascal's Law, which is used in such applications as hydraulic brakes.Pascal's Law also states that pressure remains constant throughout the syringe, needle, and tubing until the flow of fluid begins, regardless of the syringe size, speed of injection or diameter of fluid passages. Pascal's principle applies to all fluids, whether gases or liquids.

Our results showed that a certain pressure level must be overcome (opening pressure) to initiate injection into relatively non compliant nerve tissue. There are two phases of fluid administration: first, is isostatic phase during which there is no flow at the tip of the needle. A certain opening pressure must be reached within the syringe-tubing-needle system in order to initiate the injection into a tissue compartment. Second phase is dynamic phase. During initial pressure buildup in this scenario, the pressure is equal through tout the closed syringe-tubing needle injection apparatus. Consequently, pressure monitoring proximal to the site of injection should reasonably accurately reflect the pressure at the tip of the needle until the flow occurs. Once flow is established and as the perineurium ruptures (intraneural injection), pressure monitored proximal to the needle will be affected by the rate of injection and the flow characteristics of the needle. This state is in accordance with Bernoulli's principle, which states that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy (Batchelor, 2000). Fluid particles are subject only to pressure and their own weight. If a fluid is flowing horizontally and along a section of a streamline, where the speed increases it can only be because the fluid on that section has moved from a region of higher pressure to a region of lower pressure; and if its speed decreases, it can only be because it has moved from a region of lower pressure to a region of higher pressure. Consequently, within a fluid flowing horizontally, the highest speed occurs where the pressure is lowest, and the lowest speed occurs where the pressure is highest (Resnick and Halliday, 1960).

Therefore intraneural injection results with significantly higher injection pressure prior to penetration of the internal bundle of fasciculi. The pressure continue to be high due to the restricted diffusion space withhin the bundle. Anesthesiologist 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. But Hadzic *et al.* (2002) showed that the perception of the resistance can rather vary among the anesthesiologist and that this method is inconsistent and can be affected by different desings of needle (Hadzic *et al.,* 2002; Claudio *et al.,* 2004). The pressure information displayed by manometer reliably indicate the pressure at the tip of the needle, regardless to the size of the needle, or syringe or the rate of injection applied.

Conclusion

Based on our research it is obvious that there is no differences in injection pressures using syringes in different size. Opening injection pressures were similar reagdless of syringe size or method of injection (hand-held versus automated pump). As long as the injection pressure is low, injection into poorly compliant tissue can be avoided and the neurological damage can be prevented.

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