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Kerollos Moneer Neseem Mikhael
Assistant Lecturer of Anaesthesiology, Surgical ICU and Pain Management Faculty of Medicine, Beni-Suef University, Egypt

Dr. Hatem Elmoutaz Mahmoud
Professor and Head of the Department of Anesthesiology, Surgical ICU and Pain Management Faculty of Medicine, Beni-Suef University, Egypt

Dr. Ghada Korany Abdel Mottaleb
Lecturer of Anesthesiology, Surgical ICU and Pain Management Faculty of Medicine, Beni-Suef University, Egypt

Corresponding Author:
Kerollos Moneer Neseem Mikhael
Assistant Lecturer of Anaesthesiology, Surgical ICU and Pain Management Faculty of Medicine, Beni-Suef University, Egypt

The feasibility of using forearm intravenous regional anaesthesia instead of the standard upper arm technique in wrist and hand surgery

Kerollos Moneer Neseem Mikhael, Hatem Elmoutaz Mahmoud and Ghada Korany Abdel Mottaleb

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Abstract
Aim of the study: to compare between the efficacy of using forearm intravenous regional anesthesia (IVRA) and upper arm IVRA and investigate the effects of nitroglycerine (NTG) compared to fentanyl when added to lidocaine in IVRA in wrist and hand surgery.
Patients and Methods: 100 patients divided into 4 equal groups. Patients had upper arm tourniquet and received lidocaine (3 mg/kg) mixed with fentanyl (1 µg/kg) in Group I and NTG (400 µg) in Group III. Patients had forearm tourniquet and received half dose of the aforementioned drugs in Group II and Group IV.
Results: there was a rapid sensory and motor block onset and reduction in postoperative diclofenac requirement in group III and group IV compared to group I and group II.
Conclusion: Both forearm and upper arm tourniquets showed comperable results. Nitroglycerin was associated with rapid onset of sensory and motor block, and reduction in postoperative diclofenac requirement.

Keywords: Intravenous regional anesthesia, IVRA, nitroglycerine, lidocaine, fentanyl, forearm

Introduction
Intravenous regional anesthesia (IVRA) is simple, reliable, cost-effective and quite safe for minor surgical procedures of the extremities [1]. Limitations of this block include tourniquet discomfort, short duration of block and absence of post-operative analgesia. Trying to overcome these effects and improve the quality of the block various drugs have been added as nitroglycerine (NTG) to other analgesics such as lidocaine for improving sensory and motor blockade, tourniquet pain, and also postoperative analgesia [2].
One of the critical points while considering IVRA is the risk of local anesthetic systemis toxicity (LAST) therefore, it is desirable to decrease the amount of LA to a minimum. Use of a forearm tourniquet when compared to the standard upper arm tourniquet may allow the requirments of LA to be reduced to almost half, thus improving safety margin for the patients [3].
Therefore, we designed this study to compare between the efficacy of using forearm IVRA and standard upper arm IVRA for wrist and hand surgery. Also, our study investigated the effects of NTG when added to lidocaine for IVRA as compared to fentanyl when added to lidocaine in patients undergoing wrist and hand surgery as regarding sensory and motor block onset and recovery time, the quality of tourniquet pain relief, hemodynamic stability and postoperative analgesia.

Materials and methods
This randomized clinical study was carried out at Beni-Suef university hospital, after obtaining approval from the ethics committee of our institution (FM-BSU REC).
Our study included 100 patients of American Society of Anesthesiologists (ASA) physical state I and II, between the ages of 18-50 years who had wrist and hand surgery.
Patients with peripheral vascular disease, coronary artery disease, sickle cell anemia, history of allergy to any drug, or impaired kidney function, history of chronic liver disease, pregnancy, those with the history of cardiac arrhythmias, neuromuscular disorders, as well as patients on medications influencing blood flow were excluded from the study.

Tourniquet discomfort, visual analogue scale [4] (VAS, where 0=no pain and 10=worst intolerable pain) and symptoms of local anesthetic toxicity (tinnitus, perioral tingling, visual disturbances and dizziness) were discussed with the patients.

On arrival to the operating room, standard monitoring was established (pulse oximetry, electrocardiography, and noninvasive arterial blood pressure monitoring), and oxygen was delivered via a facemask. Two intravenous cannulae were placed; one in a vein on the dorsum of the hand to be operated (22 gauge) and the other (20 gauge) in the opposite hand.

After obtaining consents, patients were randomly assigned into one of four equal groups (25 patients each). Randomization was carried out using a closed envelope technique.

Group I (UF): Patients had upper arm IVRA and received 3 mg/kg of lidocaine 2% mixed with fentanyl 1 µg/kg and diluted with saline to a total volume of 40 ml.

Group II (FF): Patients had forearm IVRA and received 1.5 mg/kg of lidocaine 2% mixed with fentanyl 0.5 µg/kg and diluted with saline to a total volume of 20 ml.

Group III (UN): Patients had upper arm IVRA and received 3 mg/kg of lidocaine 2% mixed with NTG 400 µg and diluted with saline to a total volume of 40 ml.

Group IV (FN): Patients had forearm IVRA and received 1.5 mg/kg of lidocaine 2% mixed with NTG 200 µg and diluted with saline to a total volume of 20 ml.

In the upper arm groups (I, III), two pneumatic cuffed tourniquets were placed on the upper operative arm at the point of maximum diameter, and in the forearm groups (II, IV) the same tourniquets were positioned 5 cm below the medial epicondyle on the forearm.

Limb exsanguination was achieved with an esmarch bandage (upper limb elevation at 90° for 3 minutes was used for exsanguination of a painful limb). The proximal tourniquet was then inflated to a pressure of 100 mmHg above the patient's systolic blood pressure and to a minimum of 250 mmHg. Circulatory isolation of the operative arm was confirmed by absence of radial and ulnar pulses and by a loss of pulse oximetry tracing. IVRA solutions were administered slowly through the 22G cannula over 90 seconds.

Following injection, the sensory block was assessed at 1 minute intervals by response to a pinprick with a 23G needle. The sites used for sensory testing were the thenar eminence (median nerve); the hypothenar eminence (ulnar nerve) and the first web space (radial nerve).

Data Collection Methods

A sensory block was determined to have been developed once the patient had no response to the pinprick. The time for onset of the sensory block was noted as time elapsed from injection to no response to pinprick in all dermatomes. Sensory recovery time (the time elapsed from tourniquet deflation to recovery of sensation in all dermatomes, determined by pinprick test) was also noted.

Motor function was assessed by asking the patient to flex and extend his/her wrist and fingers, and complete motor block was noted when no voluntary movement is possible. Motor block onset time (the time elapsed from injection of the study drug to complete motor block) and Motor recovery time (the time elapsed from tourniquet deflation to recovery of movement wrist and fingers) were also recorded.

Subjective tourniquet discomfort was recorded intraoperatively (using a visual analog scale) at 5 minute intervals after inflation of the tourniquet.

If tourniquet pain (of the distal or operative cuff) is>3 on the VAS, the patients were given fentanyl (1 µg/kg) IV, and the total administered amount of fentanyl and time of requirement were recorded. The duration for which the patient tolerated the proximal tourniquet cuff was noted in both groups. If the surgery extends beyond 1.5 hours, general anesthesia was given, and the patient was excluded from the study group.

Intraoperative hemodynamic data of patients (mean blood pressure [MBP], heart rate [HR], and peripheral oxygen saturation [SpO2] were recorded before and after anesthesia at 1, 5, 10, 15, 20, and 40 minutes.

The distal tourniquet was deflated at the completion of surgery. Regression of the motor and sensory block was then tested at 1 minute intervals. The total tourniquet time and time for motor and sensory block regression were recorded in all the patients.

The tourniquet deflation technique was based on the total tourniquet time. Hence, if total tourniquet time was less than 20 min, then the tourniquet was deflated only after 20 min had elapsed. If the tourniquet time was between 20 to 40 min, then the tourniquet was deflated for 10 seconds followed by inflation for one minute, the tourniquet was deflated permanently after three such cycles; if the tourniquet time to be more than 40 min, then the tourniquet was deflated without cycling.

Patients were monitored for symptoms of local anesthetic toxicity throughout the operation and for 1 hour after the deflation of the tourniquet. Local complications due to the tourniquet, if any, were recorded after the removal of tourniquet.

At the end of the operation the patients was asked to qualify the operative conditions such as tourniquet pain or incisional pain according to the following numeric scale [4]:

4= (Excellent) = no complaint from pain.

3= (Good) = minor complaint with no need for supplemental analgesics.

2= (Moderate) = complaint requiring supplemental analgesic.

1= (Unsuccessful) = patient given general anesthesia.

Also, the surgeon, who was blind to patient group, was asked to score operative conditions such as disturbing movement of arm and excessive bleeding according to the following numeric scale [4]:

4=Excellent, 3=Good, 2=Acceptable, 1=Poor and 0= Unsuccessful

Postoperative pain was assessed at 30 min and 60 min after tourniquet deflation using a visual analog scale (VAS 0-10). Intramuscular diclofenac sodium in the dose of 1.5 mg/kg was given whenever the VAS ≥4.The period from releasing the tourniquet to administering the analgesic was recorded as the time of first analgesic administration. Total diclofenac sodium required in the first 24 hours after the operation was recorded.

Sample Size Calculation

Sample size calculation was done based on onset of sensory

block between forearm and standard upper arm IV regional anesthesia (IVRA) in wrist and hand surgery. In addition sample size was also calculated for comparing intraoperative fentanyl requirement between NTG and fentanyl groups in each of forearm and upper arm IVRA. Student's t test for independent samples was chosen, α-error level was fixed at 0.05, power was entered to be 80% and the groups are assumed to be of equal size.

Reviewing the literature for intraoperative extra fentanyl dose revealed that cases in upper arm technique using NTG needed a mean ± SD of 25 ± 0.0μg [5]. No data about other groups could be found. Accordingly, we assumed that a change of 20% of extra fentanyl dose is considered clinically important and thus, the minimum sample size per group was 7 cases.

Using previously published results, the mean ± SD of onset of sensory block in upper arm technique was 7 ± 1.6 minutes [6]. We assumed that a change of 20% of onset of sensory block is considered clinically important. Accordingly, we needed to study a minimum of 22 cases in each group to achieve the presumed statistical power. So we decided to take a sample size of 25 patients for each group.

Calculations were done using PS Power and Sample Size Calculations Software, version 3.0.11 for MS Windows (William D. Dupont and Walton D. Vanderbilt, USA).

Statistical Analysis

Data were statistically described in terms of mean±standard deviation (± SD), median and range, or frequencies (number of cases) and percentages when appropriate.

Comparison of numerical variables between the study groups was done using Student *t* test for independent samples. For comparing categorical data, Chi-square (χ^2) test was performed. Exact test was used instead when the expected frequency is less than 5. *P*-values less than 0.05 were considered statistically significant. All statistical calculations were done using computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows.

Results

Patient characteristics (demographic data) including age, gender, body weight and ASA physical status (PS) are demonstrated in Table (1). There was no statistically significant difference between study groups.

Table 1: Demographic data

	Age (years)	Body weight (Kg)	ASA PS (I/II)	Gender (M/F)
Group I (UF)	30.04±10.72	72.6±7.4	23/2	13/12
Group II (FF)	30.24±10.38	70.3±8.5	22/3	15/10
Group III (UN)	31.64±12.21	71.7±9.4	24/1	11/14
Group IV (FN)	32.60±11.69	69.5±7.9	23/2	16/9
P-value	0.834	0.789	0.931	0.634

Data are presented as mean±SD for age and body weight and as frequencies for ASA PS and gender. Statistically significant difference is considered if *P-value* <0.05.

Table 2: Type of operation

	Group I (UF)	Group II (FF)	Group III (UN)	Group IV (FN)
Carpal Tunnel release	3	3	3	2
Cut wound finger	2	1	3	2
Cut Tendon hand	10	11	9	12
Cut Tendon wrist	8	8	8	7
K wire (distal radius)	2	2	0	2
Median nerve neuroma	0	0	1	0

Regarding sensory block onset time, there was a statistically significant rapid onset in group III (UN) compared to group I (UF) and group II (FF). Also, there was a statistically significant rapid onset in group IV (FN) compared to group I (UF) and group II (FF).

Regarding motor block onset time, there was a statistically significant rapid onset in group III (UN) compared to group I (UF) and group II (FF). Also, there was a statistically significant rapid onset in group IV (FN) compared to group I (UF) and group II (FF).

Table 3: Statistically significant rapid onset in group III

	Sensory block onset time (min)	Motor block onset time (min)	Onset of tourniquet pain (min)	Intraoperative fentanyl dose (μg)	Sensory block recovery time (min)	Motor block recovery time (min)
Group I (UF)	10.80±3.47	14.16±3.36	38.50±8.75	65.63±15.45	27.88±9.12	20.40±6.19
Group II (FF)	10.44±2.27	13.68±2.67	39.13±8.21	65.63±15.45	27.21±8.41	20.36±6.26
Group III (UN)	7.16±1.52[ab]	10.20±1.73[ab]	40.83±8.61	58.33±7.53	32.04±9.62	22.92±6.62
Group IV (FN)	8.08±2.88[ab]	11.08±2.88[ab]	40.00±9.35	56.00±8.94	32.08±8.89	23.60±6.03
P-value	*0.001**	*0.001**	0.963	0.451	0.109	0.152

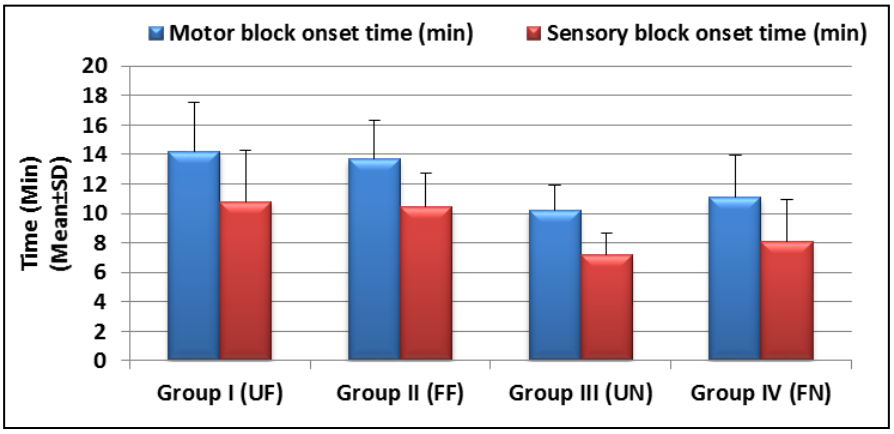

Fig 1: Comparing sensory block onset time (min) and motor block onset time (min) between the 4 study groups.

Data were presented as (mean± SD) Statistical analysis was carried out by one way analysis of variance (ANOVA)* Statistically significant difference is considered if *P-value* < 0.05. [a] Significantly different from group I (UF) value at p < 0.05. [b] Significantly different from group II (FF) value at p < 0.05.

The current study showed that there was a reduction in postoperative diclofenac requirement in 1st 24 h (mg) in group III (UN) compared to group I (UF) and group II (FF) doses. Also, there was a statistically significant reduction in postoperative diclofenac requirement in 1st 24 h (mg) in group IV (FN) compared to group II (FF) dose.

However, the two techniques had similar effects on onset of tourniquet pain, intraoperative fentanyl dose, both sensory and motor block recovery time, postoperative time of first analgesic administration, the quality of anesthesia for both the patient and surgeon, the incidence of tourniquet pain, local and systemic complications in different groups.

Furthermore, no drug-related changes in hemodynamic parameters (MBP and HR) and peripheral oxygen saturation (Spo_2) were pointed in our study subjects.

Table 4: Reduction in postoperative diclofenac requirement in 1st 24 h (mg) in group III (UN)

	Postoperative Time of first analgesic (min)	Postoperative diclofenac in 1st 24 h (mg)	Local complications	Tourniquet pain	Quality of anesthesia (Surgeon)	Quality of anesthesia (Patient)
Data	**Mean± SD**		**Frequencies**		**Median (range)**	
Group I (UF)	76.20±36.52	156.00±60.93	3/25	8/25	4(3-4)	4(2-4)
Group II (FF)	77.80±35.38	162.00±60.00	0/25	8/25	4(3-4)	4(2-4)
Group III (UN)	91.60±39.31	117.00±37.99[ab]	2/25	6/25	4(3-4)	4(2-4)
Group IV (FN)	98.40±34.45	120.00±37.50[b]	0/25	5/25	4(3-4)	4(2-4)
P-value	0.095	*0.002**	0.128	0.713	0.846	0.937

Statistical analysis was carried out by one way analysis of variance (ANOVA) * statistically significant difference is considered if *P-value* < 0.05. [a] Significantly different from group I (UF) value at $p < 0.05$. [b] Significantly different from group II (FF) value at $p < 0.05$.

Discussion

Our study results showed that patients almost equally benefit from IVRA using either the standard UA tourniquet or the modified FA tourniquet, with the advantage of using non-toxic dose of LA.

In agreement with our study, Chong *et al.* [7] showed that FA-based Bier's block IVRA is a safe and effective alternative to conventional Bier's blocks. These results are confirmed by Reuben *et al.* [8] and Tham and Lim [9].

Moreover, Hutchinson and McClinton **[10]** reported a study in which the FA tourniquet was tolerated for an average of 45% longer and with less ischemic pain, less need for additional analgesia or sedation and lesser chance of conversion to general anesthesia compared to the conventional UA tourniquet.

Our study showed no difference between all groups regarding tourniquet tolerance. This is in contrast to a trial comparing UA and FA tourniquet tolerance time in healthy volunteers in which, healthy volunteers also tolerated a FA cuff longer than an UA cuff [11].

Regarding peripheral nerve injury, our study showed no difference between all groups with none of the subjects having postoperative nerve palsy.

In contrast to our findings, Sanders [12] stated that "the tourniquet is most safely applied to that part of the limb which is of maximum circumference, and well-padded with periosseus muscle". However, our results indicate that these presumptions are not true.

Our results are supported by the review of Dekoninck *et al.* [13]. No single peripheral nerve injury was reported in the studies included in the systematic review.

Conventional IVRA has become less popular because the possibility of accidental release of the tourniquet would add the life threatening risk of LAST [14], which can be avoided by the use of smaller non-toxic doses of LA in FA-IVRA. However, the position of the tourniquet on FA may pose some difficulty to the surgeon when operating proximal to the wrist [15].

Regarding the comparison between NTG and fentanyl as adjuvants to lidocaine in IVRA, we couldn't find a single study comparing the effects of both agents. However, many studies had investigated the use of either NTG or fentanyl, alone or when added to other drugs, as adjuvans to LA in IVRA.

Regarding NTG, our results are in agreement with Sen *et al.* [2], who found that it accelerated the onset of sensory, and motor block, prolonged its duration, improved the quality of anesthesia, reduced tourniquet pain, and decreased the postoperative analgesic consumption without side effects. Abbasivash *et al.* [16], Asadi and Mehri [17] Elmetwaly *et al.* [18] and Thombre *et al.* [19] showed similar results.

These effects were explained by the potent vasodilator effect of NTG which facilitates the diffusion of LA through small veins surrounding the nerves and then into the vasa nervorum and capillary plexus of the nerves, leading to a core-to-mantle (centrifugal) conduction block. The analgesic effects of NTG were obtained through its metabolite nitric oxide (NO) which increases cyclic guanosine monophosphate in the cell that results in central and peripheral modulation of pain or its direct stimulation of peripheral nerve fibers simulating the action of acetylcholine [20].

In our study, no significant side effects were reported with the use of NTG. Also, the stability in the hemodynamic parameters (MBP and HR) could be explained by the fact that NTG has a very short half-life. Also, a minimum time of 30 minutes is needed before deflation of the tourniquet which was performed by cyclic deflation technique at the end of surgery. All these techniques combined, may reduce the frequency and severity of unwanted side effects [21].

Regarding Fentanyl, many studies evaluated its use either as a sole adjunct to LA or looked at fentanyl in combination with other drugs.

In agreement with our study, Pitkänen *et al.* [22] and Armstrong *et al.* [23] evaluated fentanyl as a sole adjunct and did not identify any benefits in terms of onset or recovery of sensory or motor block. These results are confirmed by Arthur *et al.* [24] and Abdulla and Fadhil [25].

The peripheral analgesic effect of opioids during IVRA is still controversial and its precise mechanism is not clear. Opioid may possibly produce some degree of suppression of neural conduction and this may potentiate the effect of LA in IVRA [25]. The effects of fentanyl on nerve conduction reported in experimental studies do not seem clinically relevant for IVRA [26]. This lack of peripheral analgesic effect of opioids could be due to the failure of these drugs to reach nerves in sufficient concentration after IV injection [27].

Limitations

Our study cannot be applied to procedures of long duration (1.5 h). The great proximity of forearm tourniquet to the surgical site may pose some difficulty in field exposure.

Further similar studies with greater sample sizes for obtaining more accurate findings are strongly recommended. There is still a need to compare between different adjuvant to discover the ideal one especially for the prolonged post-deflation analgesia.

Conclusion

From our present study, we can conclude that that patients can almost equally benefit from the modified forearm tourniquet IVRA with effects comparable to that of the standard upper arm tourniquet technique, with the advantage of using non-toxic dose of local anesthetics.

The administration of nitroglycerin as an adjuvant to lidocaine has been found superior to fentanyl combined to lidocaine with respect to shortening the onset of sensory and motor block and reduction in postoperative diclofenac requirement in 1st 24 h. However, the two techniques had comperable effects on onset of tourniquet pain, intraoperative fentanyl dose, both sensory and motor block recovery time, postoperative time of first analgesic administration, the quality of anesthesia for both the patient and surgeon and the incidence of tourniquet pain without severe local and systemic complications in different groups.

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