ORIGINAL RESEARCH

Enhancing Precision in Supraclavicular Brachial Plexus Blocks: A Comparative Randomized Controlled Trial of Ultrasound-Guided, Ultrasound-Nerve Stimulator Combo, and Nerve Stimulator-Only Techniques

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ABSTRACT

Background: Brachial Plexus Block has evolved as a valuable and safe alternative to GA for surgeries on upper extremities. It provides effective and reliable anaesthesia and analgesia. Successful institution of Brachial Plexus Block relies on proper techniques of nerve localization, needle placement and local anaesthetic injection. This study was designed to compare velocity, accuracy, efficacy, safety and quality of Brachial Plexus Block achieved by using any one of three techniques, viz 'Nerve Stimulator Technique', 'USG guided Technique' and 'Combined USG Guided + Nerve Stimulator Technique'

Methods: A total of 118 patients posted for elective upper limb surgeries were enrolled for study of which 25 were excluded being ASA Grades below III or having co-morbidity; and 03 declined to participate. Remaining 90 patients were randomly assigned to one of three groups (N, U&UN) with 30 patients being included in each group. Local Anaesthetic used was 1:1 mixture of 0.5% Bupivacaine (maximum 2 mg/kg body weight) and 2% Lignocaine (maximum 5 mg/kg body weight) for achieving block. Total volume of 0.5 ml/Kg body weight was injected as a loading dose. Data collected and analyzed using relevant statistical tests.

Results: There was significant difference in time taken for localization of block and onset time between N group as compared to U and UN groups. Need for supplementation and complications were more in case of N group as compared to U and UN groups. There was no significant difference between time taken for block to achieve its maximal density after injection of LA Mixture in all three groups.

Conclusion:Our study demonstrates that ultrasound guided brachial plexus block (when used alone or along with nerve stimulator) using supraclavicular approach are safer and more successful in comparison to when nerve stimulator alone is used in terms of real-time needle visualization makes localisation of nerve bundles easier, safer and more accurate and local anaesthetic spread pattern during injection can be visualised in real time and manipulated to achieve a denser block, reduced no. of needle attempts for nerve localization, reduced rate of complications and overall improved quality of sensory block and success rate.

Keywords – Brachial Plexus Block, Nerve Stimulator, Ultrasound, Regional Anaesthesia, Bupivacaine, Lignocaine

Introduction

Brachial Plexus Block has evolved as a valuable and safe alternative to GA for surgeries on upper extremities. It provides effective and reliable anaesthesia and analgesia, as also it can act as a portal for Continuous Analgesia Techniques by placing a catheter next to the plexus sheath, thereby enabling extension of analgesia well into the post-operative period.[1, 3, 5]Successful institution of Brachial Plexus Block relies on proper techniques of nerve localization, needle placement, and local anaesthetic injection. Historically the block was achieved by the classical 'Landmark' technique, where the plexus was localised blindly by choosing the needle puncture site by anatomical landmarks, and identifying the desired

injection site by raising paraesthesia.The technique was further refined by using electrical stimulation of the nerves by a 'Nerve Stimulator', leading to a visual Motor Response in the muscles / group of muscles supplied by it, thereby confirming proximity of tip of the needle to the nerve.[2, 16]Presently the technique of achieving a precise and highly localised block has been revolutionised with the introduction of Ultrasound Guided Blocks. With the use of high resolution USG equipment now available, we can visualize the plexus, achieve a precise placement of tip of the needle under direct vision, and control the spread of local anaesthetic, thereby significantly improving the quality and success rate of block and simultaneously reducing the complicationsassociated with it like risk of injury to adjacent structures.[4, 6, 7, 8]Although the 'Nerve Stimulation' technique has been in vogue for quite some time now, and the "USG Guided Blocks' have also been present for a while, there are a very few studies where the two have been combined to be used in tandem and evaluated for the advantages / disadvantages of such a combination over the two techniques being used in isolation.This study was designed to compare the velocity, accuracy, efficacy, safety and quality of Brachial Plexus Block achieved by using any one of the three techniques, viz 'Nerve Stimulator Technique', 'USG guided Technique' and 'Combined USG Guided + Nerve Stimulator Technique'. The study was aimed to compare and contrast the (a) Accuracy of Nerve localisation and needle placement, Velocity (time of onset) and duration of block and the density of block while using one of the three stated techniques of performing a Brachial Plexus Block via the Supraclavicular Route

MATERIAL AND METHODS

After obtaining approval from Hospital ethical committee, a randomized controlled trial was conducted during the period 2017-2018 at a tertiary care, multispecialty, teaching hospital and an advanced Orthopaedicand Reconstructive Surgery centre.The study population included hospitalized patients undergoing upper limb surgery for various procedures. Inclusion and exclusion criteria were as follows:

INCLUSION CRITERIA

(a) Patients posted for elective Upper Limb surgery.
(b) Physical Status Classification – ASA Grades I&II

EXCLUSION CRITERIA

(a) Physical Status Classification – ASA Grades III and below
(b) Those with co-morbidities like Neuropathy,Coagulopathy,COPD,Hepatic / Renal Failure,Pregnancy, history of allergy to local anaesthetic agents or prior surgery in supraclavicular region.

Sample size was calculated using a previous study involving 80 patients where Williamset al had examined supraclavicular block with either ultrasound alone or ultrasound with nerve stimulator. Theyhad obtained block performance time for the ultrasound group as 5.4 (+/-2.4) minutes, while for nerve stimulator group as 9.8 (+/-7.5) minutes. Assuming a power of 80% with 5% level of significance in our proposed study with reference to these values and assuming this difference to be significant, the minimum required sample size was calculated to be of 75 patients (divided into 3 groups of 25 each). However,to furtherempower our study, it was decided to enhance the sample size to 90 patients (3 groups of 30 each).

All cases posted for elective upper limb surgeries were enrolled in the study and those qualifying the inclusion were randomly allocated to one of the following three groups;
Group N: where the neural bundle was localized using a Peripheral Nerve Stimulator
Group-U: where the neural bundle was localized using Ultrasound Imaging
Group-UN: where the neural bundle was localized using a combination of Ultrasound Imaging and Peripheral Nerve Stimulator.

A total of 118 patients were enrolled for the study of which 25 were excluded being ASA Grades below IIIorhaving a co-morbidity; and 03 declined to participate. Remaining 90 patients were randomly assigned to one of the three groups (N, U & UN) with 30 patients being included in each group (Fig 1). Local Anaesthetic used was 1:1 mixture of 0.5% Bupivacaine[9,10] (up to a maximum of 2mg/kg body weight) and 2% Lignocaine[12,13] (up to a maximum of 5mg/kg body weight) for achieving the block. Total volume of 0.5 ml/Kg body weight was injected as a loading dose.

For those in Group N, the target neural bundle was localised using a 5 cm long, 22 G, insulated Nerve stimulator needle connected to a nerve stimulator device. The needle puncture site was ascertained by anatomical landmark technique. Once localised, the neural sheath was flooded with 25-30 ml of Local Anaesthetic mixture.

For patients in Group-U, the target neural bundle was localised using Ultrasonic Imaging with "Sonosite" by inserting a 5 cm long, 22 G, short bevel needle, and 25-30 ml of local anaesthetic mixture was injected around the neural bundle under direct USG guidance.

In the third group of patients(Group-UN) a 5 cm long, 22 G, insulated Nerve stimulator needle connected to a nerve stimulator device was used and the neural bundle was localised using ultrasound

guidance. Once the tip of needle was placed in proximity of the target neural bundle, the placement was further fine-tuned by stimulating the neural bundle using the nerve stimulator and tip of needle being readjusted so as to achieve maximal motor response with the least amplitude of stimulating electrical energy used. 20-25 ml of LA mixture was then injected around the neural bundle under direct USG guidance.

In patients where ultrasound guidance was employed, a linear high frequency probe covered with a sterile adhesive dressing was used to scan Supraclavicular Fossa in a coronal-oblique plane, parallel and immediately superior to clavicle, to obtain a short axis view of the neurovascular structures. Brachial plexus was identified as a compact group of nerves (trunks and/or divisions) located over the first rib, lateral and posterior to Subclavian Artery. Rib and pleura were identified before needle insertion.

The extent and quality of block were assessed by checking for absence of 'Pain' & 'Temperature' sensations using 'Pin Prick Test' and 'Hot & Cold Test Tube Test' respectively, and by assessing 'Loss of Muscle Power' in the innervated groups of muscles for assessment of motor block.The level and adequacy were assessed every 5 min after institution of block till the desired level of block with complete loss of sensations, coupled with a complete motor block was achieved. Once the peak level and density of block was achieved, the sensory and motor blocks were subsequently assessed ever 15 min in the intra-operative period.After 30 min, if the block was found unsatisfactory, or had failed completely, the technique was abandoned and the surgery performed under an alternative technique (GA/TIVA etc).In case the block achieved was satisfactory to begin with, but either waned early or the surgical procedure got prolonged, the surgery was completed by supplementing the block with GA/TIVA / any other suitable technique.

Post-operatively the block was assessed every 30 min, till complete regression of block and full recovery of motor power was achieved. Vital parameters like Pulse, NIBP, Resp & SpO2 were constantly monitored in the peri-operative period.
The observations were tabulated and analysed with respect to following parameters:

(a) Localising Time (Time taken to localise Neural Bundle)
(b) Onset Time (Time to Onset of block since injection of LA Mixture)
(c) Peak Block Time (Time to achieve peak density of block)
(d) Need for supplementation / conversion of technique
(e) Haemodynamics and vital parameters
(f) Complications if any

Collected data was subjected to statistical analysisusing Microsoft Excel, and 'Statistical Package for Social Sciences(SPSS;version 15.0)'statistical analysis Software. The Variable Data (Mean +/- SD) were compared using ANOVA (Analysis Of Variance) with Bonferroni Test, whilethe Categorical data were compared using Chi-Square/ Fisher's exact test. A probability value (p) <0.05 was considered statistically significant and a probability value(p)<0.001 was considered highly significant.

RESULTS

Patients'Characteristics like average age, average weight and sex ratio were comparable in all three groups and so was the volume of LA Mixture injected to achieve the block (mean drug volume injected being 28.67 (± 2.60) ml;28.60 (± 3.68) ml; and 25.53 (± 7.11) ml respectively in Group-N, Group-U and Group-UN). (Table-1)

Localising Time (mean ± SD) was 10.57(± 8.79) minutes in Group-N, while in Group-U and in Group-UNit was much lesser, the mean localising time being 4.30 (±1.02) minutes and 4.60 (± 0.81) minutes respectively. This difference between times taken for localising the nerve bundles between techniques employing USG Guidance and one without the use of USG guidance, was clinically and statistically significant. (Table-2)

Start of procedure to Onset Time (mean ± SD) was 21.80 (± 8.57) minutes in Group-N, while in Group-U and in Group-UN it was 14.27 (± 0.78) minutes and 15.07 (± 1.44) minutes respectively. In patients where USG guidance was used the onset time from the time of injection of the LA mixture was significantly lower (both clinically and statistically) than in those where block was achieved with a Nerve Stimulator only. The difference noticed amongst the Groups-U & UN was not clinically or statistically significant. (Table-3). This is because the time taken to localise the neural bundle without the aid of USG guidance was significantly higher than in those cases where USG guidance was used.

Injection to Onset Time(mean ± SD) was 8.63 (± 0.93) minutes in Group-N, while in Group-U and in Group-UN it was 7.53 (± 0.68) minutes and 7.80 (± 0.76) minutes respectively. Inpatients where USG guidance was used the onset time from the time of injection of the LA mixture was lower than in those where block was achieved with a Nerve Stimulator only, and this difference was clinically not significant, though statistically it was significant. However there was no difference noticed amongst the Groups-U & UN, indicating that once the neural bundle is localised, the block dynamics remain same for all if other factors like Anaesthetic Agent, Volume of injectate etc. remain constant. (Table-4)

Peak Block Time (mean ± SD) was 35.37 (± 0.83) minutes In Group-N, while inGroup-U and in Group-UN it was 34.76 (± 1.46) minutes and 34.93 (± 0.38) minutes respectively. Thus, the time taken for the block to achieve its maximal density after injection of LA Mixture was similar in all the three groups and the differences noted amongst the groups were clinically and statistically insignificant. (Fig2)

Supplementation of the block (owing to either the block being sub-optimal, or the same waning away early, before completion of the surgical procedure) was required in 16 patients in Group-N, whereas only 02 patients in Group-U and 06 patients in Group-UN required supplementation.

Of the 16 patients requiring supplementation of block in Group-N, 03 patients were instituted GA, 09 patients were supplemented with TIVA while 04 patients needed to be instituted a repeat block.

In Group-U, of the 2 patients requiring supplementation, 01 patient was instituted GA and the surgery in the other patient was completed under supplementation with TIVA. In Group-UN, 2 patients were given GA and 4 patients were instituted TIVA of the 6 requiring supplementation of block. There was no requirement of instituting a repeat block in any of the cases in Group-U and Group-UN.(Fig3)

Complications noticed were not many in all the three groups. Incidence of shivering and nausea was more common among patients in Group-N as compared to Group-U and Group-UN. Post op bruising was seen in 4 patients in Group-N as compared to no incidence of post op bruising in Group-U and Group-UN.Vascular puncture was seen in 2 patients in Group-N as compared to no incidence of vascular puncture in Group-U and Group-UN.(Fig 4)

DISCUSSION

In recent years, there has been a growing interest in the practice of regional techniques and, in particular, peripheral nerve blocks for surgical anaesthesia and postoperative analgesia. Compared with general anaesthesia, regional anaesthesia is associated with multiple benefits including reduced morbidity and mortality(Rodgers et al.,2000; Beattie et al.,2001),superior postoperative analgesia(Buist,1990; McCartney et al.,2004), cost-effectiveness(Chan et al.,2001),and a lower rate of serious complications(Aromaa et al.,1997; Moen and Dahlgren,2004). As such, the practice of regional anaesthesia has gained popularity worldwide (Brull et al.,2007)[15,18]. However, it is highly dependent on the accurate delivery of acorrect dose of local anaesthetics to attain success and to avoid rare but potentiallydevastating nerve damage. One of the principle challenges in regional anaesthesia is the unreliability of conventional modalities like electric stimulation and patient-reported paraesthesia for confirming precise nerve localization.

Peripheral nerve blockade (PNB) is usually performed without visual guidance, relying mainly on surface anatomic landmarks and electrical stimulation to localize nerves.Inaccurate needle placement and local anaesthetic spread account for most PNB failures, whereas “trial and error” needle manipulations for localization can cause complications.[16]

The onset time of block was studied in two temporal phases. The first phase being the time taken for localisation of the neural bundle, and the subsequent phase being time from injection of the LA mixture to onset of block

The mean localising time in Group-N was 10.57 (± 8.79) minutes while in Group-Uit was 4.30 (±1.02) minutes andin Group-UNit was4.60 (± 0.81) minutes. It is evident here that mean localising time was higher in the Group-N because it is a blind technique as compared to Group-U and Group-UN where we could actually visualize the nerve plexus. This intragroup difference was highly significant between the USG guided and Non-USG guided groups, whereas it was not significant when one USG guided group was compared to the other. This shows that USG Guidance is a highly effective tool in quick localisation of the neural bundle. Similar findings have been reported by *Williams et al.,2003* in their study Ultrasound Guidance Speeds execution and Improves the Quality of Supraclavicular Block.[17]

Time taken for onset of block from the time of injection of LA Mixture was also studied. In Group-N,it was 8.63 (±0.93) minutes while in Group-U and in Group-UNitwas 7.53 (± 0.68) minutes and 7.80 (±0.76) minutes respectively. It is evident thattime to onsetof blockade was more in Group-N as compared toGroup-U and Group-UN. This difference was statistically significant although clinically not much of a difference could be appreciated.

Our findings were consistent with *Brull et al. in 2007 who* emphasized advantages of Ultrasound-guided PNB. Deposition and spread of local anaesthetic are readily appreciated with real-time US imaging during injection. Thus, Ultrasound-guided PNB translates into faster onset, longer duration, and improved block quality with reduced amounts of local anaesthetics compared with blocks using peripheral nerve stimulator.[15]

Further this finding was consistent with various studies whichhave demonstrated the superiority of US with respectto block completeness at 30 minutes,overall block success(surgical anaesthesia),rapidblock performance,shorter onset

times, prolongation of block and reduced complications *(Williams et al.,2003; Marhofer et al., 2004; Soeding et al.,2005; Liu et al.,2005; Sites et al.,2006; Chan et al.,2007).*

Supplementationwas required in 16 patients in Group-N, while 02 patients in Group-U and 06 patients in Group-UNin our study required supplementation because these patients had dermatomal sparing in one or more dermatomal distribution in aspect of sensory blockade or partial or no motor blockade was seen in one or more nerve distribution. In Group-N 03 patients required GA compared to 01 patient in Group-U and 02 patients in Group-UN.Repeat block was given in 04 patients in Group-N while no patient in Group-U and Group-UN required repeat block.09 patients in Group-N were supplemented by TIVA while 04 patients in Group-UN and 01patient in Group-U required TIVA.

It is evident that more number of patients required supplementation in Group-N as compared to Group-U andGroup-UN because in nerve stimulation technique when used alone; elicitation of motor twitch does not confirm complete block in all dermatomes while with the help of ultrasound we can visualize nerve structures in which we can inject drug. We found that success rate of block was 93.33% in group U as compared to 80.00% in group UN and 46.67% in group N in terms of requirement of supplementation.

However, in terms of supplementation these findings were not consistent with study of Williams 2003 et al. In 2003 investigated, in a study involving 80 patients, examined supra clavicular block with either ultrasound alone or ultrasound with nerve stimulator.Efficacy shows no GA:no difference between ultrasound and NS 100% versus 92%(no patient in group ultrasound and 8% of patients in Group NS required general anaesthesia), no supplement:no difference between ultrasound and NS 85% versus 78%.(Surgical anaesthesia without supplementation was achieved in 85% of patients in group Ultrasound and 78% of patients in group NS)[17]

In our study Post op bruising was seen in 4 patients and vascular puncture was seen in 2 patients in Group-N as compared to no incidence of post op bruising or vascular puncture in Group-U and Group-UN.It is evident that incidence of complications like post op bruise and vascular puncture was seen in nerve stimulator Group-N because it is a blind technique as compared to other two groups where ultrasound was used where we could visualize neurovascular structures as well as whole of the trajectory of stimuplex needle used.[19]

These findings were consistent with other studies like the one published by *Enneking et al., 2005*or the one by*Urmey 2006* which analysed that the problem with designated anatomical landmarks is that they are variable from patient to patient and do not always correlate with the location of the underlying nerve or plexus.

There was no incidence of significant bradycardia, hypotension, respiratory depression or desaturation and pneumothorax or hematoma formation in any of the patients of our study group.

Our study demonstrates that ultrasound guided brachial plexus block (when used alone or along with nerve stimulator) using supraclavicular approach are safer and more successful in comparison to when nerve stimulator alone is used in terms of:

1 Real-time needle visualization makes localisation of nerve bundles easier, safer and more accurate and local anaesthetic spread pattern during injection can be visualised in real time and manipulated to achieve a denser block.
2 Improves quality of sensory block and success rate and reduces no. of needle attempts for nerve localization.
3 Prevents accidental intravascular placement of drug and prevents intraneural inj of drug and overall leads to a reduced rate of complications.

Tables

Table-1: Patient Characteristics

		Group			
		U (n = 30)	**N (n = 30)**	**UN (n = 30)**	**p-value**
Age (Yrs)	Mean (± SD)	34.23 (± 15.26)	35.93 (± 16.34)	28.98 (± 15.36)	0.207
	Min-Max	7-72	13-78	3.5-64	
Sex	F (Count)	6	5	4	-
	M (Count)	24	25	26	-
Weight	Mean (± SD)	67.7 (± 13.46)	67.3 (± 12.03)	59.42 (± 21.96)	0.094

Volume of LA Mixture used Mean (± SD)	28.60 (± 3.68)	28.67 (± 2.60)	25.53 (± 7.11)	0.020

Table-2: Localising Time

Localising Time	**N**	**Mean**	**Std. Dev**	**p-value**	**p-value**		
					N Vs. U	**N Vs. UN**	**U Vs. UN**
Nerve Stimulator	30	10.57	8.79		< 0.001	-	-
Ultrasound	30	4.30	1.02	< 0.001	-	< 0.001	-
Ultrasound & Nerve Stimulator	30	4.60	0.81		-	-	1.000
Total	**90**	**6.49**	**5.84**				

Table-3: Start to Onset Time

Start-Onset Time	**N**	**Mean**	**Std. Dev**	**p-value**	**p-value**		
					N Vs. U	**N Vs. UN**	**U Vs. UN**
Nerve Stimulator	30	21.80	8.57		< 0.001	-	-
Ultrasound	30	14.27	0.78	< 0.001	-	< 0.001	-
Ultrasound & Nerve Stimulator	30	15.07	1.44		-	-	1.000
Total	**90**	**17.04**	**6.03**				

Table-4: Injection to Onset Time

Injection-Onset Time	**N**	**Mean**	**Std. Dev**	**p-value**	**p-value**		
					N Vs. U	**N Vs. UN**	**U Vs. UN**
Nerve Stimulator	30	8.63	0.93	< 0.001	< 0.001	-	-
Ultrasound	30	7.53	0.68		-	< 0.001	-
Ultrasound & Nerve Stimulator	30	7.80	0.76		-	-	0.595
Total	**90**	**7.99**	**0.92**				

FIGURE LEGENDS

Fig 1:CONSORT 2010 flow diagram
Fig 2:Mean Injection to Peak Time
Fig 3: Supplementation Required
Fig 4:Complications

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