Supraclavicular Brachial Plexus Block In the Creation of Arteriovenous Fistula: A Study On Microcirculatory Changes

DR KHAIRUL IQAAN BIN LUQMAN

UNIVERSITI SAINS MALAYSIA

2016

Supraclavicular Brachial Plexus Block In the Creation of Arteriovenous Fistula: A Study On Microcirculatory Changes

By

DR KHAIRUL IQAAN BIN LUQMAN

UNIVERSITI SAINS MALAYSIA

Dissertation submitted in partial fulfillment of the requirement for the Degree of Master of Medicine (Anaesthesiology)

2016

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious, the Most Merciful

"The best way to become a successful writer is to read good writing, remember it, and then forget where you remember it from." – Gene Fowler

First of all, I would like to thank Allah Almighty for His blessings and for all the achievements in my life.

I take this opportunity to express my deep sense of gratitude and indebtedness to my respected main supervisor **Prof. Madya Dr Saedah Ali** and my co-supervisors **Dr Arman Zaharil Mat Saad** from Plastic and Reconstructive Surgery (PRS) Department, **Professor Dr Aida Hanum Ghulam Rasool** from Pharmacology Department and **Dr Laila Abdul Mukmin** for their kind supervision, valuable opinions and gaudiness, generous advices, excellent comments and continuous encouragement.

Thank you to School of Medical Sciences (PPSP), Universiti Sains Malaysia, especially to the Dean, Professor Dr Ahmad Sukari Halim, and Deputy Dean for their persuasion and supports throughout my studies.

I wish to thank Dr Azriani Ab. Rahman for her great help in biostatistics.

Most of all, my warm and special thanks to my beloved father Luqman Mahmood, and my sincere mother, Nik Fatimah Nik Ismail for their overwhelming motivation and heartening inspiration.

My grateful thanks and dedication to my wife, Nik Shah Hizan Nik Lah for her support, patience and companionship.

Last but not least, to my beloved daughter, Ainul Mardhiyyah and son, Muhammad Hafiz, for being the sunshine of my life.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMNS

- ACEI — Angiotensin Converting Enzyme Inhibitor drugs
- ACTH — Adrenocorticotrophic Hormone
- AFI — Awake Fiber Optic Intubation
- ASA — American Society of Anaesthesiologists
- AU — Arbitrary Unit
- AUC — Area Under Curve
- AXB — Axillary Nerve Block
- AVF — Arteriovenous Fistula
- acf — Photocurrent Autocorrelation Function
- BMI — Body Mass Index
- BP — Blood Pressure
- BPB — Brachial Plexus Block
- cAMP — Cyclic AMP
- CABG — Coronary Artery Bypass Graft
- CKD — Chronic Kidney Disease
- CL — Clearance
- Cmax — Concentration Maximum
- dc — Dual-channel
- FDA — Food and Drugs Administrations
- G — Gauge
- GA — General Anaesthesia
- GFR — Glomerular Filtration Rate
- HD — Haemodialysis

- HR Heart Rate
- HUSM Hospital Universiti Sains Malaysia
- ICP Intra Cranial Pressure
- IGVR Inspiratory Gap Vasoconstrictive Response
- ISB Inter Scalene Block
- LA Local Anaesthetic
- LDF Laser Doppler Fluximetry
- LDI Laser Doppler Imager
- LDV Laser Doppler Velocimetry
- MAC Monitored Anaesthesia Care
- MAP Mean Arterial Pressure
- MRI Magnetic Resonance Imaging
- mA Miliamphere
- mg Miligram
- ms Miliseconds
- mV Milivolts
- µcg/kg Microgram per Kilogram
- MHz Mega Hertz
- MPAP Mean Pulmonary Arterial Pressure
- NIBP Non-invasive Blood Pressure
- NSAID Non-Steroidal Anti-inflammatory Drugs
- OT Operation Theatre
- PNS Peripheral Nerve Stimulation
- PCWP Pulmonary Capillary Wedge Pressure

- PPG Photopulse Plethysmography
- PRS Plastic and Reconstructive Surgery
- PVRI Pulmonary Vascular Resistant Index
- PWD Pulsed-wave Doppler
- PVD Peripheral Vascular Disease
- RBC Red Blood Cell
- RR Recovery Room
- RRT Renal Replacement Therapy
- RSI Rapid Sequence Induction
- SkBF Skin Blood Flow
- SpO_2 Saturation of Oxygen
- SVRI Systemic Vascular Resistant Index
- TENS Transcutaneous Electrical Nerve Stimulation
- TPR Total Peripheral Resistance
- $t_{1/2}$ Half Life
- US Ultrasound
- USM Universiti Sains Malaysia
- °C Degree Celcius

Penggunaan Teknik Supraklavikular Dalam Pembiusan Brachial Pleksus Bagi Pembedahan Arteri-vena Fistula: Kajian Perubahan Pada Aliran Darah Mikro (*Microcirculation*)

ABSTRAK

Latar Belakang

Pembiusan brachial pleksus (BPB) dengan teknik supraklavikular menyebabkan vasodilatasi dan peningkatan dalam aliran darah yang menyebabkan peningkatan perfusi kulit dan suhu untuk lengan.yang dibius. Walau bagaimanapun, tiada laporan komprehensif yang menilai perubahan peredaran darah mikro (*microcirculation*) ini selepas supraklavikular BPB diberikan.

Objektif

Untuk membandingkan perubahan perfusi kulit sebelum dan selepas supraklavicular BPB dan untuk membandingkan perubahan suhu sebelum dan selepas supraklavicular BPB.

Kaedah

Tiga puluh dua orang dewasa yang mengalami kegagalan buah pinggang kronik dijadualkan untuk pembedahan arteri-vena fistula (AVF) dikaji dalam satu kaijan prospektif cross sectional. Supraklavikular BPB dilakukan dengan menggunakan mesin ultrasound. Pembiusan diberi dengan menggunakan ubat levobupivacaine 0.5%

sebanyak 20 ml. Perfusi kulit (AU) dan suhu (°C) kedua-dua lengan dicatatkan setiap 5 minit selama 15 minit sebelum blok dan dibandingkan pasca blok. Pemerhatian diteruskan selama 15 minit pasca blok dan dicatat setiap 5 minit. Untuk perbandingan perfusi kulit dan suhu antara lengan kanan dan kiri, sepuluh orang dewasa yang sihat telah diambil bagi kumpulan kawalan dan perfusi kulit dan suhu kedua-dua lengan diperhatikan selama 15 minit. Kedua-dua perfusi kulit dan suhu dirakam menggunakan mesin Laser Doppler Fluximetry (LDF) pada kedua-dua kumpulan.

Keputusan

Pada kumpulan yang dikaji,terdapat perbezaan yang signifikan pada perfusi kulit di lengan yang dibius (12.80 ± 4.89; P<0.05), tetapi tidak pada lengan bersebelahan (6.25 ± 2.35; P=0.306), sebelum dan selepas supraklavikular BPB diberikan.. Terdapat peningkatan sebanyak 5.46 ± 4.10AU di lengan yang dibius. Manakala bagi lengan yang bersebelahan, peningkatan tidak ketara (0.19 ± 1.04AU). Terdapat perbezaan yang signifikan pada perubahan suhu kulit pada kedua-dua lengan yang dibius dan lengan bersebelahan pada kumpulan kajian sebelum dan selepas supraklavikular BPB. Terdapat peningkatan suhu kulit pada lengan yang dibius (33.36 ± 3.01; P=0.004), dan pada lengan bersebelahan (32.16 ± 1.49; P=0.014) selepas supraklavikular BPB diberikan. Dari segi perubahan hemodinamik, semua pesakit tidak menunjukkan sebarang perubahan yang ketara (tekanan darah sistolik, 153.49 ± 8.34, P=0.061; tekanan darah diastolik, 74.89 ± 8.34, P=0.953; kadar denyut jantung, 74 ± 12, P=0.327). Pada kumpulan kawalan, tidak ada perbezaan yang signifikan di antara tangan kanan dan tangan kiri ketika perfusi kulit dan suhu dirakamkan (perfusi kulit, 10.42 ± 2.45, P=0.597; suhu kulit, 27.79 ± 1.01, P=0.896).

Kesimpulan

Selepas supraclavicular BPB, perubahan peredaran aliran darah mikro (microcirculation) yang berlaku adalah peningkatan dalam perfusi kulit dan peningkatan suhu kulit tanpa menjejaskan parameter hemodinamik (stabil).

Kata kunci: Pembiusan brachial pleksus secara teknik supraklavikular (SBPB), arteri-vena fistula (AVF), tahap akhir kegagalan buah pinggang (ESRF), Laser Doppler Fluximetry (LDF)

Supraclavicular Brachial Plexus Block In the Creation of Arteriovenous Fistula: A Study On Microcirculatory Changes

ABSTRACT

Background

Supraclavicular brachial plexus block (BPB) causes vasodilatation and an increase in blood flow, hence increase the skin perfusion and temperature to the ipsilateral upper limb. However, no reports have comprehensively evaluated these microcirculatory changes after a BPB.

Objectives

To compare the skin perfusion changes before and after supraclavicular BPB and to compare the temperature changes before and after supraclavicular BPB.

Methodology

Thirty two adult patients with chronic renal failure scheduled for AVF surgery were studied in a prospective cross sectional study design. The supraclavicular BPB was performed under ultrasound guidance using 20 mls of levobupivacaine 0.5%. The skin perfusion (AU) and temperature (°C) of both arms were recorded every 5 minutes for 15 minutes pre-block and compared post-block for another 15 minutes, recorded every 5 minutes. To avoid bias, ten healthy adults were recruited for control group and both perfusion and skin temperature of both arms were recorded for 15 minutes. Both skin

perfusion and temperature were recorded using Laser Doppler Fluximetry (LDF) machine in both groups.

Result

There is a significant difference found between skin perfusion value in anaesthetized arm of studied group (*12.80 ± 4.89; $P<0.05$*), but not the contralateral arm (*6.25 ± 2.35; $P=0.306$*), before and after a supraclavicular brachial plexus block. There is an increment of 5.46 ± 4.10 AU in the anaesthetized arm, post block. Whereas for the contralateral arm, the increment post block was not significant (0.19 ± 1.04 AU). There is a significant difference found between skin temperature changes in both anaesthetized and contralateral arms of studied group before and after a supraclavicular brachial plexus block. There is an increase in skin temperature in anaesthetized arm (*33.36 ± 3.01; $P=0.004$*), as well as contralateral arm (*32.16 ± 1.49; $P=0.014$*) of studied group after a supraclavicular brachial plexus block. There were no significant haemodynamic changes post block in all patients (Systolic blood pressure, *153.49 ± 8.34*, *$P=0.061$*; diastolic blood pressure, *74.89 ± 8.34*, *$P=0.953$*; heart rate, *74 ± 12*, *$P=0.327$*). In the control group, there is no significant difference between right arm and left arm in term of skin perfusion and temperature (*10.42 ± 2.45, $P=0.597$* and *27.79 ± 1.01, $P=0.896$* for skin perfusion and temperature, respectively).

Conclusion

Microcirculatory changes that occur after supraclavicular BPB include an increase in skin perfusion and an increase in temperature with stable hemodynamic parameters.

Keywords: *Supraclavicular Brachial Plexus Block, Arteriovenous Fistula (AVF), End Stage Renal Failure (ESRF), Laser Doppler Fluximetry (LDF), Arbitrary Unit (AU)*

CHAPTER 1

INTRODUCTION

It is undeniable nowadays that regional anaesthesia for upper extremity surgery has gained its reputation following undisputable discovery by Dr William Stewart Halsted and his aide Dr Richard Hall regarding the technique for blocking the inferior alveolar nerve and the antero-superior dental nerve using cocaine as an anaesthetic in 1884 (Mian et al., 2014). The complex combination of minimal systemic impairment and excellent pain reduction as well as immobilization for better surgical outcome are all additional points for providing regional anaesthesia for upper extremity surgery. Nevertheless, the anatomy of the upper extremity is well suited for the local anaesthetic blockade and with its single accessible plexus of nerves is associated with predictable landmarks which innervate the entire arms.

Dense anaesthesia following successful blockade and it is completely isolated to the peripheral site where the surgeon is going to perform the surgery. With all the anaesthesia effects, hence it will give a successful surgery and the chain reaction would be multibeneficial; minimize the surgery costs, minimize operating time and encourage faster healing by early ambulatory post-operatively.

The supraclavicular approach of brachial plexus block is more popular among the anaesthetist is due to the fact that this method can produce most complete and reliable anaesthesia for the upper limb surgery. As it is performed at the trunk level of the brachial plexus, it provides complete and reliable anesthesia to the patient because this area have a compactly dense nerve bundles. The technique also can be performed with the patient's arm in any position to provide good anesthesia for the entire arm with good anesthesia and analgesia for the preoperative period and also serve as a better and prolonged analgesia post-operatively (Alan Mcfarlane, 2009)

The use of ultrasound for nerve block was first reported by La Grange and colleagues in 1978, who performed supraclavicular brachial plexus blocks with the help of a Doppler ultrasound blood-flow detector (La Grange, Foster, & Pretorius, 1978). These early reports did not have much clinical impact because the scope for visualizing anatomical structures by ultrasound was still limited. It was confined to identifying vessels by Doppler ultrasound. Over the past 10 years, however, dramatic progress has been made. The latest ultrasound images obtained for regional anaesthesia have come a long way compared with several years ago (P Marhofer, Greher, and Kapral, 2005).

Nerves are not blocked by the needle but by the local anaesthetic. The traditional guidance techniques used in regional anaesthesia have consistently failed to meet this perfectly logical requirement. 'Blind' blocks that rely solely on anatomical landmarks and/or fascia clicks (e.g. ilioinguinal nerve blocks) are known to produce serious complications. Even the technique of nerve stimulation which has been recommended as the gold standard for nerve identification in regional anaesthesia over the past decade fails to ensure an adequate level of nerve block (e.g. in axillary brachial plexus blocks). In addition, it carries a risk of inflicting damage to nerve structures by direct puncture. Before the advent of ultrasound in regional anaesthesia, it was impossible to verify precisely where the needle tip was located relative to the nerves and how the local anaesthetic was distributed. Ultrasound visualization of anatomical structures is the only method offering safe blocks of superior quality by optimal needle positioning. In addition, the amount of local anaesthetic needed for effective nerve block can be minimized by directly monitoring its distribution (Peter Marhofer et al., 1998).

There are several studies that evaluate the effects of regional sympathetic blockade through the assessment of regional skin perfusion. Valley, M. A. et al in 1993 used laser Doppler flowmetry to monitor cutaneous perfusion of the foot and the reflex vasoconstrictive response to deep inspiration (IGVR) after the commencement of epidural local anesthetic test and bolus doses in 11 patients. The study confirmed that sympathetic block precedes sensory block in sacral dermatomes after epidural anaesthesia. Perfusion and IGVR (inspiratory gap vasoconstrictive response) changes are sensitive measures of sympathetic blockade and may predict successful epidural catheter placement (Valley, Bourke, Hamill, and Raja, 1993).

Steven M. Frank et al in 2000 evaluated the rate and magnitude of cutaneous temperature change in the distal lower extremity after lumbar sympathetic blockade and epidural anaesthesia. They concluded either technique should provide adequate sympathectomy (Frank, El-Rahmany, Tran, Vu, and Raja, 2000). Another study done in February 2012 by Manoj Karmakar et al showed an increase in blood flow velocity, change in the morphology of the pulsed-wave Doppler (PWD) spectral waveform, arterial vasodilatation and an increase in blood flow through the ipsilatertal brachial artery after an axillary BPB. The BPB was done under ultrasound guided and the regional hemodynamic parameters were measured using PWD ultrasound together with the skin temperature, which also showed a significant increment in eight healthy adult patients scheduled for elective hand surgery (Li, Karmakar, Li, Kwok, and Kee, 2012).

However, no reports have comprehensively evaluated the regional hemodynamic changes such as microcirculatory changes and skin temperature changes using a non-invasive technique despite ultrasound after supraclavicular brachial plexus block. The thinking towards getting an instrument which is accurate, valid and reliable as well as convenient to the patients (non-invasive) to measure all these parameters giving the idea to manipulate the Laser Doppler Fluximetry (LDF). This is a non-invasive device which is widely used as clinical and research tool for assessment of microvascular perfusion. In research, it has been used to study reflex control of cutaneous blood flow, and, in conjunction with other techniques (iontophoresis, microdialysis, and local warming and heating) to address the involvement of the endothelium in the local control of skin blood flow (SkBF). Furthermore, the responses to drugs can be evaluated with respect to their local effect on skin microcirculation. Its use goes far beyond research purposes as it has currently also been used in clinical practice either as part of the diagnostic procedures or to follow the effectiveness of treatment (Lenasi, 2011).

CHAPTER 2

LITERATURE REVIEW

2.1 Brachial Plexus

2.1.1 Anatomy

In order to facilitate the technical aspect of performing upper extremity regional anaesthesia and to optimize the patient-specific block selection, detail knowledge of the brachial plexus anatomy is very essential.

The outermost layer of the peripheral nerve is an epinerium. It is made of loose connective tissue which is in a continuous at the intervertebral foramen with the dura of the nerve root. This inert supporting tissue contain an axons which are then been groups together to become a fascicles by the surrounding sheath of perineum. The endoneurium therefore, serve as the connecting tissue between the axons and the fascicles. The perineurium is important in the controlling the endoneural milieu in the same fashion as the pia-arachnoid does for the central nervous system. This perineurium is made of multiple layers of the metabolically active epithelium. The endothelium of the endoneural vessels and the perineurium they together served as a ‘blood-nerve barrier’ for the fascicles (Shanthaveerappa and Bourne, 1966).

2.1.2 Formation of the Plexus

The plexus is formed by the anterior primary rami of C5–8, to T1. Sometimes, there is a contributions above from C4 and from T2 do occurred. The five *roots* of the plexus emerge from the intervertebral foramina. Each of those from C5, 6 and 7 passes behind the foramen transversarium of its respective cervical vertebra with its contained vertebral vessels, then lies in the gutter between the anterior and posterior tubercles of the corresponding transverse process.

All five roots then become sandwiched between scalenus anterior and medius. At this point, the roots of C5 and 6 unite into the *upper trunk*, the root of C7 continues as the *middle trunk* and those of C8 and T1 link into the *lower trunk*. As the roots of the brachial plexus emerge in the groove between the anterior and posterior tubercles of the transverse processes of the cervical vertebrae, they lie in a fibro-fatty space between two sheaths of fibrous tissue. The posterior part of the sheath arises from the posterior tubercles and covers the front of scalenus medius; the anterior part arises from the anterior tubercles and covers the posterior aspect of scalenus anterior.

Laterally, the sheath extends as a covering around the brachial plexus as this emerges into the axilla. The significance of this space to the anaesthetist is that it forms a sheath around the brachial plexus into which local anaesthetic can be injected to produce a brachial plexus block. The interscalene brachial plexus block technique therefore targets the *trunks* of the brachial plexus as they pass between the scalene muscles.

The sheath is, conceptually at least, continuous as far as the axilla and forms the theoretical basis of single-shot brachial plexus blocks, in that the local anaesthetic should be contained by the sheath, thereby acting on all the nerves within the sheath at that level. The three trunks emerge from between the scalenus muscles and pass in a closely grouped cluster downwards and laterally across the base of the posterior triangle and then across the 1st rib. At this point, variety of nerve block approaches can be performed that include the supraclavicular, intersternocleidomastoid and subclavian perivascular techniques. At the lateral border of the 1st rib, behind the clavicle, each trunk divides into an anterior and posterior *division*.

The six divisions stream into the axilla and there join up into three *cords*, lateral, medial and posterior, named after the relationship they bear to the axillary artery. Between the 1st rib and axilla, a variety of brachial plexus blocks have been described namely infraclavicular, vertical and coracoids approach.

2.1.3 The Cords Composition

The cords are composed as follows:

a. The *lateral cord* is formed by the union of the anterior divisions of the upper and middle trunks.

b. The *medial cord* represents the continuation of the anterior division of the lower trunk.

c. The *posterior cord* comprises all three posterior divisions.

The lateral and medial cords give off, respectively, the lateral and medial heads of the median nerve at the lateral border of pectoralis minor, beyond which the cords end in their terminal branches at lateral cord becomes the musculocutaneous nerve, the medial cord the ulnar nerve and the posterior cord the radial and axillary nerves.

2.1.4 The Summary of Brachial Plexus Composition

The composition of the brachial plexus can be summarized thus:

i. Five roots (between the scalene muscles) the anterior primary rami of C5–8 and T1.

ii. Three trunks (in the posterior triangle):

(a) *upper*, C5 and 6;

(b) *middle*, C7 alone;

(c) *lower*, C8 and T1.

iii. Six divisions (behind the clavicle) each trunk divides into an anterior and posterior division.

iv. Three cords (within the axilla):

a. *lateral*, the fused anterior divisions of upper and middle trunks (C5–7);

b. *medial*, the anterior division of the lower trunk (C8, T1);

c. *posterior*, formed by the union of the posterior divisions of all three trunks (C5–T1).

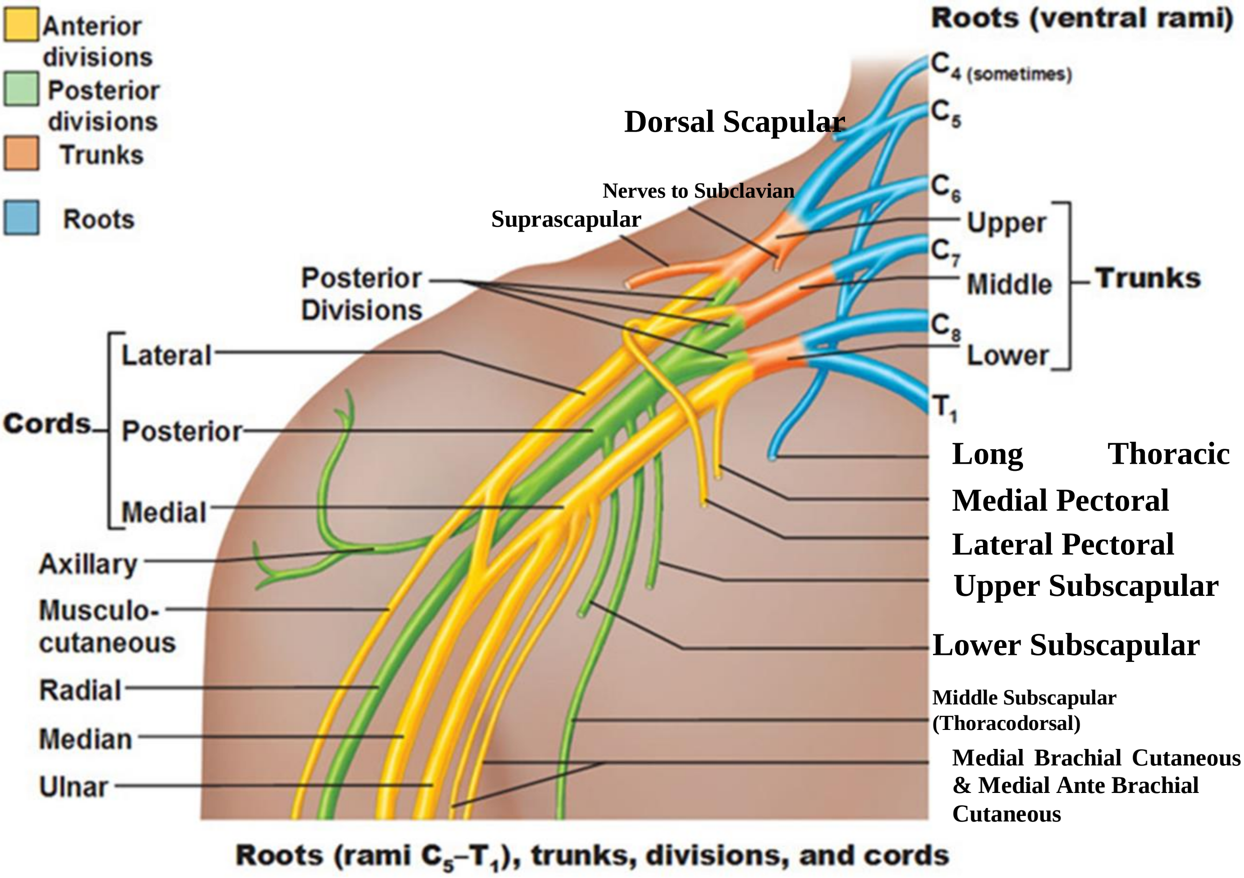

Figure 2.1 Brachial Plexus Anatomy (http://antranik.org/wp-content/uploads/2011/11/roots-trunks-divisions-cords-organization-of-brachial-plexus.jpg, 2011)

2.1.5 Axillary Sheath

The axillary sheath is a collection of connective tissue surrounding the neurovascular structures of the brachial plexus. It is a continuation of the prevertebral fascia separating the anterior and middle scalene muscles. Initially, the descriptions of the sheath is considered be a dense tubular structure extending from above the first rib to a point distal in the axilla where it is fused with the anterior surface of the medial intermuscular septum (De Jong, 1960).

It was also believed that within the sheath, the axillary vessels and nerves were all lying loose within its center. Due to this arrangement, the authors concluded that conduction anesthesia of the upper extremity could be performed with a single injection at any site along the sheath, with local anesthetic volume being the primary determinant for successful block (Winnie and Collins, 1964).

A few years later, several investigators had challenged the concept of a tubular axillary sheath. They proposed that instead the sheath is a multi-compartmental structure formed by thin layers of fibrous tissue surrounding the plexus in filmy membranes. The membrane also extended inward to create discrete fascial septae (G. Thompson and Rorie, 1983). They concluded that the nerves are arranged in a complicated manner in this tissue rather than lying separate and distinct. As a result of this enmesh arrangement, individual fascial compartments are created for each nerve and define the anatomic limits for that neural structure (Partridge, Katz, and Benirschke, 1987).

Therefore, the compartments could functionally limit the circumferential spread of injected solutions and there is a need of separate injections into each of the compartment in order to achieve maximal nerve blockade. Benhamou in 2001 stated in his review articles regards to brachial plexus block also support the conclusion that the sheath is not a single compartment. For instance, the relative successfulness of multiple stimulation/injection axillary block techniques (Benhamou, 2001). The failure of single-injection interscalene blocks as describe by Golberg *et al*., 1987 (Goldberg et al., 1987) and, single-paresthesia axillary blocks by Baranoswsky *et al*., 1990 further supported the latter statement (Baranowski and Pither, 1990).

2.1.6 Sensory Innervation of Arm

Besides knowing the anatomy of the brachial plexus, knowledge of the sensory and motor innervation of the upper extremity is clinically crucial for performing brachial plexus blockade. It will determine which cutaneous nerve distributions within a surgical field that are require to block, which terminal nerve branches require supplementation for an inadequate block, and helps to document the existence and distribution of pre- and postoperative neurologic deficits.

Sympathetic nerve block produced by the regional technique results in increased blood flow to skin and muscle. This phenomenon is more pronounced as one move distally along the arm and increases hand blood flow by 296% compared with 132% with stellate ganglion block (Cross and Porter, 1988).

The cutaneous nerves of the upper extremity are a collection of neural fibers that originate from a variety of spinal cord segments and assigning cutaneous territory to a specific peripheral nerve neither inconsistent, nor not impossible to locate it (Figure2-2).

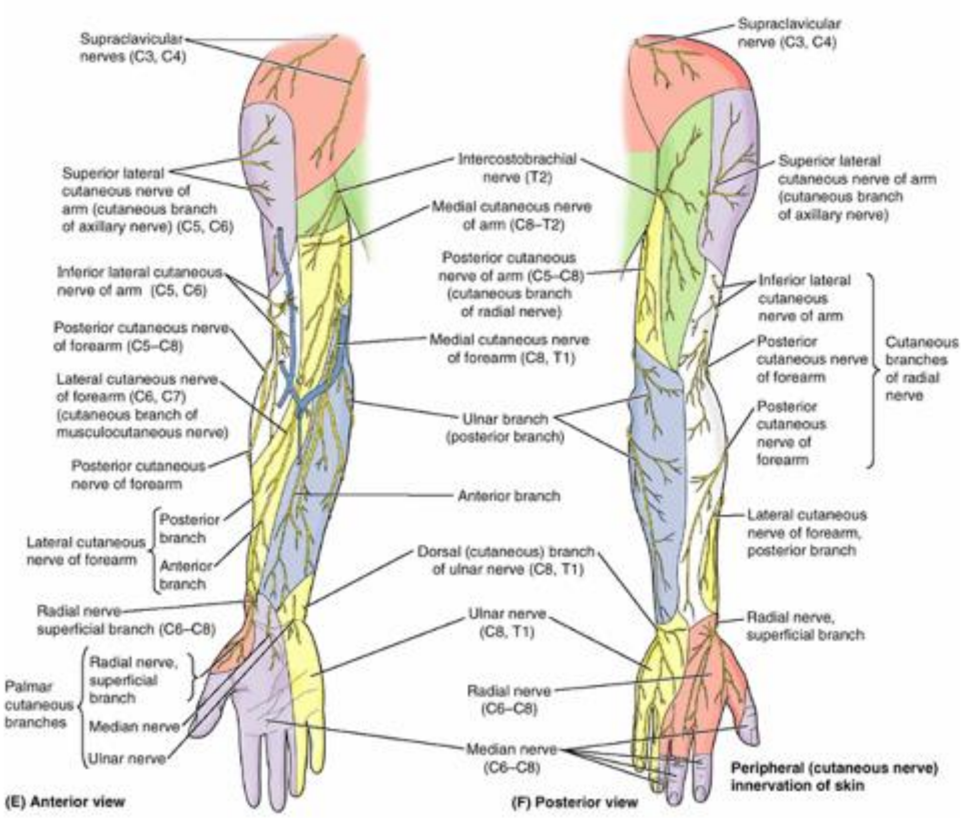

Figure 2.2 Cutaneous Innervation of the Upper Limbs (Dr. Keith L. Moore MSc PhD FIAC FRSM FAAA (Author), 2011).

2.2 Approaches to Brachial Plexus

2.2.1 Background and History

Since the first time the brachial plexus block been introduced by Hall in 19th century, many clinicians approached the nerves of the upper extremity at every anatomic division of the brachial plexus, from the level of nerve roots to that of isolated peripheral nerves (D. Brown and Bridenbaugh, 1998). Despite the existence of a numerous number of techniques; however for each of these approaches, there are few clinical comparisons of block successful rate and less still of latency or duration as a function of the chosen anesthetic approach and or technique (Tables 2-1).

Table 2.1 Comparisons of Difference Type of Block *(Adapted from D. Brown and Bridenbaugh, 1998*)

Approach	Level	Sensory block	Complications
Interscalene	Roots	Shoulder, upper arm, elbow	Phrenic nerve palsy, Horner's syndrome, subarachnoid/ epidural injection, vertebral artery injection (rare)
Supraclavicular	Trunks and proximal divisions	Entire arm	Pneumothorax, phrenic nerve palsy, Horner's syndrome
Classic Infraclavicular	Cords/terminal branches	Forearm, wrist, hand	Intravascular injection, pneumothorax
Vertical Infraclavicular	Cords	Forearm, wrist, hand	Pneumothorax, intravascular injection
Axillary	Terminal branches	Forearm, wrist, hand	Haematoma formation, intravascular injection

2.2.2 Types of Brachial Plexus Block

Interscalene Block

Indications

The interscalene approach to the brachial plexus is a suitable technique for the following situations:

i. Surgical procedures of the shoulder and upper arm
ii. Surgical procedures of the hand (will need to supplement the ulnar nerve distribution)
iii. Reduction of a dislocated shoulder, arm, and wrist fractures

Advantages

i. Ability to perform surgical procedures of the shoulder and upper arm
ii. Avoiding complications associated with general anesthesia
iii. Muscle relaxation for the surgeon
iv. Postoperative analgesia

Disadvantages

i. Moderate in complexity
ii. Need to supplement the ulnar nerve distribution for lower arm and hand surgery.

iii. Potentially serious complications can occur. Complications include inadvertent epidural/subarachnoid injection, vertebral artery injection, and pneumothorax.

The main indication in performing the interscalene block (ISB) is surgery of the shoulder. The spread of local anesthetic after interscalene administration usually extends from the distal roots or proximal trunks, and follows a distribution to the upper dermatomes of the brachial plexus and its upper trunk (Vester-Andersex, Christiansen, Hansen, Sørensen, and Meisler, 1981; Winnie and Collins, 1964). This approach however may functionally spare the distribution of an ulnar nerve in approximately 50 % of the block (C-8 and T-1 nerve roots), making it a poor choice for hand and arm surgery (Lanz, Theiss, and Jankovic, 1983).

Several techniques was developed pertaining to the ISB. Firstly, paresthesia or muscle stimulation to the arm or anterior shoulder is appropriate for shoulder surgery (Silverstein, Saiyed, and Brown, 2000). Secondly, unintended evoked motor responses may guide needle placement. Contraction of the diaphragm indicates phrenic nerve stimulation and anterior placement of the needle tip. Alternatively, trapezius muscle stimulation indicates needle placement that is too posterior.

Complications

The complication rate for interscalene blocks is relatively high. Among the complications are:

i. The stellate ganglion, phrenic, and recurrent laryngeal nerve are near the brachial plexus. Patients with a history of chronic or acute pulmonary conditions should not have an interscalene block.

ii. The phrenic nerve is commonly blocked (ipsilateral 100% of the time) with this approach, which may result in respiratory failure. Horner's syndrome is common and may be distressing to the patient.

iii. Horner's syndrome manifests itself as miosis (contraction of the pupil), ptosis (drooping of the upper eyelid), and anhidrosis (diminished or absence of sweating). In addition, the patient may experience dyspnea and hoarseness.

iv. Intra-arterial injection may occur due to the proximity of the vertebral artery to the site of injection. Aspiration prior to and during injection is essential. A small dose of 1-3 ml will lead to seizures since the vertebral artery goes directly to the brain.

v. In advertent venous injection will result in central nervous or cardiovascular system toxicity. Close proximity of the cervical neural foramina can result in an epidural, subarachnoid, or subdural injection.

vi. Pneumothorax can occur from inserting the needle too far laterally.

Supraclavicular Block (SCB)

Indications

This block is indicated for any surgery on the upper extremity distal to the shoulder or for analgesia of the entire upper extremity.

Advantages

i. Ability to perform surgical procedures of the arm and forearm
ii. Avoiding complications associated with general anesthesia
iii. Muscle relaxation for the surgeon
iv. Postoperative analgesia
v. Do not need to abduct the arm and flex at 90 degrees at the elbow

Disadvantages

i. Moderate in complexity
ii. Not for shoulder surgery.
iii. Potentially serious complications can occur. Complications include inadvertent artery injection, and pneumothorax

The supraclavicular block SCB block is performed where the brachial plexus is presented most compactly at the proximal division or trunk level. Due to the compactness of the nerve at this area may explain why the SCB has a good historical reputation of providing a short latency and the most complete and reliable mode of anesthesia available for upper extremity surgery (D. L. Brown, Cahill, and Bridenbaugh, 1993) although confirmatory data does not exist.

There are two most commonly variations of performing the supraclavicular block, firstly the classic technique that was developed by Kulenkampff *et al.* in 1928 and a minor modification of the 'plumb-bob' (vertical) approaches (Kulenkampff, 1928; VadeBoncouer and Weinberg, 1997). For the hand surgery, stimulation of the middle trunk of the brachial plexus as manifests by hand contraction or paresthesia has been associated with higher success rates (Hickey, Garland, and Ramamurthy, 1989; B. Smith, 1986). The transarterial technique of injecting on both sides of the subclavian artery is unreliable and associated with a significant risk of hematoma (Hickey, Hoffman, and Ramamurthy, 1990).

Infraclavicular Block (ICB)

The main indication pertaining to the Infraclavicular block (ICB) is surgery involving the hand and arm. The coracoid approach of the ICB was recently introduced and has revived interest in this approach (Wilson, Brown, Wong, Ehman, and Cahill, 1998). Two other comparative studies, revealed that the infraclavicular block provided more consistent anesthesia for the axillary and musculocutaneous nerves than did axillary block alone but the onset of the block was noted to be more prolonged (Kapral et al., 1999; Koscielniak-Nielsen, Nielsen, Sørensen, and Stenør, 1999).

The infraclavicular approach is not associated with changes in pulmonary function, and there are no data pertaining to the risk of pneumothorax, although theoretically it should be minimal (Rodríguez, Bárcena, Rodríguez, Aneiros, and Alvarez, 1998).

Axillary Approach (AXB)

The axillary block (AXB) normally performed for hand and arm surgery and is the most widely used, studied, and modified approach to the brachial plexus. All techniques including paresthesia seeking, nerve stimulating, perivascular, and transarterial has been introduced and was found to be effective at the level of the terminal branches of the brachial plexus (Bouaziz et al., 1997; Klaastad et al., 2002; Yamamoto, Tsubokawa, Shibata, and Kobayashi, 1995). The success rate for each individual nerve varies from 60% to nearly 100% depending on the technique (Urmey, 1996). All of the previously mentioned techniques rely on the 4 nerves being in relatively close proximity to the axillary artery.

Recently, an alternative approach of AXB was described. This midhumeral technique seeks individual evoked responses more distally, when individual branches have begun to course away from the artery (Bouaziz et al., 1997). The relationship of the musculocutaneous nerve to the brachial plexus deserves special consideration because it exits the plexus early and resides within the body of the coracobrachialis muscle at the axilla. Performing the regional block of the musculocutaneous nerve is best to be done by a separate injection into the belly of the coracobrachialis.

2.2.3 Techniques for LocalizingNeural Structure

Methods of Needle Localization

With each of the approach in performing the brachial plexus block, several methods of needle localization have been described for injecting local anaesthetic like after fascial clicks, present of mechanical paresthesia, using an electrical stimulation, transarterial injection, fanning injections, use of catheters,and using various imaging modalities. The following summarizes existing evidence for each of these localization techniques.

I. Fascial Clicks.

The technique of relying on fascial clicks did not approximate needle to nerve in cadavers (Partridge et al., 1987). There are few clinical studies that described successful rates of performing the brachial plexus block using fascial clicks However, the studies revealed mixed results. High rates of successful surgical anesthesia have been described after a single injection of local anesthetic guided by fascial clicks during infraclavicular and transcoracobrachial approaches (Pippa et al., 1992; Rousso and Whiffler, 1981). Conversely, rates lower than 85% were found when success in achieving anesthesia of all four peripheral nerves was sought after fascial clicks to guide AXB.

II. Paresthesia Versus Peripheral Nerve Stimulation.

Needle localization neither using the paresthesia technique nor peripheral nerve stimulation technique (PNS) appears to be equally effective in producing brachial plexus block. When these two methods were directly compared, almost similar successful rates (70%-90%) were reported for brachial plexus block, though these rates are generally lower than reported by others (Franco & Vieira, 2000; Goldberg et al., 1987).

Using the midaxillary approach and obtaining 4 nerve stimulations has found to be significantly increased the overall successful rate (91% versus 76%). It is also caused a reduction in the onset time of the regional block as compared with eliciting three separate paresthesias and blindly supplementing the musculocutaneous nerve.

Nevertheless, in this study, only block of the radial nerve and the musculocutaneous nerve (blocked separately) were statistically different, suggesting that the techniques may be more similar than dissimilar (Sia, Bartoli, Lepri, Marchini, and Ponsecchi, 2000). Method of using the PNS, and obtaining an appropriate motor response at 0.5 to 0.8 mA has been associated with a greater likelihood of successful block (Carles et al., 2001; Choyce et al., 2001).

III. Injection Versus Paresthesia or Peripheral Nerve Stimulation.

A two-injection transarterial technique was almost equally as successful (70% - 80%) as a single injection nerve stimulator or a single injection paresthesia technique (Goldberg et al., 1987). When compared with a 4-nerve stimulation technique, the 2-injection transarterial technique for AXB was less effective (90% versus 62% success, respectively)(Koscielniak-Nielsen et al., 1999) A single-injection, of a large volume of local anaesthetic (50 mL, 750 mg mepivacaine) via transarterial approach described by Cockings *et al.* 1987 was reported as 99% successful but was not directly compared with alternatives (Cockings, Moore, and Lewis, 1987).

IV. Perivascular Techniques.

The used of fanning or stable needle injection at perivascular axillary block techniques are associated with a high (88% and 99%) successful rate with relatively low in complication (Cockings et al., 1987; Stan, Krantz, Solomon, Poulos, & Chaouki, 1995; G. E. Thompson, 1997). Local anesthetic injected behind the artery resulted in 99% successful anesthesia (Cockings et al., 1987), and resulted in longer latency and / or less successful median nerve blockade compared with injecting in front of the artery or splitting the injection between the front and back (Hickey, Rogers, Hoffman, Ramamurthy, and Tingle, 1993).

V. Imaging Techniques

Only about two decades ago, an anaesthetist used ultrasonography to confirm the location of the needle used to perform blocks and observe the spread of local anesthetic while performing axillary nerve blocks. It was reported 100% successful rate of axillary nerve blocks with no complications during this study, and that they were able to visualize the needle tip and axillary anatomy at all times. Anupama and colleagues produced a review article regards to ultrasonography and regional block. They concluded that the used of ultrasound for supraclavicular blocks resulted in safe and more effective (Wadhwa, Kandadai, Tongpresert, Obal, and Gebhard, 2011).

2.3 Nerve Stimulation Peripheral Nerve Block

2.3.1 Background and History

Back in year 1912 for the first time, Georg Perthes used nickel made needle that was layered by lacquer and was linked to a nerve stimulator that produced the muscle contraction when the tip of the needle is positioned near to the nerve. However few years after the Kulenkampff's improved the technique which relied on the search of pareaesthesia. Both of the techniques were found to be impractical due to the heavy and unreliable material used. Only in 1962 Greeblatt revolutionized the Perthe's invention by building up the first portable stimulator equipped with transistor that produced rectangular electrical impuls of 1ms and voltage ranging from 0.3 to 3 volts (Koorn, 1997).

2.3.2 Using a Peripheral Nerve Stimulation for a Regional Block

Checking the equipments prior to the procedure is a must in performing the block. The desired initial currence of 1 mA with pulse duration of 1 ms and frequency of 2 Hz usually used for the upper limb block. The needle is then connected to the cathode of the machine and the anode is then connected to an ECG electrode attached to the patient desired arm. The needle then been connected with the syringe that contained local anesthetic. The needle is flushed with local anesthetic before the block is performed.

For a better result of the nerve conduction, certain threshold stimulus must be applied. Intensity of the current and duration of the current applied is a major determinant for the nerve stimulation. For the mixed nerve, it is advisable to perform the nerve stimulation by stimulating the motor nerve component without eliciting the pain to the patient while adjusting the 2 major determinants mentioned earlier.

The surface landmark in this method is determined by the point of the needle insertion. The completion of the circuits indicates by the audible beep or flashes of light produced by the nerve stimulation machine. The needle is advance until the desired motor movement elicits. The current is reduced slowly within the range of 0.2-0.5 mA. At the previous mentioned range of current usually produced a successful rate of the block. However, below 0.2 mA of current not selected due to fact that if with that small current the nerve stimulation still can elicit contraction of muscle, the needle placement is directly into the nerve itself and not in the nerve sheet, thus can lead to nerve damage.

When the positioned of the needle is placed, properly, the local anaesthetic was then deployed. Before the injection started, it is advisable to aspirate to make sure that the needle is not in the vessels. As the local anesthetic is given for about 0.5-1.0 ml, we can see the disappearance of the motor contraction. This is occurred probably to the mechanical displacement of the nerve from the needle or due to change in the electrical conductivity around the nerve ("http://www.nysora.com/regional-anesthesia/3010-electrical-nerve-stimulators-and-localization-of-peripheral-nerves.html,").

Ideal Electrical Characteristic of a Peripheral Nerve Stimulator

Ideal electrical characteristic of a peripheral nerve stimulator as proposed by Hadzic (Hadzic, Vloka, Hadzic, Thys, and Santos, 2003):

i. Constant current generator

ii. Monophasic rectangular output pulse

iii. Ability to vary pulse duration (0.1-1ms)

iv. Digital display of actual flowing current