CLINICAL STUDY

Variations of nerve roots of the brachial plexus

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Abstract

Outcome: **Aberrations observed during surgical treatments inspired us to initiate the investigation of variations in the formation of brachial plexus.**
Material and methods: **100 brachial plexuses in 50 cadavers were examined for the incidence of neural variations. We examined the involvement of the C4 root and eventually of that of Th2 root, as well as various deviations in the exit of individual roots and their branches from the backbone. We have focused also on their paths, anastomoses, on their thickness or on their eventual absence. In addition to the anatomical complexity and variability, the specifics of motor innervation related to diagnostics are also emphasized. The attention is paid to the mechanisms and morphological reasons of the occurrence of specific types of injuries.**
Results: **Prefixed type was present in 24 cases (48 %), postfixed type was present just in one case. Aberrations have been observed in 14 cases (28 %). They occurred more frequently on the left side (9 cases) followed by two-sided aberrations (4 cases).**
Conclusion: **This study enabled to identify and describe exceptional and hitherto undescribed anatomical variations in the formation of nerve roots of brachial plexus.** ***(Tab. 1, Ref. 2.)***
Key words: brachial plexus, nerve roots, nerve trunks, variations.

The brachial plexus develops from a connection of anterior branches of the last four cervical spinal nerves (C5, C6, C7, C8) and the first thoracic nerve (Th1). These five plexiform roots are connected in order to form three plexiform trunks:

– truncus superior made up by anterior branches of C5 and C6,
– truncus medius made up by anterior branch of C7,
– truncus inferior made up by anterior branches of C8 and Th1.

Each of these trunks is divided into two divisions referred to as anterior and posterior, which then connect in order to form three plexiform fascicles:

– fasciculus lateralis made up by the connection of anterior branches of the superior and middle trunks,
– fasciculus medialis made up from the anterior division of the inferior trunk,
– fasciculus posterior made up by the connection of the posterior divisions from all of the three trunks of the plexus.

The brachial plexus ensures sensitive and motoric innervation of the upper limb. Trapezius muscle is the only muscle of the upper limb girdle being not innervated from the brachial plexus.

The total amount of myelin fibers in the brachial plexus in adults ranges between 120000 to 150000 and up to 25 % of it innervates the upper limb girdle. The fifth cervical and first thoracic nerves contain the least amount of myelin fibers – between 15000–20000. The eighth nerve is the biggest and contains about 30000 myelin fibers. The greatest amount of motoric fibers is in C5 and then in C8, the smallest amount is in C7 and Th1. The amount of sensoric fibers is greatest in C7, then in C6 and finally in C8. The basic nerves forming the plexus with the whole mass of their anterior branches are C6, C7 and C8.

Our study has topographically specialized in anatomic variations of the formation of neural roots of the brachial plexus and their branches.

We have found only rare studies concerning this problem in literature available to us.

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Material and methods

The study involved 50 cadavers, in which the brachial plexus was observed bilaterally. The body was in a lying position with limbs slightly pulled out. The skin incision was performed from the upper third of the lateral side of sternocledomastoid muscle to the median third of the clavicle and from there along with the clavicle to its lateral part. Skin and subcutaneous tissues were moved a side.

The visualization of spinal nerves in the intraforaminal level up to the border of dura mater was performed using a resection of the endings of the transverse processes.

When it was necessary to isolate the inferior plexus as C7 spinal root – and C7 root as the middle trunk or C8 and Th1 of the inferior trunk, we have removed the insertion of the anterior scalenus muscle up to the anterior tubercle or we have cut a part of the scalenus muscle. The origin of the long thoracic nerve was found by pulling the C6 root to the front.

When anomalies were detected, we continued the preparation using a magnifying lens.

Results

Complicated connections between nerves were observed. Variations were observed more frequently on the left side.

Simultaneous contribution of the C4 and Th2 roots on the formation of the brachial plexus was not observed. The elasticity and strength of the nerve was significantly decreased in older cadavers. They were more easily damaged during preparation.

The C4, C5, C6 and C7 roots were fixed in the spinal sulcus nerve by transversal radicular ligaments to the transverse processes to the vertebrae. They were missing in C8 and Th1.

Tab. 1. Variations of the brachial plexus in the level of neural plexiform roots.

	SIN	DX	Bilat
Roots C5 and C6 divided into anterior and posterior branch	2		
Root C7 is thin and does not form anterior branch	1		1
Root C7 forms a branch to the C8 root	1		1
Root C8 forms two branches to the posterior branch of the middle trunk	1		1
C8 divides into 2 branches, the anterior goes to the anterior branch of the superior trunk and the posterior connects with the Th1 root			1
Two branches of the C8 root connect with the anterior branch of C6 root	1		
Branches of the C8 root connect with the lateral and posterior fascicle	1		
Th1 root is as broad as C8 root	2		1
Total	9	1	4

SIN – left, DX – right, Bilat – bilateral

Upper cervical nerves C4, C5, C6 and in lesser rate C7 are located due to the physiologic curve of the spine more in the front in relation to C8 and Th1 roots. The roots forming the plexus were usually going through the fissure between the anterior and middle scalenus muscles.

In one case the C5 root and in one case both the C5 and C6 ran over the anterior scalenus muscle.

The branches to the scalenus muscles and to musculus longus coli exited from the lower parts of the anterior cervical roots as small lateral and medial branches or as branches leaving these proximal spinal nerves near their exit from the intervertebral foramens. The Th1 root had no proximal branches. The phrenic nerve was connected by one and in two cases by more branches with the C5 root.

The most proximal branch of the C5 root is nervus dorsalis scapulae. It was observed to originate in the lower side of root C6 in 4 cases. The long thoracic nerve was formed by contributions of C5 in all cases. In 16 cases (32 %) by C5, C6, C7 and in four cases by contributions of C4, C5 and C6. Mostly by roots C5 and C6 in 30 cases (60 %). The biggest trunk was always formed by the C6 root.

We have observed variations of the formation of the neural roots 18 times in 14 cadavers, out of which four were bilateral (Tab. 1).

Suprascapularis nerve originated from the C5 root in three cases.

The C5 and C6 roots divided into anterior and posterior branches in two cases.

The C8 and Th1 roots were parallel in one case, Th1 was even broader.

Clinical, motoric and innervation particularity in relation to diagnostics

In case of prefixed types of nerve trunk they receive more fibers from neurons located more cranially. Root C4 may significantly contribute to the suprascapular nerve, but also to the axillary nerve. The radial nerve receives more fibers from C5. The same is being observed in relation to the musculocutaneous nerve and others.

Injury to the C5 root may be manifested in the first case by plegia of the deltoid, biceps and brachial muscles but also by plegia of the wrist extensors, brachioradial muscle, supinator muscle and pronator teres. The same injury of the C5 root in case of caudal localization of the plexus may not manifest at all or it can lead only to a mild impairment of the function of the forearm muscles. Brachial and biceps muscles may be affected only partially.

In case of the postfixed type the Th1 root may contain several fibers normally carried in the C8 root and a contribution of the Th2 to the plexus may be greater.

The C7 root provides an extensive innervation of the upper limb and variably contributes to the formation of all nerve trunks of the upper limb. In the rare cases of its injuries we can observe rather a diffuse impairment of function, without complete anesthesia or paralysis of some significant muscle group. The eighth

cervical nerve contributes to the innervation of the thumb and finger extensors. The first thoracic nerve provides almost the same and it partially contributes to the innervation of the triceps muscle.

The presence of Horner syndrome indicates avulsion of the C8 and Th1 spinal roots.

Three branches of nerve roots seem to be clinically important. Nervus thoracicus longus and nervus dorsalis scapulae – if the function of the muscles supplied by these nerves is impaired, it signifies a proximal injury of plexiform roots or an avulsion from the spinal cord. On the other hand, if muscles innervated by these nerves work well, even if no other muscle is functional, there is a presumption that the proximal nerve roots are preserved and they can be identified and used for a reconstruction surgery of the brachial plexus.

Mechanisms and morphological reasons of some types of injuries

The root is most vulnerable in the site of its origination from the spinal cord. The motoric roots contain less radicular fibers and they are thinner than the sensitive roots. They are therefore pulled out more frequently. The sheaths of the spinal nerves are firmly connected with the dural bag and the traction forces are therefore transferred on its infundibular concavity into the intervertebral foramens, where the C8 and Th1 roots are freely movable. In comparison with the C5, C6 and C7 spinal nerves that are located in the sulcus spinalis nerve where they are firmly fixed with strong fibrous connective tissue and thereby protected. They are arranged in a way to be less vulnerable during traction forces compared with the C8 and Th1 roots, which are not fixed. The upper roots are therefore affected more distally during traction – more on the periphery. If an avulsion is to occur, the fixation of these roots has to be broken as well or a transverse vertebral process have to be fractured. A presence of avulsion fractures on this level is strongly suspicious for an avulsion of the nerve roots from the spinal cord.

Even in case of an avulsion of C5, C6, C7 and C8 the injured patient may be able to perform movements in the shoulder. We suppose it can be caused by the function of the XI cranial nerve and the cervical plexus.

The biceps brachii muscle may, even in complete types of plexus injury with avulsion of the roots, restore its function in some cases. The C3, C4 roots and the phrenic nerve contribute on the innervation.

Discussion

The variations of the formation of nerve roots of the brachial plexus are of a clinical and surgical importance. Knowledge of its anatomical variations may contribute to the explanation of inconceivable clinical pictures. It is supposed that the variations are caused by a deviation of normal development. They are important especially for surgeons engaged in plexus reconstruction injuries.

The main variations described in literature concerned the contrubution of C4 or Th2 (1, 2). We haven't encountered any studies concerning the variations of the formation of neural roots.

The anatomical arrangement of the brachial plexus is complicated. It is necessary to be aware of the individual variations in the development of the clinical picture, diagnosis and surgical treatment, because it can prevent surprises from some findings during surgery.

References

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