EVALUATION OF THE TOURNIQUET LEAK DURING FOREARM INTRAVENOUS REGIONAL ANESTHESIA

- Manual vs Automatic Pump Injection -

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Summary

Background: The present study was conducted to compare the effect of pump injection versus manual injection on the venous pressure, during forearm intravenous regional anesthesia (IVRA) and the incidence and the magnitude of lidocaine leak, .

Methods: A crossover randomized study of IVRA with a forearm tourniquet was conducted on 14 male healthy volunteers. This study was performed, once using manual injection of local anesthetic and once using automatic pump injection, on two separate sessions. In both techniques, 0.3 ml/kg lidocaine 0.5% was injected over 90 seconds. The occlusion pressure, continuous venous pressure and the serum lidocaine two minutes at end of injection, were recorded.

Results: The mean occlusion pressure 161.6 (17.2) mmHg was always higher than the mean initial arm systolic blood pressure 131.7[11]. The maximum venous pressure was significantly higher in the manual technique 176.7 (15.4) mmHg than in the pump technique 161.3 (12.3) mmHg ($p = 0.04$). The incidence of lidocaine leak was significantly lower (35.71%) in the pump technique compared to (78.5%) in the manual technique ($p = 0.02$). Moreover; the mean lidocaine plasma concentrations was significantly higher [0.86 (0.5) $\mu g.ml^{-1}$] in the manual technique compared to [0.32 (0.4) $\mu g.ml^{-1}$] the pump technique ($p = 0.04$).

Conclusion: The use of pump injection for forearm IVRA could significantly decrease the maximum venous pressure, and decrease the incidence and the magnitude of lidocaine leak past the tourniquet.

Keywords: Anesthetic technique: regional intravenous. Drug: lidocaine. Measurements: Venous pressure, Lidocaine plasma conc.

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Introduction

Intravenous regional anesthesia (IVRA) is a safe and effective technique for providing anesthesia as well as a bloodless field during hand surgery, with published success rates ranging from 94% to 98%[1,2]. IVRA is easy to perform and the only necessary technical skill is inserting an intravenous (IV) cannula.

Traditionally, an upper arm tourniquet has been used for these procedures. However, the recommended doses of local anesthetics for upper arm IVRA do have the potential risk of systemic toxicity[3,4].

Forearm IVRA, however, allows the dose of local anesthetic to be decreased by up to 50% without affecting the quality of analgesia[5,6]. In addition, the forearm tourniquet can be tolerated longer and was consistently rated as less painful when compared with the upper arm tourniquet[7]. However, this technique was unpopular in the past because it was thought that "compression forces of an inflated forearm tourniquet cannot obliterate the anterior and posterior interosseous arteries seated in the deep 'valley' between the prominent radius and ulna"[8]. It was therefore assumed that tourniquet leakage was inevitable, thus increasing the possibility of local anesthetic toxicity and block failure. A quantitative study showed that forearm IVRA results in tourniquet leakage comparable with upper arm IVRA[9].

During intravenous regional anesthesia, leakage of local anesthetic agent past the tourniquet into the systemic circulation could occur if the tourniquet pressure was inadequate to maintain occlusion of the underlying vessels in the face of the venous pressures generated by the injection[10]. Previous studies had measured venous pressure during actual or simulated upper arm IVRA, at different injection rates and volumes. To my knowledge, limited data of using automatic pump injection for forearm IVRA are available.

The main objective of the present trial is to study venous pressure during lidocaine forearm IVRA, using manual versus automatic pump injection, and evaluate its effect on the possible leak past the tourniquet.

Methods and Materials

Following the Institutional Ethics Committee approval and volunteer informed written consent, a prospective randomized study of IVRA with a forearm tourniquet was conducted on 14 male healthy volunteers, each volunteer acting as his own control. This study was performed, once using manual injection of local anesthetic and once using automatic pump injection, on two separate sessions. The sequence of the technique of IVRA (manual or pump technique) for each session, was allocated randomly and separated by at least one week.

For each session, immediately before the start of the procedure, arterial blood pressure was measured in the contra lateral arm with a standard adult cuff using a mercury sphygmomanometer. An 8 cm wide pneumatic tourniquet was placed over padding on the forearm 1 cm below the medial epicondyle of the humerus. An automatic pneumatic tourniquet machine (Zimmer A.T.S. 2000) was used for inflating the pneumatic tourniquet. The gauge on the machine was calibrated against a mercury column before each operating session.

"Occlusion pressure", the tourniquet pressure required to occlude the radial blood flow was measured. This was determined by slowly lowering the tourniquet pressure from well above the systolic value and recording the tourniquet pressure at which the radial pulse first became palpable. Having found the occlusion pressures, the pneumatic tourniquet was removed and placed in a similar manner over the forearm to be operated on. A 20-gauge Teflon catheter was inserted in a dorsal vein of the hand and used for injection of local anesthetic. A similar cannula was inserted in a vein just distal to the tourniquet for venous pressure recording during the injection. The limb distal to the pneumatic tourniquet was exsanguinated by an Esmarch's bandage, starting from the finger tips. The tourniquet was then inflated to a pressure equal to the occlusion pressure plus 50 mmHg (inflation pressure), and the Esmarch's bandage was removed.

The calculated amount of 0.5 per cent preservative-free lidocaine solution (0.3 $ml.kg^{-1}$ body weight) was injected over 90 second in all volunteers, by either the same anesthesiologist (manual technique) or by using automated infusion pump [Baxter Flogard. FAAM.3047K] (pump technique), through the intravenous cannula on the dorsum of the hand. Venous pressure distal to the tourniquet was recorded every 10 seconds during injection by another anesthesiologist using pressure transducer connected to the proximal venous catheter.

In all patients two venous blood samples were taken for estimation of lidocaine concentration from an indwelling intravenous catheter placed in the contra lateral upper limb, before and two minute after lidocaine injection. The tourniquet was deflated 15 minutes after injection.

Statistics

The sample size was determined assuming a paired design in which forearm IVRA using different mode of injection would be applied to each volunteer on two separate occasions. To have an 80% probability of detecting 17% difference (from a pilot study) of maximum intravenous pressure, between the two techniques ([beta] = 0.2), and testing at the 0.05 level ([alpha] = 0.05), the sample size was found to be 14 patients. Data was analyzed using a paired *t*-test to compare venous pressure and lidocaine serum level. Fisher's exact test was used to compare the incidence of leak. Statistical significance was assumed to be achieved at $P < 0.05$.

Results

The mean age of the volunteers was 33.7 (7.7) yr, mean height was 172.3 (7.2) cm, mean weight was 74.7 (5.1) kg and the mean forearm circumference was 25.9 (3.2) cm.

The occlusion pressure 161.6 (17.2) mmHg was always higher than the initial arm systolic blood pressure 131.7 (11) mmHg and the difference between them which ranged from 5 to 50 mmHg (29 ± 12.6) did not show any correlation with either the initial systolic blood pressure measured over the upper arm, (R^2 = 0.008), or the circumference of the forearm at a point 1 cm distal to the medial epicondyle of the humerus (R^2 = 0.03).

There was significant difference in the incidence of lidocaine leak past the pneumtic cuff into the systemic circulation prior to tourniquet release, between the manual technique 11/14 (78.5%) and the pump technique 5/14 (35.71%) p = 0.02. The lidocaine plasma concentrations was 0.86 (0.5) $\mu g.ml^{-1}$ in the manual technique and 0.32 (0.4) $\mu g.ml^{-1}$ in the pump technique with significant difference between both techniques ($P < 0.04$).

Venous pressure before exsanguinations, before and during injection is presented in Fig. 1. There was a significant difference between the maximum venous pressure in the manual technique 176.7 (15.4) mmHg and in the pump technique 161.3 (12.3) mmHg (p = 0.02).

There was significant correlation between the maximum venous pressure and the lidocaine plasma levels in both manual (Fig. 2) and pump techniques (Fig. 3) (R^2 = 0.82 and 0.68 respectively).

Discussion

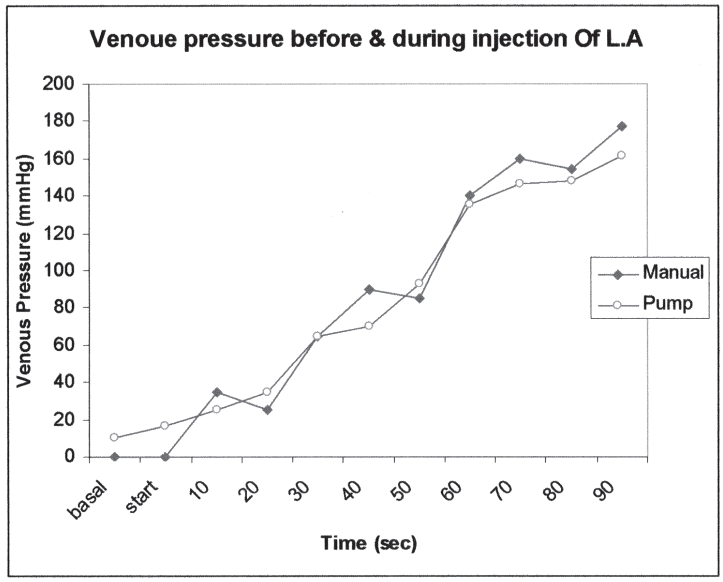
The present crossover randomized study, showed a significant higher value of venous pressure during forearm IVRA when using manual injection than when using pump injection, with significant lower incidence and magnitude of the leak (lidocaine plasma level) in the pump group compared to the manual group.

One important factor affecting the success of IVRA is the tourniquet pressure. The present study used 8 cm wide pneumatic cuff, which is much narrower than the standard adult sphygnomanometer cuff used for measuring blood pressure. As the narrow cuff is less able to transmit tourniquet pressure to blood vessels lying deep inside the limb[11,12], this could explain why the occlusive pressure was always higher than systolic blood pressure. Similarly this could explain why the difference between them was smaller in the present study 29.6 (12.6) mmHg using 8 cm wide cuff than Chan, et al study 67 (25) mmHg using 5 cm wide cuff[5].

In the present study, the highest venous pressure was observed at the end of injection in both techniques, with significant higher value in the manual injection technique. This could be expected, as the use of infusion pump for injection could induce a steady rise of venous pressure given a chance for the veins to distend over the time with a final lower pressure at the end of injection.

To my knowledge none of the previous studies had evaluated the effect of using pump injection versus

Fig. 1
Evaluation of venous pressure for the manual ( ) and pump ( ) techniques during the 90 sec. of injection



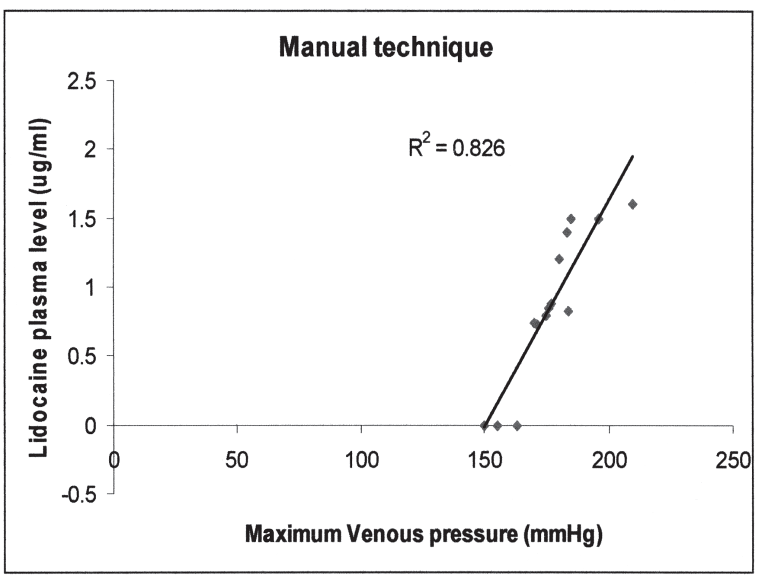
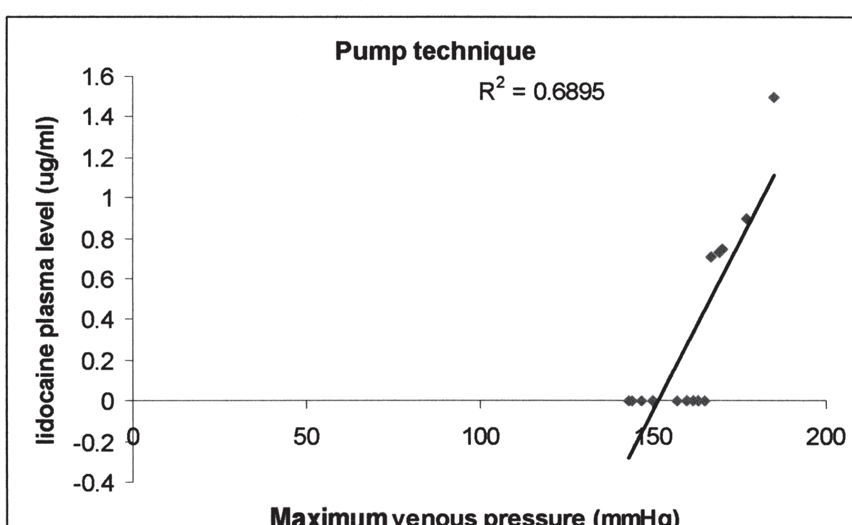


Fig. 2
Correlation between the maximum venous pressure achieved at the end of injection and the lidocaine plasma level in the Manual technique

Fig. 3
Correlation between the maximum venous pressure achieved at the end of injection and the lidocaine plasma level in the pump technique



manual injection on the venous pressure during forearm IVRA. However, El-Hassan et al[12] had compared the effect of different rates of infusion on the rate of rise of venous pressure on one volunteer during simulated Bier's block. They reported that the slower the rate of injection the lower was the venous pressure.

It has been suggested that, the occurrence of convulsions during the performance of intravenous regional analgesia with the tourniquet *in situ* may be partly explained by the generation of exceptionally high pressures in the venous system of the arm. The pressures generated were greater than or equal to the occluding pressure of the tourniquet. This in turn may lead to flow of injectate under the tourniquet and into the systemic circulation[14-16].

In the present study, although non of the volunteer in both techniques had a maximum venous pressure that exceeded the inflation pressure, leak of lidocaine had occurred in 11 out of 14 cases (78.5%) in the manual technique, and 5 out of 14 cases (35.7%) in the pump technique with a magnitude of 0.86 (0.5) $\mu g.ml^{-1}$ and 0.32 (0.4) $\mu g.ml^{-1}$ respectively. This in agreement with Kalso et al[13], and Chan et al[5], who reported a lidocaine leakage rate of 55% and 67% respectively.

More interestingly, the present study reported a linear correlation between the magnitude of the leak and the maximum venous pressure in both techniques. The possible explanation is that, decrease in the pressure gradient between the inflation pressure and the venous pressure could exacerbate the unavoidable leak through the interosseous vessels which are assumed to be protected from the tourniquet pressure.

Limitations of this study consist of, First; this trial would be strengthened if it used different rates of injection as well as different levels of inflation pressure, but this necessitated multiple sessions which was refused by the volunteers. However; this could be an idea for further study. Second; the present study did not test the clinical efficacy of the performed block, this is because the clinical efficacy of forearm IVRA had been proven by many of previous studies[5,17,19], as well as for ethical reason as this study was done on volunteers.

The present study concluded that the use of pump injection for forearm IVRA could significantly decrease the maximum venous pressure, and reduce the incidence and the magnitude of lidocaine leak past the tourniquet. This possibly will increase the duration of the block and further decrease the incidence of potential systemic toxicity.

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