Variation in the Anatomy of the Brachial Plexus and Surrounding Structures and its Implications for Blocks above the Clavicle.

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Abstract

Brachial blocks in one of the commonest blocks to be given by anaesthetist and anatomical knowledge plays a crucial role in success of these blocks. Variations in anatomy are no uncommon in brachial plexus and the present review provides a basic understanding of these anatomical variations and their clinical implications.

Keywords: Anatomy, Brachial plexus, clinical implications

Introduction

'To quote Sir William Osler "*Variability is the law of life, and as no two faces are the same, so no two bodies are alike*" [1].

Anatomical variation by definition is a structure which is different to what is observed in most population and under normal circumstances has no deleterious effect on the function of organ or organism. If a structure has negative influence then it is called malformation.

If you look under the bonnet of two cars of the same make and model, made in the same factory in the same year, you will find the arrangement of electrical wires in the same position. However we are not made in the same factory. Even though arrangement of nerves and other structures in our body is similar it never is exactly the same. Even the arrangement of structures on the right side of the body differs from the left side in the same individual.

Human limbs are not rigid structures and position of nerves in the neurovascular bundle can change according to position of the limb.

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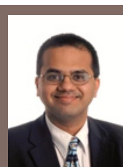

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Normal Anatomy' of the brachial plexus and its branches in the neck

When we learn anatomy in medical school this what we are told is the normal anatomy of the brachial plexus. Anterior primary rami of cervical (C) and thoracic (T) spinal nerve root C5 to T1 form the roots of the brachial plexus. Roots of C5 and C6 form the upper trunk. C7 root forms the middle trunk. Roots of C8 and T1 unite to form the lower trunk. Each trunk in turn divides into anterior and posterior divisions. All posterior trunks unite to form the posterior cord. Anterior divisions from upper and middle trunk form the lateral cord. Anterior division of lower trunk continues as medial cord. Cords then divide into terminal branches. Roots emerge through respective intervertebral foramina and pass through the interscalene groove between the scalene anterior and scalene medius muscle (Fig. 1).

Trunks are formed as the roots emerge between the scalenes and lie posterolateral to the subclavian artery as it passes over the first rib. Trunks form divisions at the lateral border of the first rib. Divisions unite to form cords and are so named according their position around the axillary artery. Terminal branches are given out from the cords in the axilla.

Other nerves which are important in relation to the brachial plexus anaesthesia in the neck are phrenic nerve, dorsal scapular nerve, long thoracic nerve and suprascapular nerve. This is how the 'normal' anatomy of the nerves is described in the textbooks.

Phrenic nerve arises from cervical roots 3-5 and passes anterior to scalene anterior muscle and exits the neck passing between subclavian artery and vein.

The dorsal scapular nerve arises from C5 nerve root. Once the nerve leaves C5 it commonly pierces the middle scalene muscle and continues deep to levator scapulae and then innervates the rhomboids. Long thoracic nerve arises from Cervical nerve root 5 to 7. Roots from C5 and C6 pierce scalene medius and C7 contribution lies in front of it.

Suprascapular nerve arises from the upper trunk and then passes parallel to inferior belly of omohyoid muscle, deep to trapezius muscle.

'Variant anatomy' of the brachial plexus and its branches in the neck

However the 'normal' description of the brachial plexus is an oversimplified description. Variant anatomy is the norm rather than exception.

Brachial plexus often receive contribution from C4 or T2. Brachial plexus is called 'Prefixed' if the branch it receives from C4 is larger than the branch from T2. In prefixed plexus the branch from T2 is often absent and the branch from T1 is reduced in size. It is called 'postfixed plexus if branch from C4 is absent and branch from T2 is present [2]. Prefixation of the brachial plexus is more common than post fixation.

Cadaveric studies show great variation in configuration of the brachial plexus. At the turn

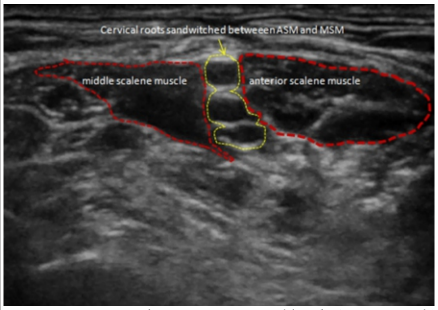

Figure 1: shows so called 'normal' arrangement of the roots of the brachial plexus in the interscalene groove.

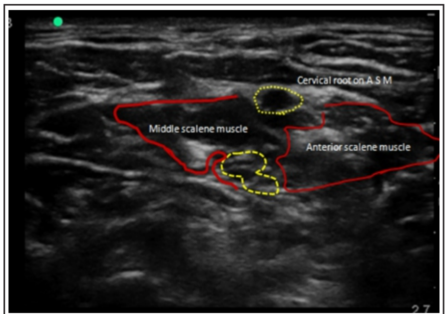

Figure 2: showing C5 root over the anterior scalene muscle.

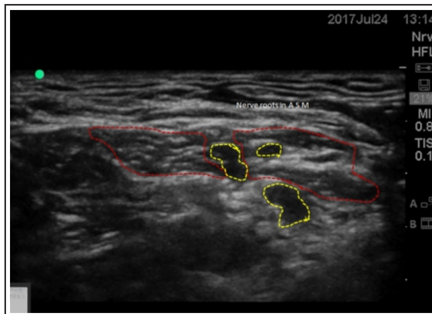

Figure 3: shows root passing through the anterior scalene muscle.

of 19th century Kerr described brachial plexus anatomy in 175 dissected cadaver [3]. He found 7 major configurations and 29 total configurations of the brachial plexus. No configuration had more than 57% representation. 61% of cadavers exhibited right /left asymmetry. He divided the plexus into three groups according to spinal nerves forming the plexus. Group 1 (62.85%) fourth cervical root contributed to the plexus. In group 2 (29.7%) fifth cervical root in its entirety contributed to brachial plexus without any contribution from the fourth. In group 3 (7.43%) there was no contribution from the fourth and also fifth contributing only partially. In another study done on Korean cadavers group 2 was found to be more dominant (64.2%).4200 brachial plexuses were studied in human foetuses.5In that study only 46.5% had 'normal' origin of the brachial plexus. Prefixation of the plexus is observed in about 48% of cases while postfixation is reported in 0.5-4% of cases [5]. Variation in the origin of the brachial plexus and its branching pattern is nicely illustrated in this anatomy atlas [6].

Roots of the brachial plexus lie between the scalene anterior and medius muscle. In a study done on 51 cadavers this relationship of the roots with the scalene anterior and medius muscle was found in only 60% of cases.7The most common variation was penetration of anterior scalene muscle by C5 and C6 nerve root. TheC5 and C6 roots may fuse before piercing the anterior scalene muscle (15% of cadavers on one side and in 4 cadavers bilaterally). In 13% of cadavers C5 root alone pierced the belly of anterior scalene. In 6% cadavers the roots pierced the belly of anterior scalene muscles independently. C5 root was found to lie in front of anterior scalene muscle in 3% of cadavers. Fig. 2 and 3 show alternative arrangement of the roots of the plexus.

Trunks of the brachial plexus lie posterolateral to the subclavian artery as it passes over the first rib. This relationship of the brachial plexus to the artery helps identify the plexus when using the ultrasound and the 'corner pocket' technique of supraclavicular block [8]. This relationship of the artery with the brachial plexus can be disrupted with other structures. Scalene minimus muscle arises from the anterior border of the seventh cervical vertebra and inserts on the first rib just behind the groove of the subclavian artery and can lie between it and the brachial plexus. This muscle can increase the distance between the subclavian artery and the brachial plexus [9,10]. Cervical rib can alter the anatomical relation between the artery and the plexus [11]. Sometimes part of the plexus can be seen medial to the artery [12]. In 0.7% of population the subclavian artery can pass medial to the scalene anterior muscle.13Serratus anterior muscle has also been reported to lie between the sunclavian artery and the first rib [14].

Phrenic nerve anatomy can be variable. In addition to its origin from cervical nerve roots it may also get branches from the cervical or brachial plexus or can arise entirely from the brachial plexus. Cranial nerves can also contribute to the phrenic nerve [15]. The Accessory phrenic nerve is a highly variable anatomical structure present in over one third of the population [16]. The Accessory phrenic nerve originates from the ansa cervicalis or the nerve to the subclavius muscle.

Dorsal scapular nerve (DSN) shows variation as well. Cadaveric study done on 20 cadavers showed that 70% of the DSNs originated from the spinal nerve roots of C5, whereas 22% arose from C4 and 8% from C6. There was variation in the route of the DSN in relation to the middle scalene muscle. 74% pierced the muscle, whereas 13% of the DSNs traveled anterior to the middle scalene muscle, and 13% traveled posterior to the muscle [17].

The long thoracic nerve (LTN) classically is formed by an upper portion originating from C5 and C6 nerve roots and a lower portion coming from C7 [18]. However variations include early or late union of two parts, common origin with dorsal scapular trunk, either C5 or C7 trunks not contributing or parts derived from roots supplying serratus anterior without uniting. Great deal of variation was seen in the origin of the Suprascpular nerve in a cadaveric study. Out of 100 cadavers dissected the suprascapular nerve originated from the posterior division of the upper trunk distal to the bifurcation of the upper trunk (61 %); the point of upper trunk bifurcation (29%), the upper trunk proximal to the bifurcation point (6%); and directly from the C5 root (4%) [19].

Variation in branches of the subclavian artery in the neck

The branches of subclavian artery are the vertebral artery, the internal thoracic artery, the thyrocervical trunk, the costocervical trunk and the dorsal scapular artery. The thyrocervical trunk divides into inferior thyroid artery, suprascapular artery and transverse cervical artery. Dorsal scapular artery can arise from transverse cervical artery.

Arteries arising from subclavian artery are frequently found to divide the brachial plexus. Dorsal scapular artery passes between the superior and middle trunks of the plexus in 40–50% of subjects, between

the middle and inferior trunks in another 40–50% and in other locations in approximately 10% [20,21].
In a cadaveric study the dorsal scapular artery, either originated from subclavian artery (75% of cadavers) or from the transverse cervical artery(25%) [22].

Implications of anatomic variation on blocks above the clavicle

Multiple needle passes:
Before ultrasound, blocks were done by either eliciting paraesthesia or using a nerve stimulator to locate the nerve. Both these techniques relied on using anatomical landmarks to locate the position of the nerve or the plexus. This worked well if patient had 'normal' anatomy and 'normal' body habitus but failed miserably if they had 'variant' anatomy or their body habitus was not 'normal'. Let us take example of interscalene block done using Winnie's technique. In this needle was inserted at the level of cricoid cartilage in the interscalene groove. This assumed that the roots were present in the interscalene groove. However only in 60% of cases this was the case.7 In remaining 40% this may need multiple needle passes before either paraesthesia or appropriate muscle twitch can be elicited. In extreme 'variant' cases there can be failure to elicit either paraesthesia or muscle response.
For doing subclavian perivascular approach for doing supraclavicular block we use posterolateral location of the trunks of the brachial plexus as a landmark. Pulsations of subclavian artery are felt in the lowest part of interscalene groove and needle is inserted posterior to the pulsations. However if the 'normal' relation of the subclavian artery with the trunks of brachial plexus is absent then it leads to multiple needle passes before plexus can be located.

Inability to rely on normal goal posts:
'Normal' position of the phrenic nerve is anterior to the roots and 'normal' position of the dorsal scapular nerve is posterior to the roots. When using nerve stimulator to perform interscalene block, if diaphragmatic stimulation is seen (phrenic nerve) then needle is assumed to be too anterior and therefore directed more posteriorly to elicit response from the brachial plexus (Deltoid/biceps stimulation). If the needle stimulates dorsal scapular nerve (DSN) then it is assumed too posterior and is directed more anteriorly to stimulate the plexus. So phrenic nerve and DSN act as goal posts to direct the needle towards the goal (roots of the brachial plexus). However if the roots are situated in 'variant position' or the goalposts are in 'variant' position then the response obtained to nerve stimulation cannot be relied upon to find the roots.

Increased risk of complications:
Although with interscalene block the risk of phrenic nerve blockade is almost 100%, it is only around 50%with supraclavicular block. Quality of phrenic nerve blockade also differs between the two groups. Those with interscalene block there is 25% reduction in forced vital capacity (FVC) but those having phrenic nerve blockade following supraclavicular block no reduction in forced vital capacity is seen.
It has been suggested that it could be due to presence of accessory phrenic nerve in the supraclavicular area or branch from brachial plexus contributing to the phrenic nerve getting blocked by the injected local anaesthetic [15]. As the main phrenic nerve is not blocked there is no effect on the FVC. Those patients who do not have accessory phrenic nerve or do not have a communicating branch from the brachial plexus to the phrenic nerve are less likely to be affected by this if the volume of local anaesthetic injected is not excessive.
It follows that if variability increases the chance of complications it will also increase the chance of success if a person's anatomy conforms to 'normal' anatomy.

Minimizing effect of anatomic variation on block success

The first step in reducing impact of anatomical variation on block success is to educate anaesthetists about anatomical variation. When we are taught anatomy in medical school or read from textbook it is very easy to form an impression that variant anatomy is rare. However it is more common that we think it is. Good knowledge of anatomy and anatomical variations is important to improve success of regional anaesthesia and practice it safely Before wide spread use of ultrasound for regional anaesthesia it was impossible to see variation in anatomy and adapt the regional block technique to it. However with use of ultrasound for regional anaesthesia it is easier to see anatomical variation and change the technique to improve success and reduce complications. Good knowledge of anatomical variation is still essential even with the use of ultrasound for regional anaesthesia as 'eyes can't see what mind does not know'.

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