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ORIGINAL ARTICLE

Assessment of the Learning Curve of Axillary Brachial Plexus Block by the Novice Trainee: A CUSUM Analysis

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ABSTRACT

Background and objective: The axillary brachial plexus block is one of the entry-level blocks suitable for novices. Studies about the minimum number of blocks required to achieve competency for neuraxial and epidural anaesthesia exist but data is astray for proficiency in an ultrasound-guided axillary brachial plexus block. The objective of this study was to quantify the number of blocks required by a novice to successfully perform an ultrasound-guided axillary brachial plexus block independently. In addition we aimed to identify the obstacles faced by novice during block performance which leads to its failure or the need for an intervention by an expert.

Methods: The novice trainee was given an introductory training on sono-anatomy of the axillary brachial plexus by an experienced anaesthetist. The trainee was instructed about criteria for failure and success at each procedure along with instruction to use the in-plane technique for axillary brachial plexus block. An ultrasound guided axillary brachial plexus block by multiple injection technique was performed. Whenever the expert anaesthesiologist realised any commitment error by the novice anaesthesiologist which could compromise the patient safety and could cause actual patient harm the procedure was taken over by the expert.

Results: A total of thirty-seven blocks were performed by single novice anaesthesiologist on patients who were scheduled to undergo axillary brachial plexus blocks for orthopaedic or plastic surgery of hand, wrist or forearm. Out of the thirty-seven cases 14 cases were categorized as failure since it required

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intervention by a supervisor whereas 23 cases were performed by novice independently. The trainee faced number of challenge such as (1) identification of sono-anatomy of brachial plexus at axilla, identification of radial nerve was reviewed to be the most difficult out of all structures with a difficulty of 16% in radial nerve, 10% in musculocutaneous nerve and 8% in both median and ulnar nerve. Other challenges include (2) needle guidance to the nerve, (3) difficulty in drug placement.

Conclusion: Attainment of proficiency in independently performing axillary brachial plexus blocks would require a minimum of 23 supervised blocks with main obstacle being identification of sono-anatomy of axilla.

KEYWORDS

• Axillary Brachial Plexus Block • Learning Curve • Cusum Analysis • Novice Trainee • Regional Anesthesia • Technical Skills Training

INTRODUCTION

Ultrasound-guided regional anesthesia has emerged as a rapidly growing sub-specialty of anesthesia with extensive literature attesting to its popularity within a short span. Despite so much information about the efficacy of various blocks, there is limited information about the challenges faced by novices while performing various blocks and their learning curves. In order to create appropriate training programs and feasible guidelines, more studies and trials are required to better elaborate the obstacles faced by beginners so as to achieve procedural competency.[1]

The axillary brachial plexus block is one of the entry-level blocks suitable for novices. An extensive literature search[2,3] provides statistics about the minimum number of blocks required to achieve competency for neuraxial and epidural anesthesia but data is however astray for proficiency in an ultrasound-guided axillary brachial plexus block.

Unlike nerve stimulator and landmark guided blocks, ultrasound guided blocks require knowledge of sono-anatomy, hand-eye coordination of the probe with holding of probe in tripod grip, acquisition of optimum ultrasound image, identification of intra-neural injections if any along with continuous visualization of tip of the needle and also the assessment of the motor and sensory function of various nerves before the surgery commences.[1,4]

The primary objective of this study was to quantify the number of blocks required by a novice to successfully perform an ultrasound-guided axillary brachial plexus block independently in patients undergoing hand, wrist and forearm orthopedic and plastic surgery.

The secondary aim was to identify the obstacles faced by novice during block performance which leads to its failure or the need for an intervention by an experienced anesthesiologist. This information could help formulate future guidelines for training in regional anesthesia.

In medicine practice, as competency of a trainee increases with time the supervision provided by the experienced doctor decreases. Hence, the study helps to define a decisive point in an objective manner beyond which the supervision can be withdrawn by the supervisor.[5]

METHODS

Study area: Sancheti Institute for Orthopedics and Rehabilitation, Pune, India.

Study population: The patients who presented to Sancheti Institute for Orthopedics and Rehabilitation during the study period and were undergoing upper limb orthopedic or plastic surgery using axillary brachial plexus block were included.

Study design: This was a prospective observational study.

Sample size: This pilot study involved 37 patients (who were eligible and underwent surgery during the study period). A convenience sample was used whenever the expert clinician was available for an axillary brachial plexus block.

Study duration: Approval was obtained from the hospital ethics committee during the study period of August 2022 to November 2022.

Inclusion criteria:

1. Patients who were ASA physical status 1–3.
2. Patients aged between 18–80 years and undergoing upper limb orthopedic or plastic surgery using axillary brachial plexus block.

Exclusion criteria:

1. Patients who had a history of allergy to local anaesthetics (LA).
2. Unwillingness for regional anaesthesia.

A newly joined trainee with no experience in performing ultrasound guided nerve blocks was recruited for the study. Before the study began, the novice trainee was given an introductory training on sono-anatomy of the axillary brachial plexus using didactics along with the demonstration of the steps and asepsis to be abided by an experienced anaesthetist. Training of needling techniques on blue phantom was also imparted.

Procedures were performed under an instructor's supervision (who had an experience of more than 10 years of regularly performing ultrasound-guided nerve blocks and was regularly teaching ultrasound-guided regional anesthesia in a clinical setting).

At the beginning of the study, the trainee was instructed about criteria for failure and success at each procedure. The block was defined as "successful" when given independently, without assistance from a senior anaesthesiologist and defined "failure" when block was taken over by an expert so as to ensure patient safety.

The trainee also recorded the effect of block. The effect of block was a 'success' when block required no supplemental analgesia. An 'adequate' block was defined as one only requiring supplementation with a dose of intravenous (IV) analgesic such as fentanyl. An 'inadequate' block was defined as one requiring other modes of anesthesia such as conversion to general anaesthesia, supplementation with lignocaine, administration of ketamine as judged by an expert clinician. The trainee was instructed to use the in-plane technique for axillary brachial plexus block. An informed consent was taken from the patient for the procedure of axillary brachial plexus block and from the trainee for participation in the study.

The patient was taken inside the operation theatre and all mandatory ASA monitors (blood pressure, electrocardiogram, pulse oximetry) were attached. A 20 G cannula was secured and Ringer lactate infusion was started. The patient was informed about the procedure and the axilla of the ipsilateral side which had to be operated was cleaned and draped with all aseptic precautions. An ultrasound probe was placed in the axilla receiving the brachial plexus block. All the procedures were done by the novice who was supervised by an expert (who had an experience of more than 5 years of regularly performing ultrasound-guided nerve blocks and was regularly teaching ultrasound-guided regional anesthesia in a clinical setting).

An ultrasound guided axillary brachial plexus by multiple injection technique was performed with the aim to individually target and block median, ulnar, radial and musculocutaneous nerves. Ten-fifteen mL of 0.5% bupivacaine and 10-15 mL of 2% lignocaine (5-7 mL per injection) were administered after a prior confirmation of correct placement using hydrodissecton and ruling out any blood aspirate.

The procedure of axillary brachial plexus block was discontinued whenever patient experienced pain on injection, if at any moment it was anticipated to cause harm or deemed necessary for patient safety and patient care, and on patients' request.

At any point when the expert anaesthesiologist realised any commitment of a critical error by the novice anaesthesiologist which could compromise the patient safety and had the potential to cause actual patient harm (such as inadvertent intraneural or intravascular needle placement), the procedure was taken over by the expert. We defined the block as successful when given independently, without assistance from a senior anesthesiologist and defined failure when block was taken over by expert. The primary outcome was the procedural attempts required to attain proficiency in performing independent ultrasound guided axillary brachial plexus block.

To assess the proficiency, we recorded the time to sensory block, time to motor block and effect of block (successful, adequate or inadequate). The secondary outcome measurement was obstacles faced by trainee which required expert intervention. This was assessed by requirement of rescue analgesia, conversion to general anaesthesia, supplementation with local anaesthetic (lignocaine), difficulty in needle guidance, difficulty in identification of anatomy.

STATISTICAL ANALYSIS

Data was summarized as medians (interquartile range) for continuous variables and frequencies (percentage) for categorical variables. Evaluation between the association between categorical variables was done using the Fisher's exact test or the chi-square test as appropriate, while the Wilcoxon rank-sum test was used for continuous variables. Assumption of normality was tested using the Shapiro-Wilk test.

To assess the number of procedural attempts required to attain proficiency in performing independent USG-guided axillary brachial plexus block, we decided to perform a CUSUM (cumulative sum) analysis.[6]

To calculate the control limit, we set the odds multiplier at a value of 2, for 10000 simulations, and a 5% probability of accepting a false signal. Competency is achieved when the trend line crosses the control limit downwards, and competency is lost when the trend line crosses the control limit upwards.

p-values less than 0.05 were considered to be statistically significant. Data were analyzed using R, version 4.2.2 using the package 'cusum'.[7]

RESULTS

Study population: Thirty-seven patients who were scheduled to undergo axillary brachial plexus blocks for orthopedic or plastic surgery involving either hand, wrist or forearm were recruited for the study. Block was given by a single novice anesthesiologist at a tertiary care teaching institute, who had no previous experience of USG guided axillary brachial plexus block.

The median age of the recruited patients was 38 years (IQR: 32 – 49). Eighty-four percent patients were males, and sixteen percent patients were females.

Procedure details: Details regarding information about volume of anesthetic used, adjuvant anesthesia or analgesic used, time to sensory block, time to motor block and difficulties experienced by the anesthesiologist are described in *Table 1*. Overall, the block was unsuccessful in 14 (38%) patients out of which first five blocks failed as a result of difficulty in identification of anatomy, six blocks failed due to inability to guide the needle towards the radial nerve and rest three blocks failed due to presence of multiple vascular structures in vicinity of the nerve plexus, thus causing abandonment of procedure to prevent accidental intravascular needle placement.

Out of the first 10 blocks, all 10 blocks failed and required guidance and intervention by expert. In the next 10 blocks, only 2 blocks required guidance. Similarly, 2 blocks required assistance from 21st to 30th case and beyond 31st case no block required guidance by expert.

Table 1: Population and procedure related characteristics

Characteristic	N = 37
Age, Median (IQR)	38 (32 – 49)
Sex, n (%)	
Female	6 (16)
Male	31 (84)
Number of vascular structures, n (%)	
2	22 (59)
3	13 (35)
4	2 (5.4)
Needle-Nerve contact, n (%)	2 (5.4)
Paresthesia, n (%)	2 (5.4)
Median nerve LA volume, Median (IQR)	5.00 (5.00-5.00)
Ulnar nerve LA volume, Median (IQR)	5.00 (5.00-5.00)
Radial nerve LA volume, Median (IQR)	10.00 (10.00-10.00)
Musculocutaneous nerve LA volume, Median (IQR)	5.00 (5.00-5.00)
Time to sensory blockade, Median (IQR)	18.0 (15.0-20.0)
Time to motor blockade, Median (IQR)	23.5 (20.0-30.0)
Time to incision, Median (IQR)	30 (25-40)

IQR: interquartile range
LA: Local anaesthetic
N: number

Table 2: Analgesia Outcomes

Parameter	n (%)
Block effect	
Adequate	15 (41)
Inadequate	5 (14)
Successful	17 (46)
Rescue analgesia, n (%)	
Paracetamol /Diclofenac	37 (100)
Fentanyl, n (%)	16 (43)
Dose of fentanyl (mcg), n (%)	
25	3 (19)
50	13 (81)
Local lignocaine, n (%)	1 (2.7)
Ketamine, n (%)	2 (5.4)
Dose of ketamine (mg), n (%)	
15	2 (100)
General anaesthesia, n (%)	1 (2.7)
Difficulty experienced, n (%)	
Drug placement	1 (5.0)
Identification of anatomy	7 (35)
Inadequate blockage	2 (10)
Multiple vascular structures in vicinity	2 (10)
Needle guidance	7 (35)
Time to needle placement	1 (5.0)
Failures, n (%)	14 (38)
Remarks, n (%)	
Converted to general anaesthesia	1 (25)
Intravascular needle placement	2 (50)
Supplementation with lignocaine locally	1 (25)

LA – Local anaesthetic
IQR – Interquartile Range

CUSUM Analysis:

Figure 1 illustrates the CUSUM graph for the anesthesiologist. The blue line indicates the limit calculated from the CUSUM analysis. Yellow points indicate the procedures where competency is not yet achieved according to the limit set. An upward trend reflects failures while a downward trend reflects successes. Competency is said to be achieved when the trend line falls below the set limit. The results of the CUSUM analysis suggest that 27 attempts were required to achieve competency in giving USG-guided brachial plexus blocks in a novice anesthesiologist. After the 23rd attempt, no further failure was experienced while administering the blocks. and beyond this 14 blocks were given by novice independently.

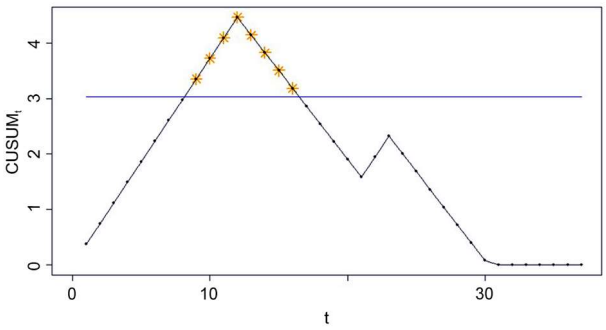

Figure 1: CUSUM graph for competency analysis for USG-guided brachial plexus blocks

Factors associated with failure:

Associations between success of block and various patient-related and procedure-related parameters is provided in *Table 3*.

Table 3: Associations of population and procedure related characteristics with successful or failed blocks

Characteristic	Success, N = 23	Failure, N = 14	p-value
Age, Median (IQR)	41 (32-53)	38 (28-41)	0.42
Sex, n (%)			>0.99
F	4 (17)	2 (14)	
M	19 (83)	12 (86)	
Number of vascular structures, n (%)			0.87
2	13 (57)	9 (64)	
3	9 (39)	4 (29)	
4	1 (4.3)	1 (7.1)	
Needle-Nerve contact, n %	1 (4.3)	1 (7.1)	>0.99
Time to sensory blockade, Median (IQR)	15.0 (15.0-20.0)	20.0 (16.0-20.0)	0.20
Time to motor blockade, Median (IQR)	25.0 (20.0-30.0)	22.0 (20.0-25.0)	0.62
Time to incision, Median (IQR)	30 (25 – 40)	32 (29 – 40)	0.90
Effect of block, n (%)			0.008*
Adequate	6 (26)	9 (64)	
Inadequate	2 (8.7)	3 (21)	
Successful	15 (65)	2 (14)	
Rescue analgesia, n (%)			
Paracetamol/Diclofenac	23 (100)	14 (100)	
Fentanyl, n (%)	6 (26)	10 (71)	0.007*
Dose of fentanyl (mcg), n %			0.036*
25	3 (50)	0 (0)	
50	3 (50)	10 (100)	

table cont....

Characteristic	Success, N = 23	Failure, N = 14	p-value
Difficulty experienced, n %			0.16
Drug placement	0 (0)	1 (7.7)	
Identification of anatomy	2 (29)	5 (38)	
Inadequate blockage	2 (29)	0 (0)	
Multiple vascular structures in vicinity	1 (14)	1 (7.7)	
Needle guidance	1 (14)	6 (46)	
Time to needle placement	1 (14)	0 (0)	
Remarks, n (%)			>0.99
Converted to GA	1 (33)	0 (0)	
Intravascular needle placement	1 (33)	1 (100)	
Supplementation with lignocaine locally	1 (33)	0 (0)	

Wilcoxon rank sum test; Fisher's exact test; Pearson's Chi-squared test[1]

DISCUSSION

Clinicians in every field need exercising of their skills, although standardization in terms of methodologies as well as institutional practices may vary remarkably.[8] Wright coined the term "learning curve" which is customarily applied in medical practice for acquisition of skills by a novice whilst it was originally coined for airplane manufacture workers' productivity. This was based on the concept that if the same procedure is repeated over and over, the worker's efficiency improves and time taken declines. Even though we do use the term 'learning curve' in medicine practice, but the intention is to refine the quality of result instead of saving time and effort.[9]

Over the years, various studies have defined procedural competency in anesthetic practice for venous access, epidurals, spinals, and orotracheal intubations,[2,10] our goal was to define similar constituents which enhance skills in ultrasound guided regional anesthesia in novice.

We tried to define a number for procedural competency in a beginner anesthetist with no prior knowledge of ultrasound guided axillary brachial plexus block along with the aim to delineate the hurdles faced by beginner.

Thirty seven cases were performed, out of which 14 cases were categorized as failure since it required intervention by a supervisor whereas 23 cases were performed by novice independently.

The first 15 cases of study were marked by intervention by expert as the trainee faced number of challenge the foremost being identification of sono-anatomy of brachial plexus at axilla. The identification of radial nerve was reviewed to be the most difficult out of all structures with a difficulty of 16% in radial nerve, 10% in musculocutaneous nerve and 8% in both median and ulnar nerve.

The second challenge was needle guidance to the nerve, when the tip of needle could not be visualized. This observation was consistent with the observations made by Sites *et al*[1] as an error commonly performed by novice. Sites *et al* reported an error of 43.7% during needle advancement whereas our study reported an error of 18.9% during needle guidance to the nerve. Needle advancement without visualization of tip may cause injury to structures in vicinity such as axillary artery or intra-neural injections but no such cases were reported as the procedure was taken over by the expert.

The third challenge faced by novice was difficulty in drug placement primarily due to two reasons poor ergonomics and involuntary probe movements. Despite an earlier training about the correct ergonomics, novice faced challenge in the efficient and most user-friendly positioning of the ultrasound probe in the beginning of the study, which progressively improved as the study gathered momentum.

The effect of block was inadequate in some cases (both independent and expert intervened), supplementation with intravenous ketamine or local application of lignocaine was carried out. One out of 37 cases required conversion to general anaesthesia as patient complained of pain due to inadequate blockage of musculocutaneous nerve as a result of aberrant anatomy which was later scanned in detail by the expert anaesthetist.

Two cases reportedly had intravascular positioning of needle, as the novice faced difficulty in needle guidance to target nerves in case of multiple vascular structures in vicinity and inability to visualize needle tip during advancement, therefore, taken over by expert.

From the study, we could deduce that a minimum number of 23 cases were required by a novice anesthetist to successfully perform USG guided axillary brachial plexus block independently.

There are several limitations to the study which we would like to address. First, there was no video recording of the procedure being performed which could have helped us to improve on the ergonomics in future cases. Second, there are no data of time taken by novice to complete the procedure which may help to suggest the procedural competency as time taken to perform axillary brachial plexus block decreases with improvement in efficiency. Third, no out of plane blocks were performed which could have enlightened new errors, challenges and acquisition of additional skills by novice anesthetist.

Fourth limitation was not to compare multiple novice anesthetist for same block and average the time taken to achieve competency.

For a novice to achieve procedural competency few parameters need to be worked upon 1) needle tip visualization during advancement 2) optimal ergonomics 3) minimal involuntary movement of ultrasound probe 4) knowledge-based practice.

In future, more such studies on various other blocks such as femoral nerve, supraclavicular brachial plexus and interscalene block etc. could be performed by novice. Standardized guidelines for beginners in regional anesthesia can be formulated and training programs can be launched.

To conclude, for attaining proficiency in independently performing axillary brachial plexus blocks, 23 supervised blocks would be required to be performed. Main hindrance in successful performance of blocks was understanding the sono-anatomy. Hence, more didactic and volunteer-based training are needed.

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