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Original Research Article

Efficacy of Electrostimulation-Guided Vertical Infraclavicular Brachial Plexus Block for Upper Limb Surgery- A Randomized Prospective Clinical Study

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ABSTRACT

Introduction: Regional anesthesia in the form of brachial plexus block is a well known technique for orthopaedic upper limb surgery. More recently it has been shown that during infraclavicular blockade injection of local anesthetic after posterior cord stimulation is associated with more success rate (upto 96%) than medial or lateral cord stimulation.
Objective: Therefore we planned this study to determine the efficacy of vertical approach of infraclavicular block using electrostimulation guided cord stimulation in upper limb surgeries.
Materials and Methods: This study was conducted on 60 ASA physical status grade I or II of both sexes between 20 and 60 years of age scheduled for forearm and hand surgery. Unwilling patients, patients with history of allergy to local anaesthetics, infection at local site of block, sensory neuropathy or motor deficit in the arm on which surgery is to be performed were excluded from the study.
Results: In the present study we observed mean age was 35.50±12.63 yr. Out of 60 cases 42 (70%) are male and 18 (30%) are female. Incidence of successful block in axillary nerve was (76.7%), MCN (86.7%), radial (96%), median (86.7%), ulnar (93.3%), MCNA (86.7%), MCNF (83.3%) and ICBN (83.3%). 'Complete sensory block' was achieved in 48 (80%) cases. Successful block was observed in 58 (96.6%) cases
Conclusion: We conclude that vertical infraclavicular block provided higher incidence of complete sensory block (blockade of all 8 nerve territories).

Key Words: Regional anesthesia, vertical infraclavicular block, electrostimulation.

INTRODUCTION

Regional anesthesia in the form of brachial plexus block is a well known technique for orthopaedic upper limb surgery. This technique not only provides surgical anesthesia and post-operative analgesia but also avoids the side effects of general anesthesia. The brachial plexus may be approached at various sites like interscalene, supraclavicular, axillary and mid-humeral.

Axillary approach is a commonly used technique for its simplicity, reliable efficacy and safety but is associated with a 0.2% to 19% incidence of postoperative neurologic symptoms. [1,2] However, its application may be difficult in patients with limited limb movement, as in those with painful injuries because to perform axillary block arm has to be abducted 90º at shoulder and flexed 90º cranially at the elbow with a supinated forearm. [3] Also, with the standard single injection technique

musculocutaneous (MCN) and radial nerve escape as they leave brachial plexus sheath before it reaches axilla. [4]

The interscalene and supraclavicular approaches often fail to provide anaesthesia in the distribution of the ulnar nerve and there is risk of lung or pleural puncture and injury to the neurovascular structures in the neck and difficult in landmark identification in obese patients. [5] These limitations can be overcome by Infraclavicular approach. Favourable characteristics of this approach are less painful arm positioning, easily palpable landmarks (even in obese patients) and the single injection block is time efficient. There is a lower incidence of tourniquet pain, lung or pleural puncture and injury to the neurovascular structures in the neck. Vertical infraclavicular block anaesthetizes upper arm and forearm with high levels of tourniquet tolerance (97%), probably because of reliable anaesthesia of the axillary (81%) and intercostobrachial (71%) nerves. [8] Finally, it is an ideal site for inserting a catheter for continuous infusion of local anaesthetic. [3]

More recently it has been shown that during infraclavicular blockade injection of local anesthetic after posterior cord stimulation is associated with more success rate (upto 96%) than medial or lateral cord stimulation. [9]

Therefore we planned this study to determine the efficacy of vertical approach of infraclavicular block using electrostimulation guided cord stimulation in upper limb surgeries. It was also investigated whether taking posterior cord stimulation as a guide to injection had higher success rate as compared to lateral or medial cord in infraclavicular block.

MATERIALS AND METHODS

This study was conducted on 60 ASA physical status grade I or II of both sexes between 20 and 60 years of age scheduled for forearm and hand surgery at the S.C.B Medical College & Hospital, Odisha, India after gaining approval of the Medical Ethics Committee and written informed consent from the subjects..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 were excluded from the study. All the patients received electrostimulation guided vertical infraclavicular block. As per aim of our study 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.

VIB was given as described by Kilka et al Patient was placed 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. Skin overlying this point was cleaned and infiltrated with 1% lignocaine. A 50-mm 22G short-bevel insulated needle connected to a neural stimulator (NSML-100) was inserted perpendicular to the skin. The stimulator was to be set 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. [6]
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 anesthetics were injected when motor response of any of the above cords stimulation is visible at a stimulator current of 0.5 mA.

End of injection was taken as time 0 (t0) to calculate further data. Surgery was allowed to start after 30min from time 0 (t0) if sensory block was achieved at proposed operative site. If it was not achieved then general anesthesia (GA) with intubation was given and case was excluded from study. 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 were recorded for each patient in self made structure proforma. Demographic and surgical variables like age, sex, height, weight, ASA grading, indication of surgery, type of surgery and baseline vital parameters were recorded.

Block performance time would be calculated from start of attempt to locate the nerve till end of injection, block associated pain or discomfort was evaluated using visual analogue score (VAS) from 0 to 10 (0-no pain, 10- maximum pain).

Sensory and motor functions were evaluated at 5 min interval after end of injection of local anaesthetic (t0). 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 described using the following scale;

Grade 2 - Normal sensation

Grade 1- Hypoaesthesia (reduced sensation)

Grade 0 - No sensation felt

Grade 0 was dfined as sensory block for that nerve. Onset of sensory block in each nerve territory was defined as the time from end of drug injection (t0) to achievement of sensory block (grade 0) and was recorded. 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: [13]

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 if patient has achieved sensory block on proposed incision site it was described as 'successful block' and surgery was allowed to start in block. If surgery was completed without any intraoperative supplementation it was defined as 'completely successful block'. If patient complained of intraoperative pain or discomfort, intraoperative supplementation with small doses of intravenous ketamine 1 mg/kg was given followed by sedative doses of propofol infusion (50 mcg/kg/min) if needed. They were considered as "partially successful block". If sensory block was not achieved at proposed operating site, GA was given at the outset to allow start of surgery and case was defined as 'failed block'. The cases in whom surgery was started under block but intraoperative pain was severe were intubated under general anesthesia to accomplish the surgery. The case was declared as 'failed block'. The cases of failed block were excluded from further data analysis.

Vital parameters like Heart rate, systolic blood pressure, diastolic blood pressure and SpO2 were recorded at baseline, at the end of block procedure (time t0) and thereafter at every 15min interval. Duration of surgery was defined as the time from skin incision to completion of surgical procedure.

Duration of sensory block was recorded only in 'completely successful block' cases. It was calculated from time of block completion (t0) 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 neurapraxias lasting more than 24 hours unrelated to the surgical site, systemic complications related to administration of local anaesthetic were recorded. Postoperative dysesthesia was assessed on day 2 and day 10 by asking numbness, heaviness, tingling sensation in the operated limb.

Patient acceptance for block was assessed ten days after block procedure by asking "if needed whether they are willing to undergo same block procedure in future or not".

Statistical analysis:-

The sample size is calculated based on a projected difference of 20% in primary outcome among the two groups permitting a type 1 error of alpha = 0.05 with a type II error of beta = 0.2 and power of 0.8 with 95% confidence interval. Data were entered using MS Excel and Epi Info 6 and SPSS 12.0 for windows. The data were compared using Pearson Chi square test, student 't' test and analysis of variance (ANOVA). Analysis of data within the group was done by using paired t-test. Analysis of data between the different groups was done by using student t-test. P <0.05 was considered as statistically significant.

RESULTS

In the present study we observed mean age was 35.50±12.63 yr. Out of 60 cases 42 (70%) are male and 18 (30%) are female, mean weight was (65.10±8.00 kg), mean height (162.10 ±5.85 cm), 42 (70%) cases are ASA grade 1 and 18 (30%) cases are 2, mean duration of surgery was 91.67±14.46 min. We also recorded indication of surgery, type of surgery. Tourniquet was used in all cases. Baseline vital parameters like HR, SBP, DBP and SpO2 recorded. The mean block performance time for single injection infraclavicular block using nerve stimulator was 7.10±0.80 min. Incidence of successful block in axillary nerve was (76.7%), MCN (86.7%), radial (96%),median (86.7%), ulnar (93.3%), MCNA (86.7%), MCNF (83.3%) and ICBN (83.3%). (Table 1)

Table 1. Incidence of success and failed block in individual nerve territory at 30 min

Outcome of block	Axillary (n=60)	MCN (n=60)	Radial (n=60)	Median (n=60)	Ulnar (n=60)	MCNA (n=60)	MCNF (n=60)	ICBN (n=60)
Successful block	46 (76.7%)	52 (86.7%)	54 (90%)	52 (86.7%)	56 (93.3%)	52 (86.7%)	50 (83.3%)	50 (83.3%)
Failed block	14 (23.3%)	8 (13.3%)	6 (10%)	8 (13.3%)	4 (6.6%)	8 (13.3%)	10 (16.7%)	10 (16.7%)

Data are n (%).
MCN-Musculocutaneous nerve
MCNA-Medial cutaneous nerve of arm
MCNF- Medial cutaneous nerve of forearm

Mean onset time of sensory block in the successful block cases was 13.78 ±1.83min. (Table 2)

Table 2: Comparison of mean time to onset of sensory block (min) in individual nerve territory

Nerve	\Time to onset of sensory block (min) n=60
Axillary	15.87±4.17 (n=46)
MCN	15.38± 5.64 (n=52)
Radial	10.93±4.17 (n=54)
Median	12.50±4.53 (n=52)
Ulnar	15.18±5.35 (n=56)
MCNA	14.81±5.19 (n=52)
MCNF	13.80±5.26 (n=50)
ICBN	11.80±4.54 (n=50)

Data are mean ±SD as appropriate.
MCN-Musculocutaneous nerve
MCNA-Medial cutaneous nerve of arm
MCNF- Medial cutaneous nerve of forearm

Onset time of sensory block (min) for each nerve territory was calculated in the patients who achieved successful sensory block in that nerves territory which is showed by number of patients in each group in the tables as (n).

Table 3. Distribution of patients according to "complete sensory block" (sensory block in all 8 nerve territories)

Complete sensory block	(n=60)
Yes	48 (80%)
No	12 (20%)

Data are n (%).

'Complete sensory block' was achieved in 48 (80%) cases. Adequate motor block was achieved in 54 (90%) cases. Mean onset time of adequate motor block was 11.67±4.16 min. Successful block was observed in 58 (96.6%) cases in whom surgery was started in block without any need of supplemental analgesic. (Table 3)

Table 4. Distribution of patients according to outcome (adequacy) of block (Failed/Successful/Supplementation needed)

Outcome(Adequacy) of block		(n=60)
Failed block (surgery started under GA)	Converted to GA to allow start of surgery	2 (3.4%)
Successful block (surgery started under block)	Complete success (surgery completed without supplementation)	48 (80%)
	Partial success (intraoperative supplementation needed for pain)	10 (16.6%)

Data are in n (%).

As per study protocol when loss of sensation to pin prick at the proposed operative site was achieved surgery was allowed to start and the case was defined as 'successful block'.

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). (Table 5)

Table 5. Distribution of patients according to different cords of brachial plexus stimulated in Infraclavicular block and their success rate

Cord stimulated (n=30)	Successful block	Failed/Inadequate block	P value		
			PC v/s LC	PC v/s MC	MC v/s LC
Posterior cord (PC) (n=26, 43.3%)	26 (100%)	0 (0%)	0.017	0.133	0.831
Lateral cord (LC) (n=18, 30%)	10 (55.6%)	8 (44.4%)			
Medial cord (MC) (n=16, 26.7%)	12 (75%)	4 (25%)			

Data are n (%). PC = Posterior cord, LC = Lateral cord, MC = Medial cord.

While performing infraclavicular nerve block using nerve stimulator twitching in different muscle groups were observed. Twitching in anterior (flexor) compartment muscles of arm indicates stimulation of lateral cord, twitching in posterior (extensor) compartment muscles of arm & forearm indicates stimulation of posterior cord and twitching in anterior (flexor) compartment muscles of forearm indicates stimulation of medial cord. If stimulation of any of the cord was achieved as indicated by muscle twitching, the drug was injected and the type of cord stimulated was noted.

During nerve stimulation for infraclavicular block posterior cord was stimulated in 26 (43.3%), lateral cord was stimulated in 18 (30%) and medial cord was stimulated in 16 (26.7%) cases.

Mean duration of block was observed as 344.33±16.59 min. (Table 6)

Table 6. Distribution of patients according to duration of block

Time (min)	(n= 48)
320-340	30 (62.5%)
>340-360	16 (33.3%)
>360-380	14 (29.1%)
Range	320-374
Mean ±SD	344.33±16.59 min (≈ 5.7 hr)

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

In postoperative period when patient complained of pain at the surgical site it was the end point to define the 'duration of block'. It was calculated from the time of end of injection during block procedure (t0) to time of first complaint of pain in postoperative period (t pain). This was calculated only in 'completely successful cases' i.e. 48(80%) cases, in which surgery

was completed without any supplementation. The cases in whom GA was given at the start or intraoperative supplementation was given were excluded while calculating duration of block, because it will interfere in assessment of pain.

It was observed that 54 (90%) patients were willing to undergo same block procedure as a future anesthetic procedure if needed. Postoperative dysesthesias was seen in 10 (16.7%) on day 2 and 4 (6.7%) cases on day 10. These dysesthesias were mild type.

DISCUSSION

Brachial plexus block is close to the ideal anaesthetic technique for upper limb surgeries for the patients, anaesthesiologists and surgeons. The axillary approach to the brachial plexus block enjoys great popularity as it is easy to perform and relatively safe. It is however problematic in patients with limited arm mobility. Also, with the standard single injection axillary block, reliable musculocutaneous nerve and radial nerve anaesthesia is limited by anatomical conditions and success rates vary widely. [4,12]

The vertical infraclavicular approach introduced by Kilka and colleagues is the most proximal infraclavicular approach to the brachial plexus. [6] In this approach, the brachial plexus is blocked at the cord level, which is expected to result in a wider dermatomal distribution of anaesthesia than the axillary approach.

In this study, we evaluated the efficacy of vertical infraclavicular approaches to brachial plexus block using a peripheral nerve stimulator. Previous authors have compared infraclavicular block with axillary block with varying results. [1,12,15] In these infraclavicular block was given using nerve stimulator or ultrasound guided technique. Axillary block were given using nerve stimulator, transarterial or paresthesia guided technique. [11,12]

In our study it took 7.10±0.80 min to perform infraclavicular block. Similarly Chin KJ et al [10] using nerve stimulator took 3.2 minutes to perform infraclavicular block. Sariguney D et al took 4.23 ± 2.4min for single injection technique during infraclavicular approach. [17]

We observed pain associated with block performance was 3.10±2.17 using VAS scale. Similar to our study Chin KJ et al found block-associated pain was lower with ICB. [10] Minville et al and Kapral et al also reported significantly less pain with ICB, [13,15]

We observed incidence of successful block in axillary nerve (76.7%), MCN (86.7%), radial (96%), median (86.7%), ulnar (93.3%), MCNA (86.7%), MCNF (83.3%) and ICBN (83.3%) cases. Fleishmann E et al and Heid FM et al observed similar incidence of blockade. [14,16]

Blockade of ICBN provides at least a theoretical advantage of better tourniquet tolerance. In our study ICBN was blocked in 50 (83.3%) cases. Similar to us Vikram U L et al found that ICBN was blocked in 83.3% of patients. [12] Macfarlane A et al observed that VIB was simple to perform with just a nerve stimulator and has a high success rate with just one injection and anaesthetize the upper arm and the forearm, with high levels of tourniquet tolerance (97%), probably because of reliable anaesthesia of the axillary (81%) and intercostobrachial (71%) nerves. [7]

We observed the mean onset time of sensory block in the successful block cases was 13.78±1.83min. Similar results were observed by Vikram U L et al. [12]

We observed mean duration of sensory block was 344.33±16.59 min. Similar to our study Vikram U L et al reported that the mean duration of sensory block in infraclavicular block was 332±44 min. [12] Chin KJ et al observed the average duration of sensory block by infraclavicular approach was 438 min. [10] In contrast to our study longer block durations of sensory block was documented by Kilka et al (3-20 hours with an average of 8 hours) in infraclavicular block. [6]

Our study suggests that the four major nerves (MCN, Median, Radial and Ulnar) are blocked completely in 89.17% of patients. Similar results are observed by Vikram U L et al. [12]

In our study we observed that adequate motor block was achieved in 54 (90%) patient [grade 0 in 30 (50%) and grade 1 in 24 (40%) patients]. Mean onset time of adequate motor block was 11.67 ± 4.16 min in patients who achieved adequate motor block (n=54, 90%). Similar to our study Vikram U L et al observed that 66-100% motor block was seen in 90% patients in infraclavicular block at 30 mins. [12] The difference was statistically insignificant (P>0.05).

Varying rates of block success have been documented by various authors. [12] However, the definition of "success" appears inconsistent. Some have defined success as analgesia in the distribution of nerves innervating the surgical site only while others have defined it in terms of ability to perform surgery or operability. [6] This makes the inter-study comparison of success rates unreliable. As per our study protocol when there was loss of sensation to pin prick at the proposed operative site, surgery was allowed to start and the case was defined as 'successful block'. If it was not achieved then the case was given GA at the outset and defined as 'failed block'. In our study 'completely successful block' was seen in 48 (80%) cases. 'Successful block' was seen in 58 (96.6%) cases and 'failed block' was seen in 8 (13.3%) cases. Intraoperatively 5 (16.6%) cases complained of little pain and supplemented with injection ketamine 1mg/kg.

We observed success rate in 96.6% cases and complete success rate in 80% cases in whom surgery could be completed in block without any need of supplemental analgesic. Similarly Vikram U L et al in their study achieved a success rate of 96.6% of patients in VIB. [12]

In our study the need of general anaesthesia at the outset to achieve adequate surgical anaesthesia was 3.3%. Similarly Vikram U L et al found 3 patients in infraclavicular block required conversion to general anaesthesia. [12] Chin KJ et al also found 2.3%of patients with ICB requiring general anaesthesia. [10]

Our study shows that Success rate was significantly higher 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 failure rates following stimulation of PC, LC, MC were 5.8%, 28.3%, 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 ($P< 0.05$). [9] Chin KJ et al 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. [10]

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. [6] Overall, VIP is a very safe method for brachial plexus anaesthesia with regard to the risk of pneumothorax.

It was observed that 54 (90%) patients were willing to undergo same block procedure as a future anesthetic procedure if needed. Similarly Tedore et al found that 97% of the patients were opted to have the same anesthetic procedure again when required. [11]

We observed postoperative dysesthesias in 10 (16.7%) on day 2 and 4 (6.7%) cases on day 10. These dysesthesias were mild type. Similarly Tedore et al found postoperative dysesthesias in 17.1% of cases at 2nd day and 6.31% at 10th day by using ICB. In contrast to our study Tedore et al observed that pain and tenderness was lower

at the site of injection by infraclavicular block. [11]

According to this study significantly more patients are willing to undergo the infraclavicular block (90%) as a future procedure if needed. Similarly Tedore et al found that 97% of the patients undergoing the infraclavicular block procedure opted to have the same anesthetic procedure again. [11]

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 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 VIP using a nerve stimulator is a simple, reliable and uncomplicated method for plexus-brachialis-anaesthesia, which is easy to learn. [6]

Limitations:

It is recommend that future studies utilizing electrostimulation to locate the brachial plexus should specify a distal posterior cord motor response as the endpoint for infraclavicular blockade. The future studies should be directed towards the administration of brachial plexus block under ultrasound guidance. The axillary sheath catheters can be placed to achieve analgesia for longer duration.

CONCLUSION

We conclude that vertical infraclavicular block provided higher incidence of complete sensory block (blockade of all 8 nerve territories). That could be a reason that acceptance rate for future block modality was also high with vertical infraclavicular block. While comparing success rate after different cord stimulation during vertical infraclavicular block, success rate was significantly higher when drug was injected after stimulation of posterior cord (100%) as compared to lateral cord (55.6%) or medial cord (75%). However further study with adequate number of cases in all cord distribution groups need to be done to verify this, as our study was not sufficiently powered to evaluate this finding. Thus present study favours the administration of electro-stimulation-guided vertical infraclavicular block for forearm and hand surgeries. Injection of drug on posterior cord stimulation significantly increases the success rate.

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