No change in impedance upon intravascular injection of D5W

Aucun changement d'impédance lors d'une injection intravasculaire de dextrose 5 %

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Received: 9 October 2009 / Accepted: 24 February 2010 / Published online: 11 March 2010
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Abstract

Purpose Electrical impedance increases following test injections of non-conducting solutions around nerves; however, this increase should diminish rapidly with intravascular needle placement, wherein the systemic circulation will dissipate the solution. For this observational study, we hypothesized that the impedance increases significantly at the perineural space after an injection of 5% dextrose in water (D5W), but that it does not increase correspondingly at the intravascular location

Methods After Ethics Research Board approval, electrical impedance was measured by a nerve stimulator displaying resistance, Stimuplex® HNS 12, before and during (30 sec) an injection of D5W 3 mL: 1) during intravenous cannula placement using an insulated stimulating needle sheathed in its plastic cannula, MultiSet NanoLine with 18G needle; and 2) during needle placement (Pajunk 22G insulated) for an ultrasound-guided supraclavicular block in patients undergoing hand surgery. The impedance changes at each location were analyzed and compared.

Results Data were collected from 16 patients. Baseline impedance was lower intravascularly (mean $16.5 \pm$ standard deviation $7.2 \text{ k}\Omega$) compared with perineurally ($23.5 \pm 8.3 \text{ k}\Omega$) ($P = 0.037$). Peak impedance after intravascular D5W injection was $20.1 \pm 6.8 \text{ k}\Omega$, which was not a significant change ($P = 0.15$). In contrast, peak impedance after perineural D5W injection was

$58.6 \pm 29.1 \text{ k}\Omega$, an increase of $35.1 \pm 26.4 \text{ k}\Omega$ ($155 \pm 117\%$), and then it reached a plateau of $36.7 \pm 19.6 \text{ k}\Omega$. The increase in impedance was significantly greater at the perineural location ($P < 0.0001$).

Conclusion The absence of a significant increase in impedance upon injection of D5W prior to injection of local anesthetic may provide useful information to warn of intravascular injection.

Résumé

Objectif L'impédance électrique augmente après les injections de test de solutions non conductrices autour des nerfs; toutefois, cette augmentation devrait diminuer rapidement lors d'un positionnement intravasculaire de l'aiguille, situation dans laquelle la circulation systémique dissipera la solution. Pour réaliser cette étude observationnelle, nous avons émis l'hypothèse que l'impédance augmentait de façon significative dans l'espace périmérial après une injection de dextrose à 5 % diluée dans de l'eau (D5W), mais qu'elle n'augmentait pas de la même manière dans un site intravasculaire.

Méthode Après avoir reçu l'approbation du Comité d'éthique de la recherche, l'impédance électrique a été mesurée à l'aide d'un stimulateur nerveux affichant la résistance, le Stimuplex® HNS 12, avant et pendant (30 sec) une injection de 3 mL de D5W: 1) pendant le positionnement d'une canule intraveineuse à l'aide d'une aiguille de stimulation isolée protégée par sa canule de plastique, le MultiSet NanoLine avec une aiguille 18G; et 2) pendant le positionnement de l'aiguille (Pajunk 22G isolée) pour un bloc supraclaviculaire par échoguidage chez des patients subissant une chirurgie de la main. Les changements d'impédance à chaque site ont été analysés et comparés.

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Résultats Au total, des données ont été recueillies auprès de 16 patients. L'impédance de départ était plus basse au site intravasculaire (moyenne $16,5 \pm \text{écart type } 7,2 \text{ k}\Omega$) comparativement au site périméneural ($23,5 \pm 8,3 \text{ k}\Omega$) ($P = 0,037$). L'impédance maximale après une injection intravasculaire de D5W était de $20,1 \pm 6,8 \text{ k}\Omega$, ce qui n'a pas constitué un changement significatif ($P = 0,15$). En revanche, l'impédance maximale après une injection périméneurale de D5W était de $58,6 \pm 29,1 \text{ k}\Omega$, une augmentation de $35,1 \pm 26,4 \text{ k}\Omega$ ($155 \pm 117 \%$), pour ensuite atteindre un plateau de $36,7 \pm 19,6 \text{ k}\Omega$. L'augmentation de l'impédance était significativement plus élevée au site périméneural ($P < 0,0001$).

Conclusion Une augmentation significative de l'impédance lors de l'injection de D5W avant l'injection de l'anesthésique local pourrait fournir des informations utiles pour prévenir les cas d'injection intravasculaire.

Intravascular injection of local anesthetic resulting in local anesthetic toxicity is a significant risk during regional anesthesia that potentially causes seizures and cardiac arrhythmias.¹⁻⁵ This possibility is of particular concern at the upper extremity since many of the nerve targets are located in highly vascular regions. Methods to minimize this risk include the use of slow incremental injection, the aspiration of syringes prior to injection of local anesthetic, and monitoring heart rate or T-wave amplitude changes following injection of a test dose of epinephrine.^{1,6} Recently, ultrasound visualization (incorporating the use of colour Doppler) of block needle placement and local anesthetic spread outside the vessels has been used to avoid or detect intravascular injection,^{7,8} which, unfortunately, still occurs despite these methods.^{3,9,10}

One potential method for identifying intravascular placement is the use of electrical stimulation after a test injection of a non-conducting (non-electrolyte) solution, e.g., 5% dextrose in water (D5W). Injection of a non-conducting solution around a nerve, i.e., into the perineural or interstitial tissue, creates a significant increase in electrical resistance (impedance), because the current density around the tip of the electrode is increased.^{11,12} In contrast, injection of a conducting solution, e.g., local anesthetic or normal saline, does not increase perineural impedance; in fact, it may be lowered slightly.¹¹ Conversely, intravascular injection should not result in an increase of impedance of similar magnitude and/or duration, because the systemic circulation would efficiently remove the solution from the injection site. Our hypothesis was that electrical impedance would increase after a perineural injection of D5W; however, electrical impedance would not increase significantly after an intravascular injection of D5W.

Based on this principle, a practical test could be developed to detect intravascular placement by observing impedance changes. Absence of this increase in impedance upon D5W injection may indicate intravascular needle placement. Our primary objective was to demonstrate that electrical impedance would increase significantly at a perineural location (during peripheral nerve block) upon injection of non-conducting (D5W) solutions via a stimulating electrode, but that impedance would not increase at an intravascular (during intravenous cannula placement) location. Additionally, the impedance values measured after injection of conducting solutions at these locations were used as controls to verify that D5W was the appropriate solution.

Methods

After receiving approval from the Health Ethics Research Board at the University of Alberta, Canada, patients scheduled for ultrasound-guided supraclavicular blocks for hand and wrist surgery at the University of Alberta Hospital were recruited to participate in this study throughout November 2007 and December 2007. Patients older than 18 yr and able to provide informed consent were included in this study.

Intravascular impedance measurements

An 18-gauge intravascular catheter was placed in the patient's arm or forearm on the opposite side of the operation, and measurements of impedance were taken from the catheter via an 18-gauge electrode, MultiSet NanoLine with an 18G insulated needle (Pajunk Medizintechnologie, Germany) inserted through the catheter (Figure 1). A Stimuplex® HNS 12 nerve stimulator (B. Braun Medical, Bethlehem, PA, USA) displaying resistance was connected to the electrode. The ground electrode was placed on the opposite shoulder, and 0.4–0.5 mA pulses of 100 μsec duration were delivered at a frequency of 2 Hz. Impedance was recorded (via review of video recordings described below) before (baseline) and after an injection of D5W 3 mL and a subsequent control injection of 0.9% normal saline 3 mL through the stimulating electrode. The electrode was flushed with normal saline prior to the control injection.

Perineural impedance measurements

Supraclavicular brachial plexus blocks were performed under ultrasound guidance using an in-plane needle alignment to a small footprint curved array probe, M-Turbo® with C11 8–5 MHz transducer (Sonosite Inc., Bothell, WA,

Fig. 1 MultiSet NanoLine with 18-gauge insulated needle (Pajunk Medizintechnologie, Germany) for measuring impedance at the intravascular location

USA), as previously described.¹³ Upon placement of the tip of the needle (Pajunk 22G insulated) at the site of the brachial plexus, impedance was recorded before and after an injection of D5W 3 mL. To serve as a control and to assess the impedance changes over the clinical course of the block procedure, attempts were made to record impedance values in patients during (30 sec) the bolus injection of local anesthetic solution, which consisted of 1.5% lidocaine and 0.125% bupivacaine. Similar nerve stimulator settings were used as for the intravascular injection.

Sample size and data collection

For this observational study, we chose a convenience sample size of patients receiving supraclavicular nerve blocks for hand and wrist surgery during a two-month period.

For all injections, the nerve stimulator screen was filmed with a digital camera for at least 20 sec after the start of the injections. These recordings were reviewed and data were transferred to a spreadsheet with one impedance value recorded at each 0.5 sec interval. The objective measurement obtained directly from the nerve stimulator and recorded from the screen of the video recorder limited bias with respect to data collection. The baseline (last value prior to injection), peak, and average post-peak impedance values (if applicable) were recorded for each injection. The primary outcome variables were whether there was a change of impedance (from baseline to peak) at each location after D5W injection and whether there was a difference in the changes of impedance between the perineural and the intravascular locations. The secondary outcome variable was whether there was a difference

between impedance changes after injections of conducting (local anesthetic or normal saline) solutions between the locations. The only data collected were from those patients where both intravascular and perineural impedance values could be obtained.

Statistical analysis

Data were reported as mean $\pm$ standard deviation (SD) and compared using two-sided Student's *t* tests for independent (between locations) and paired (within location) samples, with the significance level set at $P < 0.05$ using STATISTICA 5.0 (StatSoft Inc., Tulsa, OK, USA). No accommodations were made for multiple comparisons.

Results

Patient demographics

Twenty-three of the 24 eligible patients who were approached consented to participate in this study. Data from 16 patients were included in our analysis, since both intravascular and perineural impedance values could be recorded and compared in these patients. Seven patients were excluded from the data analysis: two patients - due to difficulty with intravascular insertion, three patients - due to mechanical resistance encountered while threading the electrode, and two patients - due to surgery cancellation, i.e., no supraclavicular block performed. Fifteen of the 16 patients were male. The age, weight, height, and body mass index of the patients were 27.8 ± 11.5 yr, 84.4 ± 21.7 kg, 175.2 ± 8.5 cm, and 27.4 ± 6.7 kg·m⁻², respectively. Intravascular catheters were inserted in the 16 patients in the following positions: 12 patients - right antecubital fossa, three patients - left antecubital fossa, and one patient - left forearm.

Intravascular injection of D5W

The average stimulating pulse was 0.51 ± 0.2 mA. Prior to and after injection of D5W, the baseline and peak impedance values at the intravascular site did not increase significantly (16.5 ± 7.2 k Ω to 20.1 ± 6.8 k Ω , respectively; increase of 3.6 ± 4.7 k Ω [$31.5 \pm 45.3\%$]; $P = 0.15$) (Figure 2A).

Intravascular control injection of normal saline

The baseline and peak (lowest) impedance values after intravascular injection of normal saline were similar (15.2 ± 6.9 k Ω and 14.7 ± 6.7 k Ω , respectively; $P = 0.08$). The baseline impedance values at the intravascular

Fig. 2 Change in impedance due to intravascular vs perineural (supraclavicular) injection of 5% dextrose in water (D5W) solution. **A** The injection of D5W did not change intravascular impedance significantly, while the injection of D5W resulted in a significant increase (155%) in perineural impedance to reach a peak of 58.4 ± 29.1 kΩ. **B** The increase in impedance in the perineural space was sustained over the 30 seconds of recording. Mean $\pm$ standard deviation (SD) represent data; * denotes $P < 0.05$ compared with all other values

site prior to injection of D5W and normal saline were similar ($P = 0.61$).

Perineural injection of D5W

The average stimulating pulse was 0.44 ± 0.05 mA. The baseline perineural impedance was higher than the intravascular impedance (23.5 ± 8.3 kΩ and 16.5 ± 7.2 kΩ, respectively; $P = 0.037$). The perineural impedance was elevated in all patients after D5W injection (Figure 2). The baseline and peak impedance (58.4 ± 29.1 kΩ) values were significantly different ($P < 0.0001$), with the magnitude of the increase being 35.1 ± 26.4 kΩ ($155 \pm 117\%$). The peak impedance and change of impedance at the perineural space were greater than those recorded at the intravascular location ($P < 0.0001$ for both).

Fig. 3 Impedance values recorded during (30 sec) the injection of a bolus of local anesthetic (surgical solution) ($n = 10$). The needle was not flushed with the conducting solution prior to the injection; hence, the impedance at the start of the injection reflected that seen after the D5W injection

The average time to reach peak perineural impedance was 7.9 ± 5.9 sec (Figure 2B). The average perineural impedance for the remainder of the recording (post-peak) was 36.7 ± 19.6 kΩ, which was greater than the baseline perineural impedance and greater compared with all intravascular impedance values ($P = 0.028$).

Perineural control injection of local anesthetic solution

In ten patients, it was possible to record impedance measurements at the perineural location before and during D5W injection as well as during bolus injection of local anesthetic (15–20 mL). During the local anesthetic solution injection, which followed shortly after the D5W injection, baseline and lowest (peak) impedances were 36.5 ± 16 kΩ and 12.31 ± 5.43 kΩ, respectively ($62\% \pm 19\%$ reduction; $P < 0.001$) (Figure 3). At this location, the baseline impedance value was higher before injection of the local anesthetic solution compared with the D5W solution (36.5 ± 16 vs 23.5 ± 8.3 , respectively; $P = 0.011$), yet the impedance decreased to a value similar to that after normal saline injection at the intravascular location (12.31 ± 5.43 kΩ vs 14.7 ± 6.7 kΩ, respectively; $P = 0.35$).

Discussion

The findings from this study suggest that test injections of D5W could be used to detect intravascular needle placement when performing regional blocks. When D5W was injected intravenously, there was no significant or sustainable rise in impedance as detected on our nerve stimulator. However, supraclavicular perineural injection of D5W

resulted in a significant and sustained rise in impedance ($155 \pm 117\%$ at peak and 59% to 30 sec). The rapid rise in impedance could prove very useful in clinical practice.

The control intravascular normal saline injection demonstrates that intravascular injections of a conducting solution do not lead to a rise or change in impedance from that seen after baseline or during perineural injection. This confirms that there will be no significant change in impedance measured after injection of conducting solutions between the perineural and intravascular locations. As a result of these observations, conducting solutions would not be suitable for use as a test of intravascular placement.

During the control injection of surgical solution at the perineural location, it was demonstrated that the impedance will quickly return to baseline level or fall below after injection of a bolus injection of local anesthetic. The needle was not flushed with conducting solution prior to the local anesthetic injection, therefore the presence of the D5W within the needle led to higher impedance at the start of the injection (36.5 ± 16) compared with the baseline impedance before the D5W injection (23.5 ± 8.3). Nevertheless, this raised baseline impedance was quickly diminished (2.6 ± 2.3 sec) with the injection of the conducting solution. In addition to confirming that the D5W caused the higher impedance of the tissue (through an increase in current density) and that the local anesthetic will reverse this by dissipating the current, these results also indicate that this test is reversible and reusable. Presumably, the test could be repeated if one were to either purposely move the needle (as is common during ultrasound guidance when there is evidence of inadequate spread of local anesthetic) or suspect inadvertent needle movement during the (often incremental) injection of surgical solution. Due to time constraints and practical issues during injections, obtaining constant measurements of the impedance values during the local anesthetic injection was only feasible in ten patients.

One limitation of this study is that the study model was unable to evaluate the situation pertaining to the partial intravascular needle placement, i.e., leaking D5W around the needle tip. Theoretically, such partial intravascular needle placement may lead to a different change in impedance. Possibly, the rise in impedance would only be moderate and thus difficult to interpret. Further study examining this test using a larger sample size is required to reliably determine its sensitivity and specificity to predict intravascular needle placement and to generalize the results with reference to perineural and inadvertent intravascular needle placement during peripheral nerve block placement.

Recently, electrical impedance has gained interest for clinical monitoring. In animals, a significant increase in electrical impedance (at the needle tip) has also been reported with intraneural needle placement in comparison with perineural needle placement;¹⁴ thus, monitoring

impedance during block needle placement may help to prevent intraneural injection of local anesthetic. In addition, it has also been suggested that electrical impedance influences the threshold current required when using nerve stimulation.^{12,15-17} Given that peripheral nerve blocks are generally performed with the guidance of nerve stimulation and that currently available stimulators display resistance, this study serves as a reminder for clinicians to utilize this information for such uses as detection of intravascular placement of the stimulating electrode. The adjuvant use of ultrasound also benefits from a test injection of D5W, given that the observed spread enables prediction of the local anesthetic spread without adding to the total local anesthetic volume or altering the threshold currents used for nerve stimulation. Further validation of this method should be performed.

Funding sources This work was supported in part by a Clinical Scholar Award from the Alberta Heritage Foundation for Medical Research, Edmonton, Alberta, Canada, a CAS/Abbott Laboratories Career Scientist Award from the Canadian Anesthesiologists' Society, and an Operating Grant from the Canadian Institutes of Health Research (B Tsui). Dr. Chin is supported by departmental funding.

Conflicts of interest None declared.

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