Comparison of the Effect of Intravenous Regional Anesthesia with Single-Cuff Forearm and Upper Arm Tourniquets on Pain in Patients Undergoing Elective Hand Surgery

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Background: Intravenous regional anaesthesia (IVRA), also known as the Bier block, is an effective anaesthetic technique for upper limb surgery. This study aimed to compare the efficacy of IVRA using a single-cuff tourniquet applied to the forearm versus the upper arm in patients undergoing elective hand surgery.

Materials and Methods: In this randomized controlled trial, sixty patients (ASA class I–II) scheduled for elective upper limb surgery were randomly assigned to two groups. The intervention group (n = 30) received IVRA with a single-cuff forearm tourniquet and 100 mg of lidocaine, whereas the control group (n = 30) received IVRA with a single-cuff upper arm tourniquet and 200 mg of lidocaine. Pain intensity at the surgical and tourniquet sites was assessed using the Verbal Descriptive Scale (VDS) at baseline and intraoperatively.

Results: Pain intensity at the surgical site was significantly lower in the intervention group at 90 minutes (p = 0.028) and postoperatively (p = 0.03). Conversely, pain at the tourniquet site showed no significant difference between groups (p > 0.05). The English abstract in the original document had indicated a non-significant decrease in operative site pain (p = 0.83) and a non-significant increase in tourniquet site pain (p = 0.29), which contradicted the Persian results section; the present version reflects the verified findings. No serious adverse events were reported in either group.

Conclusion: For procedures lasting up to 30 minutes, IVRA with a single-cuff forearm tourniquet using 100 mg of lidocaine provides analgesia comparable to that of the upper arm technique requiring 200 mg. The forearm approach represents a viable alternative, particularly given the reduced local anaesthetic requirement.

Keywords: Intravenous Anesthesia, Regional Anesthesia, Pain Measurement, Tourniquets, Upper Extremity

Introduction

Anaesthesia for upper limb surgery may be achieved through various methods, including general, regional, and local techniques. Intravenous regional anaesthesia (IVRA), first described by August Bier in 1908 and commonly known as the *Bier block*, is a widely used regional technique. The principle of IVRA involves exsanguinating the limb, isolating it from systemic circulation with an arterial tourniquet, and subsequently injecting a local anaesthetic into the limb's venous system.

IVRA is indicated for surgeries below the elbow or knee, such as tendon repairs, foreign body removal, fracture reductions (e.g., Colles' fracture), and amputations. It is regarded as a low-risk option for both elderly and paediatric patients. However, it is contraindicated in cases of local infection, severe peripheral vascular disease, semi-comatose states, or in uncooperative individuals.

The traditional Bier block technique employs a double-cuff tourniquet placed on the upper arm. Following exsanguination of the limb using an Esmarch bandage, the proximal cuff is inflated to a pressure approximately 150 mmHg above the patient's systolic blood pressure to occlude arterial flow. A local anaesthetic is then injected through a pre-placed distal intravenous catheter. Tourniquet pain is a common complication, typically developing after 30–45 minutes. In the double-cuff technique, this discomfort may be mitigated by inflating the distal cuff—positioned over anaesthetised skin—and deflating the proximal one. The tourniquet should not be released earlier than 20–30 minutes after injection to prevent a rapid systemic release of the anaesthetic.

The ideal agent for IVRA should have a rapid onset, require a low dose, and provide prolonged analgesia with minimal tourniquet pain. Lidocaine remains the most commonly used drug and is the only agent approved by the FDA for this purpose in some regions. Systemic toxicity, the principal safety concern, usually arises from anaesthetic leakage past the tourniquet, overdose, or premature cuff deflation. The overall incidence of side effects, including central nervous system and cardiovascular manifestations, is approximately 1.5%. To enhance block quality, various adjuvants such as opioids, non-steroidal anti-inflammatory drugs (e.g., ketorolac), alpha-2 agonists, and muscle relaxants have been investigated.

A major limitation of the traditional upper arm tourniquet technique is tourniquet pain, which may restrict the duration of surgery. Ischaemia beneath the cuff contributes to this pain by inducing nerve compression and the release of algogenic substances such as serotonin. The use of a forearm tourniquet has been proposed as an alternative, as this position may be better tolerated due to the presence of two bones (radius and ulna) that distribute pressure more evenly, unlike the single humerus of the upper arm. Moreover, the smaller volume of the forearm requires a lower anaesthetic dose, which has been shown to be as safe as the larger doses employed in upper arm techniques.

This study was therefore designed to compare the efficacy of a single-cuff forearm tourniquet using a lower dose of lidocaine with that of the conventional single-cuff upper arm method using a standard dose. It was hypothesised that the forearm technique would provide effective anaesthesia with enhanced patient comfort and a superior safety profile, owing to the reduced anaesthetic requirement.

Materials and methods

Study Design and Patient Selection

This single-blind, randomised controlled trial was conducted at Shahid Beheshti and Ayatollah Rouhani Hospitals following approval from the institutional ethics committee. Sixty patients aged between 20 and 60 years, classified as ASA physical status I or II, were enrolled. All participants were scheduled to undergo elective soft tissue or bone surgery of the hand.

Inclusion and Exclusion Criteria

Patients were eligible for inclusion if they were candidates for elective hand surgery performed under intravenous regional anaesthesia (IVRA). Exclusion criteria included emergency surgery; ASA physical status greater than II; severe cardiovascular disease or hypertension; a history of seizures, psychiatric disorders, or drug addiction; local infection at the tourniquet or injection site; pregnancy; peripheral vascular disease; severe coagulopathy; allergy to local anaesthetics; or inability to provide informed consent.

Randomization and Blinding

After obtaining written informed consent, patients were randomly assigned to one of two groups (n=30 each) using a sealed envelope method based on a lottery system. Patients were blinded to their group allocation.

- **Group A (Forearm Group)**

Received IVRA with a single-cuff tourniquet placed on the forearm and an injection of 100 mg of preservative-free lidocaine diluted to 20 mL with normal saline.

- **Group B (Upper Arm Group)**

Received IVRA with a single-cuff tourniquet placed on the upper arm and an injection of 200 mg of preservative-free lidocaine diluted to 40 mL with normal saline.

Anesthetic Procedure:

All patients received standard monitoring (ECG, NIBP, SpO_2) and premedication with 1 mg midazolam and 50 µg fentanyl intravenously, along with 200 mL of normal saline. An intravenous catheter was inserted into a vein on the dorsum of the hand of the operative limb. The limb was exsanguinated by elevation for one minute followed by the application of an Esmarch bandage from distal to proximal. The pneumatic tourniquet was then inflated. The prepared lidocaine solution was injected over 90 seconds. The adequacy of the sensory block was confirmed by pinprick testing in the distributions of the median, ulnar, and radial nerves before the start of surgery.

Data Collection and Outcomes

The primary outcome was pain intensity, assessed using the Verbal Descriptive Scale (VDS; 0 = no pain, 5 = very severe pain). Pain was evaluated at both the surgical and tourniquet sites at 10-minute intervals throughout the procedure. Secondary outcomes included the onset and duration of sensory block, quality of anaesthesia (rated by the anaesthesiologist on a 5-point Likert scale), haemodynamic variables (heart rate and blood pressure), patient satisfaction, and the total doses of supplemental analgesics (fentanyl) or sedatives (propofol) required. Rescue analgesia (50 µg fentanyl) was administered if the VDS score exceeded 2. If pain persisted (VDS > 3), additional fentanyl was administered up to a maximum of 3 µg/kg. When the VDS exceeded 4 or the procedure lasted longer than 90

minutes, deep sedation with propofol was initiated. All patients were monitored for 24 hours for signs of local anaesthetic systemic toxicity (LAST) and thrombophlebitis, and for 48 hours for the development of Volkmann's ischaemic contracture or cellulitis.

Statistical Analysis

The sample size was calculated based on a previous study, with an alpha of 0.05 and a power of 80%. A sample size of 22 per group was required; this was increased to 30 per group to account for dropouts. Data were analyzed using SPSS version 25.0. A P-value < 0.05 was considered statistically significant.

Results

Patient Characteristics:

The two groups were comparable with respect to age, gender, type of surgery, and duration of surgery (p > 0.05 for all). No patients required conversion to general anesthesia.

Anesthesia and Pain:

The onset of analgesia was significantly faster in the Upper Arm Group (Group B) compared to the Forearm Group (Group A) (6.17 ± 2.52 min vs. 7.67 ± 2.25 min, p = 0.019). However, the quality and duration of analgesia were not significantly different between the groups (p=0.671 and p=0.554, respectively).

Surgical site pain was significantly higher in the Upper Arm Group at 90 minutes (VDS score: 1.3 ± 0.54 vs. 1.07 ± 0.25, p = 0.028) and immediately after surgery (1.3 ± 0.48 vs. 1.1 ± 0.3, p = 0.03).

Tourniquet pain increased over time in both groups (p < 0.0001), but there was no statistically significant difference between the groups at any time point measured. For example, at 60 minutes, the mean VDS score for tourniquet pain was 4.3 ± 2.32 in the Forearm Group and 4.17 ± 2.67 in the Upper Arm Group (p = 0.814).

Medication and Hemodynamics

There were no significant differences in the frequency of supplemental analgesic injections or the total dose of fentanyl administered between the groups. The total dose of sedative medication required was significantly higher in the Upper Arm Group (p=0.037). There were no clinically significant differences in hemodynamic parameters (systolic blood

pressure, diastolic blood pressure, heart rate) between the groups throughout the study.

Patient Satisfaction and Adverse Events:

Patient satisfaction was similar in both groups (p=0.671). No serious adverse events, such as signs of LAST or neurological complications, were observed in either group.

Discussion

This study compared the efficacy of single-cuff forearm intravenous regional anaesthesia (IVRA) with single-cuff upper arm IVRA for elective hand surgery. Our findings indicate that the forearm technique, using a lower dose of lidocaine (100 mg), provides a quality of anaesthesia and level of patient satisfaction comparable to the upper arm technique involving a higher dose (200 mg), particularly for procedures lasting up to 30 minutes.

The onset of anaesthesia was faster in the upper arm group, likely attributable to the larger administered dose of lidocaine. Interestingly, despite the slower onset, surgical site pain was significantly lower in the forearm group during the later stages of surgery (at 90 minutes and postoperatively).

This may reflect anatomical differences: the presence of two bones in the forearm could allow for a more uniform distribution of both anaesthetic and tourniquet pressure, thereby reducing ischaemic pain compared with the single humerus of the upper arm. This observation aligns with the report by Chiao et al., who similarly noted reduced discomfort associated with a forearm tourniquet.

Tourniquet pain remains a major limitation of IVRA. In the present study, although tourniquet pain increased significantly over time in both groups, no significant difference was observed between the forearm and upper arm sites. This suggests that, for surgeries of this duration, the single-cuff location did not differentially affect tourniquet tolerance. However, our results contrast with those of Arslanian et al., who found that a forearm Bier block produced less tourniquet pain than a conventional upper arm block. This discrepancy may be explained by variations in tourniquet type (single versus double cuff) or differences in surgical populations.

Safety constitutes an essential aspect of the forearm IVRA technique. Concerns have been raised regarding the potential for increased systemic leakage of local anaesthetic with a forearm tourniquet. Nevertheless, several studies—including the present one-support the clinical safety of the forearm approach, particularly as it permits a substantially lower total dose of anaesthetic. No clinical signs of local anaesthetic systemic toxicity (LAST) were observed among our participants, corroborating the safety of administering 100 mg of lidocaine with a forearm tourniquet.

This study has several limitations. It was conducted at a single centre, and anaesthesiologists could not be blinded to group allocation. Furthermore, we employed a single-cuff tourniquet in both groups to standardise comparison; hence, our findings may not be generalisable to the double-cuff technique.

Conclusion

Intravenous regional anaesthesia using a single-cuff forearm tourniquet with 100 mg of lidocaine represents an effective and safe alternative to the upper arm technique for elective hand surgery. Although the onset of anaesthesia may be marginally slower, the forearm approach provides comparable analgesia and patient satisfaction, and may be associated with reduced surgical site pain during the later operative period. The marked reduction in the required dose of local anaesthetic constitutes a major advantage of the forearm technique.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethics approval statement

The ethics committee of Babol University of Medical Sciences, Iran (IR.MUBABOL.HRI.REC. 1397. 208) IRCT Number: IRCT 2010121300-5381N13

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