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COMPARISON OF ELECTROSTIMULATION-GUIDED VERTICAL INFRACLAVICULAR BLOCK VERSUS TRANSARTERIAL AXILLARY BLOCK FOR UPPER LIMB ORTHOPEDIC SURGERY: A RANDOMIZED PROSPECTIVE CLINICAL STUDY

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ABSTRACT
Background: Many approaches to brachial plexus block are used routinely for upper limb orthopedic surgery. Aim was to compare the effectiveness of vertical approach of infraclavicular block using electrostimulation and transarterial axillary block and also the success rate of infraclavicular block achieved by posterior cord stimulation technique with that of the lateral or medial cord. **Materials and Methods:** In a prospective randomized double blind study, 60 patients of American Society of Anesthesiologists grades I and II of either sex, 20–60 years of age were included after approval from the Ethics Committee. Informed consent was taken and patients were randomly divided into two groups of 30 each, to receive either a vertical infraclavicular plexus block (Group I) or transarterial axillary block (Group A). Patients were monitored for sensory and motor block characteristics, haemodynamics, side effects and postoperative complications. **Results:** Block performance time (min) for single injection infraclavicular block using nerve stimulator was significantly longer in Group I (7.10±0.80 min) as compared to single injection transarterial axillary block in Group A (3.70±0.95 min).Incidence of successful block was higher in Group I as compared to Group A in axillary nerve (76.7% vs 33.3% , P=0.001), MCN (86.7% vs 40% , P=0.0004) and ICBN (83.3% vs 10% , P=0.0001).Onset time of sensory block was significantly shorter in Group A in axillary nerve (P=0.005), MCN (P= 0.0004), ulnar nerve (P= 0.002), MCNA (P= 0.019) as compared to Group I. Success rate was significantly higher when drug was injected after posterior cord stimulation (100%) as compared to lateral cord stimulation (55.6%) , P=0.017. Patients remained hemodynamically stable and side effects and complications were comparable in both groups. Data was analyzed using "Chi square test", paired 't' test, student 't' test and analysis of variance (ANOVA). **Conclusion**: Vertical infraclavicular block provided higher incidence of complete sensory block as compared to transarterial axillary block. Success rate was significantly higher with posterior cord stimulation technique as compared to lateral cord or medial cord.

KEY WORDS: Vertical Infraclavicular Block, Transarterial Axillary Block, Upper Limb Orthopedic Surgery, Ropivacaine.

INTRODUCTION
Brachial plexus block is commonly used for upper limb orthopedic surgery. Different approaches to a brachial plexus block are: interscalene, supraclavicular, infraclavicular and axillary.

Axillary approach is known for its simplicity, reliable efficacy and safety but may produce postoperative neurologic symptoms.[1] Its major limitations include sparing of musculocutaneous and radial nerve and difficulty of application in patients with limited limb movement.

The infraclavicular approach have advantage of allowing single injection of local anesthetics because of compact anatomical distribution of plexus structures, less painful arm positioning, easily palpable landmarks and better anesthesia in the distribution of ulnar nerve. There are lower incidence of tourniquet pain, lung or pleural puncture and injury to the neurovascular structures in the neck.[2]

More recently it has been shown that during infraclavicular blockade injection of local anesthetic after posterior cord stimulation is associated with better success rate than medial or lateral cord stimulation.[3] Efficacy of vertical approach using nerve stimulator for infraclavicular block as compared to transarterial axillary block (conventional method) was not much investigated.

Our study compared the effectiveness of vertical approach of infraclavicular block using electrostimulation and transarterial axillary block in forearm and hand surgeries using ropivacaine. It also compared the success rate of infraclavicular block achieved by injecting drugs after stimulating the posterior cord with that of the lateral or medial cord.

MATERIALS AND METHODS

After gaining approval of the Medical Ethics Committee and written informed consent from the subjects, the study was conducted at M.B. Hospital attached to RNT Medical College, Udaipur (Rajasthan, INDIA).

Study population

Sixty patients in the age group 20-60 years of either sex and ASA physical status I or II scheduled for forearm and hand surgery were recruited for the study. The exclusion criteria included the following: Unwilling patients, patients with history of allergy to local anaesthetics, infection at local site of block, history of convulsions, bleeding disorders, cardiac, respiratory, renal or liver ailment, sensory neuropathy or motor deficit in the arm on which surgery is to be performed.

The patients were allocated into two groups (30 patients in each group) according to computer generated randomized table to receive either a vertical infraclavicular plexus block (group I, n = 30) or transarterial axillary block (group A, n = 30)

All patients received 30 ml of 0.5% ropivacaine with 3 ml of 8.4% sodium bicarbonate in 5 ml increments with repeated intervening aspiration.

Primary outcome of the study was achievement of adequate surgical anaesthesia at proposed surgical site within 30 minutes of block completion. Secondary outcome were extent of sensory block of individual nerves, onset time of sensory blockade, block performance time, block associated pain and complications related to the block.

Anesthetic technique

In group A, axillary block (AXB) was given by using transarterial approach. Patient was placed in supine position with the operative arm abducted to 90 degree and elbow flexed to 90 degree. After palpating the axillary artery at the highest point in axilla, the overlying skin was instilled with 1% lignocaine and then a 23-gauge, short-bevel needle with syringe was inserted with continuous aspiration. When arterial blood was visualized, under continuous aspiration, the needle was advanced until blood flow ceases. At this position posterior to the axillary artery, 75% of the local anesthetic was injected. Then the needle was withdrawn under continuous aspiration anterior to the artery, where the remaining 25% of the local anesthetic was injected.

In group I, Vertical infraclavicular plexus block was achieved with the patient in supine position with forearm relaxed on the chest and his head turned to opposite side. Following landmarks were marked: 1) Ventral acromion process of scapula 2) Jugular notch. The puncture site was exactly midway between the above two landmarks immediately below the midpoint of the clavicle. A 50-mm 22G short-bevel insulated needle connected to a neural stimulator (NSML-100) to deliver rectangular direct current impulses with a frequency of 2 Hz and pulse width of 100 ms. The initial stimulator current was set at 1.0 mA. Once proximity to a cord was identified by visible contraction of an appropriate muscle group, the current was reduced incrementally and the needle slowly inserted until muscle activity resumed.

The cords were identified by observation of the specific muscle response as follows:
Lateral cord – *flexor carpi radialis*; forearm pronation and elbow flexion.
Medial cord – *flexor carpi ulnaris*; wrist flexion, intrinsic hand muscle contraction.
Posterior cord – *triceps, extensor carpi radialis*; elbow/ wrist extension.

Local anesthetic injected when motor response is visible at a stimulator current of 0.5 mA. On complain of pain, intraoperative anaesthetic and analgesic supplementation with injection ketamine 1mg/kg and if needed injection propofol infusion at the rate of 50 microgram/kg/min was allowed to be given.

Data regarding demographic and surgical variables were recorded and block associated pain was evaluated using visual analogue score (VAS) from 0 to 10.

Sensory function was evaluated by pinprick in entire distribution of all the 8 nerve territories such as axillary nerve, musculocutaneous nerve (MCN), radial nerve, median nerve, ulnar nerve, medial cutaneous nerve of arm (MCNA), medial cutaneous nerve of forearm (MCNF), intercostobrachial nerve (ICBN).

Sensory block in each distribution was graded as
Normal sensation (Grade 2),
Hypoaesthesia (Grade 1),
No sensation (Grade 0).
Grade 0 was defined as sensory block for that nerve. If sensory block was achieved in all 8 nerve territories the case was defined as "complete sensory block".

Motor block was assessed as per Lavoie and colleagues:[4]
Grade 3 (0% block) - Flexion and extension in both the hand and arm against resistance

Grade 2 (33% block) **-** Flexion and extension in both the hand and arm against gravity but not against resistance
Grade 1 (66% block) **-** Flexion and extension movements in the hand but not in the arm
Grade 0 (100% block) **-** No movement in the entire upper limb
Motor block of 66% (grade1) or 100% (grade 0) was considered as adequate motor block.
After 30min of block, depending on the extent of sensory block, cases were classified into:
'Completely successful block': No supplementation required
"Partially successful block": Supplementation required
'Failed block': Patient intubated under GA (excluded from data analysis)

Vital parameters were recorded at regular interval. Duration of sensory block was recorded only in 'completely successful block' cases. It was calculated from time of block completion to time to first complaint of pain in postoperative period and injection Diclofenac sodium 75mg was given intramuscularly.

Complications like pneumothorax, vascular puncture, Horner's syndrome, neurological deficits, including residual neuropraxia lasting more than 24 hours unrelated to the surgical site, systemic complications related to administration of local anaesthetic were recorded. Postoperative dysesthesia and patient acceptance were assessed.

STATISTICAL ANALYSIS

The sample size is based on a hypothesis of 10% improvement (ie from 75% to 85%) in success rate by VIB over axillary block with a SD of 11.51. For the study to have α error of <0.05 and a power of 90%, 29 patients in each group were required. To compensate for possible dropouts and to satisfy the central unit theorem, we decided to include 30 patients in each group. Open epi (version 3.01) was used to calculate the sample size.

Data were entered using MS Excel and Epi Info. Statistical analysis was performed using Pearson Chi square test, paired 't' test, student 't' test and analysis of variance (ANOVA). A p-value < 0.05 was considered as statistically significant.

RESULTS

Both the groups were comparable regarding mean age, sex, mean weight, mean height, ASA grading, mean duration of surgery, indication of surgery, type of surgery and use of tourniquet (P>0.05). Baseline vital parameters (HR, SBP, DBP, SpO2) were statistically comparable in both the groups (p>0.05).There was no significant inter-group variations in Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic blood pressure (DBP) and SpO2 in both the groups at different time intervals intraoperatively (p>0.05) along with no significant change from the baseline.

Block performance time (min) for single injection infraclavicular block using nerve stimulator was significantly longer in Group I (7.10±0.80 min) as compared to single injection transarterial axillary block in Group A (3.70±0.95 min), p=0.000. (Table1). There was no statistically significant difference in pain or discomfort felt during block procedure with both the techniques (P=0.233).

Table 1: Showing distribution of patients according to block performance time

Time (min)	Group I (n=30)	Group A (n=30)	P value
0-3	0 (0%)	15 (50%)	0.000
>3-6	8 (26.7%)	14 (46.7%)	
>6-9	22 (73.3%)	1 (3.3%)	
Range	6-34	8-34	
Mean ±SD	7.10±0.80	3.70±0.95	

(The block performance time was calculated from time of "start of locating the insertion point to end of drug injection". It included time of localization of nerves and injection time)

Both groups were comparable regarding incidence of achievement of sensory block in radial nerve (p=0.471), median nerve (P=0.506), ulnar nerve (P=0.145), MCNA (P=0.730) and MCNF (P=1.000). Incidence of successful block was higher in Group I as compared to Group A in axillary nerve (76.7% vs 33.3%, P=0.001), MCN (86.7% vs 40%, P=0.0004) and ICBN (83.3% vs 10%, P=0.0001) and this was statistically significant (Table 2).

Table 2: Incidence of success and failed block in individual nerve territory at 30 min

Outcome of block	Axillary		MCN		Radial		Median		Ulnar		MCNA		MCNF		ICBN	
	I (n=30)	A (n=30)	I (n=30)	A (n=30)	I (n=30)	A (n=30)	I (n=30)	A (n=30)	I (n=30)	A (n=30)	I (n=30)	A (n=30)	I (n=30)	A (n=30)	I (n=30)	A (n=30)
Successful block	23 (76.7%)	10 (33.3%)	26 (86.7%)	12 (40%)	27 (90%)	24 (80%)	26 (86.7%)	23 (76.7%)	28 (93.3%)	23 (76.7%)	26 (86.7%)	24 (80%)	25 (83.3%)	24 (80%)	25 (83.3%)	3 (10%)

Failed block	7 (23.3 %)	20 (66.7 %)	4 (13.3 %)	18 (60 %)	3 (10 %)	6 (20 %)	4 (13.3 %)	7 (23.3 %)	2 (6.6 %)	7 (23.3 %)	4 (13.3 %)	6 (20 %)	5 (16.7 %)	6 (20 %)	5 (16.7 %)	27 (90 %)
P value	**0.001**		**0.0004**		0.471		0.506		0.145		0.730		1.000		**0.0001**	

MCN-Musculo-cutaneous nerve
MCNA-Medial cutaneous nerve of arm
MCNF- Medial cutaneous nerve of forearm

Time to onset of sensory block was significantly shorter in Group I (11.80 ± 4.54) in the distribution of ICBN as compared to group A (15.00 ± 5.00), P=0.0001. Onset time of sensory block was significantly shorter in Group A in axillary nerve (P=0.005), MCN (P= 0.0004), ulnar nerve (P= 0.002), MCNA (P= 0.019) as compared to Group I. It was comparable in two groups in distribution of radial nerve (P=0.927), median nerve (P=0.292), MCNF (P= 0.510) (Table 3). Mean onset time of sensory block in the successful block cases was 13.78 ±1.83min in Group I (n=29) and 12.16 ±1.61min in Group A (n=26), which was comparable (P=0.082).'Complete sensory block' was achieved in significantly higher number of patients in Group I (80%) as compared to Group A (20%), P=0.000.

Table 3: Comparison of mean time to onset of sensory block (min) in individual nerve territory

	Group I n=30	Group A n=30	P value
Axillary	15.87±4.17 (n=23)	11.0±4.49 (n=10)	**0.005**
MCN	15.38± 5.64 (n=26)	14.17±2.89 (n=12)	**0.0004**
Radial	10.93±4.17 (n=27)	11.04±4.93 (n=24)	0.927
Median	12.50±4.53 (n=26)	11.09±4.76 (n=23)	0.292
Ulnar	15.18±5.35 (n=28)	10.87±4.17 (n=23)	**0.002**
MCNA	14.81±5.19 (n=26)	11.46±4.54 (n=24)	**0.019**
MCNF	13.80±5.26 (n=25)	12.71±6.25 (n=24)	0.510
ICBN	11.80±4.54 (n=25)	15.00±5.00 (n=3)	**0.0001**

Data are mean ±SD
MCN-Musculocutaneous nerve
MCNA-Medial cutaneous nerve of arm
MCNF- Medial cutaneous nerve of forearm
ICBN –Inter Costo Brachial Nerve

Motor block was comparable in two groups at various time intervals, P >0.05.Incidence of achievement of adequate motor block in two groups was also comparable at various time intervals (P = 0.789). Adequate motor block was achieved in 27 (90%) patients of Group I as compared to 24 (80%) patients of Group A, statistically comparable, P=0.492.Mean onset time of adequate motor block was comparable; Group I (11.67 ± 4.16) vs Group A (10.42 ± 4.40).

Table 4: Distribution of patients according to adequacy of motor block and time to onset of adequate motor block after 30min

Adequacy of motor block	Grade of motor block	% of motor block	Group		P value
			I (n=30)	A (n=30)	
Inadequate block	3	0%	1 (3.3%)	1 (3.3%)	0.542
	2	33%	2 (6.7%)	5 (16.7%)	

	Total	0% & 33%	3 (10%)	6 (20%)	
Adequate block	1	66%	12 (40%)	11 (36.7%)	0.492
	0	100%	15 (50%)	13 (43.3%)	
	Total	66% & 100%	27 (90%)	24 (80%)	
Mean onset time of adequate motor block (min)			11.67 ± 4.16	10.42 ± 4.40	0.302

Data are in (%) or Mean ±SD as appropriate.

Success rate in Group I (96.6%) and in Group A (86.7%) in whom surgery was started in block was also comparable.

Success rate was significantly higher when drug was injected after posterior cord stimulation (100%) as compared to lateral cord stimulation (55.6%) , P=0.017. Success rate after medial cord stimulation was intermediate (75%), hence no significant difference was observed in success rate following stimulation of posterior cord versus medial cord (P=0.133) and medial cord versus lateral cord (P= 0.831). Mean duration of block was comparable (P= 0.924).

Block acceptance was significantly more in infraclavicular block technique in comparison to axillary block (P = 0.030) while there was no significant difference in incidence of postoperative dysesthesia in two groups.

DISCUSSION

A brachial plexus block can be performed using multiple approaches. The axillary approach to the brachial plexus block is simple and safe but musculocutaneous nerve and radial nerve may be spared and success rates vary widely.[5]

The vertical infraclavicular approach results in a wider dermatomal distribution of anaesthesia than the axillary approach.

Selection of the appropriate approach is subjective and based on the surgical site, patient comfort, risk of complications and preference of the anesthesiologist.

Our study found that vertical infraclavicular block provided higher incidence of complete sensory block as compared to transarterial axillary block (80% v/s 10%) Also that, stimulating the posterior cord of brachial plexus during infraclavicular brachial plexus block provides greater success rate of block, compared with stimulating the lateral cord of brachial plexus.

In our study it took significantly more time to perform infraclavicular block than axillary block (7.10±0.80 min v/s 3.70±0.95min, P=0.000). Similarly results were cited by Chin KJ et al[6] to perform infraclavicular block than single-injection axillary block. However, Damla Sariguney et a [7] took significantly more time for AXB compared to ICB (13.7 ± 4.0 min v/s 4.23 ± 2.4min , P=0.0001) because they used multiple injection technique in axillary approach but single injection technique during infraclavicular approach.

Our results reaffirm results by Chin KJ et al[6] where the pain associated with block performance was insignificantly lower in ICB group than axillary group. But, Minvilleet al[8] and Kapral et al[9] reported statistically significant less pain with ICB, P < 0.05.

Regarding axillary nerve blockage, we found that it was blocked in significantly higher number of cases by infraclavicular approach than axillary approach (76.7% v/s 33.3%, P=0.001). This was in concordance with Fleishmann E et al [10], Heid FM et al[11], Koscielnak-Nielsen ZJ et al.[12]

Similar to other studies [9, 11, 12] we found that MCN was blocked in significantly higher number of cases in infraclavicular group than axillary group (86.7% v/s 40%, P=0.0004). It happened because MCN normally escapes from axillary sheath before it reaches axilla.

Both our study and study conducted by Vikram U L et al[5] found that ICBN was blocked in significantly higher number of cases in infraclavicular block than axillary block.

Heid F M et al [11] described a significantly higher incidence of blockade of radial nerve in infraclavicular approach as compared to axillary approach (P<0.05). However, we found that both groups were comparable.

In our study Median, ulnar, MCNA and MCNF nerves were comparably blocked by both the approaches which is in accordance with Vikram U L et al [5] and Heid F M et al. [11]

Time to onset of sensory block was significantly shorter in Group I in the distribution of intercostobrachial nerve. Sensory onset time was significantly shorter in Group A in the distribution of axillary nerve, MCN, ulnar nerve, MCNA. Onset time was comparable in two groups in distribution of radial nerve, median nerve, MCNF.

Very few studies[5, 13] have analyzed onset times of individual nerves while comparing the two approaches, where they observed no significant difference between the two approaches.

Success rate of 29 (96.6%) patients in Group I and 26 (86.7%) patients of Group A was observed. Motor block was comparable in two groups at all time intervals, p >0.05, except at 10 min. Both these results are comparable to that of Vikram U L et al. [5]

In our study, adequate motor block was achieved in 27 (90%) patients of Group I as compared to 24 (80%) patients of Group A. Similar to our study Vikram U L et al [5] observed that 66-100% motor block was seen in 90% patients in infraclavicular group and 87% patients in axillary group at 30 mins. The difference was statistically insignificant (P>0.05). In contrast to our study Reda S et al[14] found significantly more incidence of motor block in the axillary group than the coracoids infraclavicular group (*P-value*=0.016). This difference was due to their use of four nerve stimulations technique in axillary group in comparison to single nerve stimulation technique in infraclavicular group.

No statistically significant difference was found between the duration of sensory block in both the approaches and is comparable with earlier studies.[11, 15] In contrast, longer block duration of sensory block was documented by Kilka et al[16] and Arcand et al [17] in infraclavicular block.

Varying rates of block success have been documented by various authors.[5,8,14] However, the definition of "success" appears inconsistent. Some have defined success as analgesia in the distribution of nerves innervating the surgical site only[17] while others have defined it in terms of ability to perform surgery or operability.[8, 16] This makes the inter-study comparison of success rates unreliable. Complete success rate was 80% in Group I and 70% in Group A in whom surgery could be completed in block without any need of supplemental analgesic. Similarly Vikram U L et al[5] in their study achieved a success rate of 96.6% of patients in VIB and 87% of patients in Axillary block which is comparable to that achieved by us.

In our study no significant difference was found between the success rates of infraclavicular and axillary approaches, which were in accordance with the results of other studies.[18, 19] In contrast to our study Quang et al[19] reported that single-stimulation ICB reliably produced a significantly higher success rate than a single-stimulation AXB (97–100% *v/s* 80–85%; P≤ 0.05) possibly due to better blockade of the axillary, radial and musculocutaneous nerves.

In our study general anaesthesia was given to 3.3% in Group I versus 13.3% in Group A which was comparable to Vikram U L et al[5] who found that a higher percentage of patients in axillary block (23%) required supplementation as compared to infraclavicular block (20%) and general anaesthesia was given to 4 patients in axillary group and 3 patients in infraclavicular group . Chin KJ et al[6] also found no significant difference in the proportion of patients requiring general anaesthesia with ICB compared to double injection axillary block (2.3% versus 3.9%, P = 0.19). But when they compared ICB to a single-injection axillary block, found that requirement of general anaesthesia was significantly higher in axillary block (9.7% versus 2.8%, P = 0.03).

Our study showed significantly higher success rate when drug was injected after posterior cord (PC) stimulation (100%) as compared to lateral cord (LC) stimulation (55.6%), P=0.017. Success rate after medial cord (MC) stimulation was intermediate (75%). According to Lecamwasam H et al[3] failure rates following stimulation of PC, LC, and MC were 5.8%, 28.3%, and 15.4% respectively. Intergroup comparison between lateral versus posterior cord was highly significant (*P* < 0.001) and is similar to our result. They have also documented a low failure rate by stimulation of more than one cord simultaneously (*P*< 0.05). Recently Minville et al[8] has observed that a posterior cord (radial nerve) motor response was associated with the highest success rates in Infraclavicular block (up to 96%).Chin KJ et al[6] in their review of articles in Ultrasound guided block procedures found that there was more complete spread of local anaesthetic around the brachial plexus following injection at the posterior cord. Use of multiple injection technique can further increase the success rate with both the approaches,[20] however concerns have been raised regarding patient comfort during performance of these techniques. [21]

In our study, no serious complications occurred. Complications of VIB can be avoided by exact adherence to the anatomic landmarks and the use of short needles with a puncture depth not exceeding 4 cm. [22] Overall, VIP is a very safe method for brachial plexus anaesthesia with regard to the risk of pneumothorax.

We found that postoperative dysesthesia seen in AXB and VIB was 23.3% &16.7% on 2nd day (P = 0.519), 13.3% v/s 6.7% on 10thday (P = 0.389).Similarly Tedore et al[23] found that there was no significant difference between the blocks in terms of postoperative dysesthesia (23.9% in AXB v/s 17.1% in ICB at 2nd day and 11.0% v/s 6.31% at 10th day. However they observed that pain and tenderness at the site of injection was significantly more in the transarterial axillary group as compared to the infraclavicular block group. This may be due to the accumulation of blood within the axillary fascial sheath resulting from puncture of the axillary artery during the transarterial axillary block.[24, 25]

The ICB using a nerve stimulator appears to be a superior technique compared to the single- injection transarterial axillary block. In addition the risks of requiring general anaesthesia and of failing to achieve sensory block of the musculocutaneous nerve and axillary nerve were significantly lower in ICB. The risk of tourniquet pain is decreased, which in turn may reduce the need for additional intraoperative sedatives or analgesics. The decrease in tourniquet pain has been attributed to local anaesthetic spread to the intercostobrachial nerve. The VIB using a nerve stimulator is a simple, reliable and uncomplicated method for plexus-brachialis-anaesthesia, which is easy to learn. [22]

CONCLUSION

We conclude that both techniques provide comparable surgical anaesthesia for upper limb surgeries in terms of success rate, time to onset and duration of block. However vertical infraclavicular block provided higher incidence of complete sensory block as compared to transarterial axillary block. Using different cord stimulation techniques during vertical infraclavicular block, success rate was significantly higher with posterior cord stimulation as compared to lateral cord or medial cord. Thus present study favors the administration of electrostimulation-guided vertical infraclavicular block as compared to transarterial axillary block for forearm and hand surgeries. Injection of drug on posterior cord stimulation significantly increases the success rate.

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LIMITATIONS

We performed traditional blind technique for axillary block (trans-arterial) and nerve stimulation guided technique of infraclavicular block and compared disparate techniques. The future studies should be directed towards the administration of brachial plexus block under ultrasound guidance

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