ANATOMIA HISTOLOGIA EMBRYOLOGIA
JOURNAL OF VETERINARY MEDICINE
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Anatomia Histologia Embryologia

ORIGINAL ARTICLE

Morphology of Brachial Plexus and Axillary Artery in Bonobo (*Pan paniscus*)

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With 1 figure and 1 table

Received February 2010; accepted for publication October 2010

doi: 10.1111/j.1439-0264.2010.01040.x

Summary

A left brachial plexus and axillary artery of bonobo (*Pan paniscus*) were examined, and the interrelation between the brachial plexus and the axillary artery was discussed. This is the first report of the brachial plexus and the axillary artery of bonobo. The bonobo brachial plexus formed very similar pattern to that of other ape species and human. On the other hand, the branches of the bonobo axillary artery had uncommon architecture in comparison with human case. The axillary artery did not penetrate the brachial plexus and passes through all way along anterior to the brachial plexus. Only 4.9% of human forelimbs have this pattern. Moreover, the brachial artery runs through superficially anterior to branches of the brachial plexus.

Introduction

One of the most attractive things concerning the brachial plexus is the relative position to the axillary artery. The brachial plexus could have varied branching pattern, depending on the position of the axillary artery relative to the brachial plexus.

In human, 85% of axillary artery went through the roots or trunks of brachial plexus towards ventrally on the position between the seventh cervical nerve (C7) and the eighth cervical nerve (C8) of the spinal nerve (Kodama, 2000). But the position where the axillary artery went through the roots or trunks of brachial plexus was varied (ibid.), i.e. between the sixth cervical nerve (C6) and C7 (0.3%); C7 and C7 (3.6%); C7/C8 and C7/C8 (0.3%); C8 and C8 (3.9%); C8 and the first thoracic nerve (T1) (1.0%); T1 and T1 (1.3%). Furthermore, there were two cases that the axillary artery did not get through into the brachial plexus at all, but passed through between medial brachial cutaneous nerve and ulnar nerve (2.9%), or T1 and the second thoracic nerve (T2) (2.0%).

The brachial plexus architecture (with axillary artery) in most of ape species has been reported (Kusakabe et al., 1965; Nishimura et al., 1965; Mizoguchi et al., 1967; Koizumi, 1980; Koizumi and Sakai, 1995; Kawashima et al., 2007), whereas bonobo (*Pan paniscus*) has not been examined in detail yet only because of a few bonobo being dissected concerning muscle (Vereecke et al., 2005; Payne et al., 2006a,b). This study gives a light upon the architecture of the brachial plexus and axillary artery of bonobo and discusses the interrelation of the brachial plexus and axillary artery.

Materials and Methods

The left brachial plexus and axillary artery of male bonobo (*Pan paniscus*) were examined. This specimen is property of the Japan Monkey Centre, Inuyama, Japan. The fresh cadaver after unfreezing for 3 days was dissected. The soft tissues, muscle fascia and fat were removed to expose the brachial plexus and axillary artery. Then, the sketch was drafted by the pencils. After the sketch was imported into the computer, the lines of nerves, vessels and contours of muscles were clearly traced (Adobe Photoshop Elements 7.0).

Results

The brachial plexus consisted of three trunks, i.e. the superior trunk comprised C5 and C6, the middle trunk

C7 and the inferior trunk C8 and T1 (Fig. 1, abbreviations are shown in Table 1). Individual trunk divided into anterior and posterior parts. The anterior divisions formed medial and lateral cords, and the posterior divisions merged into a posterior cord. Interestingly, the first thoracic nerve, which is a part of the inferior trunk, did not attend to the posterior divisions.

The ventral divisions

Two branches of the suprascapular nerve (Ss) originate from C5 and C6, respectively. Then shortly after, these branches were communicated to be the suprascapular nerve. The lateral pectoral nerve (Pl) ramified from the lateral cord and divided into four small branches. The most medial branch of the lateral pectoral nerve communicated with the medial pectoral nerve (Pm). The medial pectoral nerve branched from C8 and T1 and ramified into two branches; one branch communicated with the Pl and the other branch distributed into the anterior brachial cutaneous portion [maybe 'anterior brachial cutaneous nerve (Cba)', which distributes in the anterior part of the brachialis]. The musculocutaneous nerve (Mc), median nerve (M) and ulnar nerve (U) ramified in the manners of the ordinary human formations.

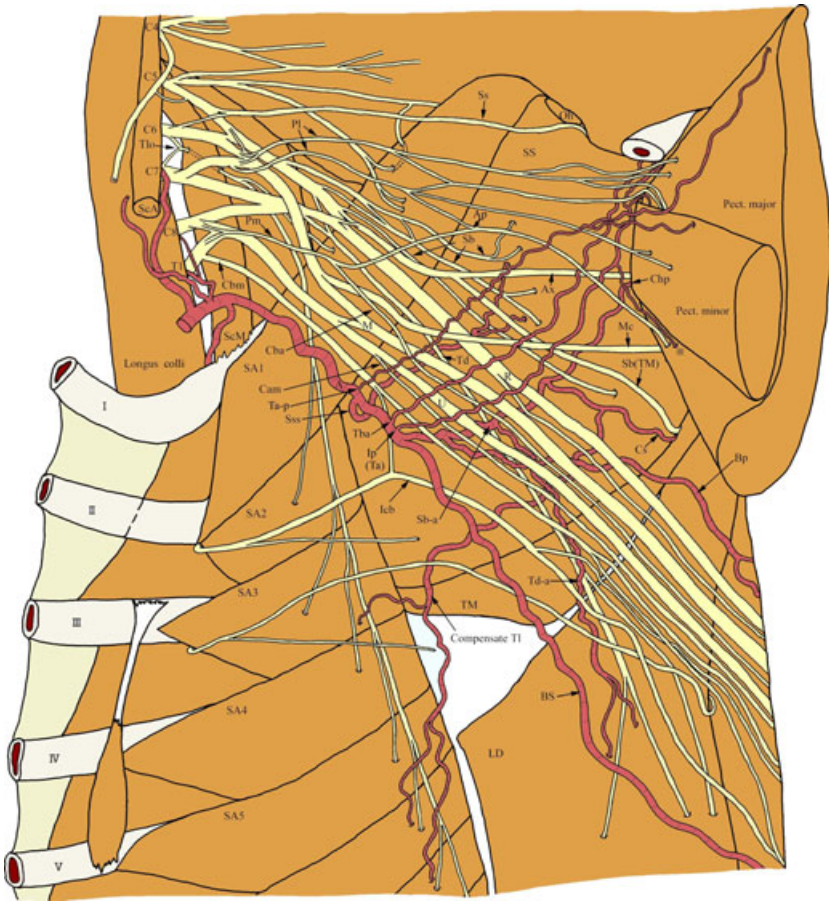

Fig. 1. Illustration of the left brachial plexus and the axillary artery in the bonobo in the ventral view. The straight lines with no mark indicated as nerves. The objects drawn with stripe were arteries. Abbreviations in nerve: C, cervical nerve; Ap, ansa pectoralis; Ax, axillary nerve; Cam, medial antebrachial cutaneous nerve; Cba, anterior brachial cutaneous nerve; Cbm, medial brachial cutaneous nerve; Icb, intercostobrachial nerve; M, median nerve; Mc, musculocutaneous nerve; Pl, lateral pectoral nerve; Pm, medial pectoral nerve; R, radial nerve; Sb, subscapular nerve; Ss, suprascapular nerve; T, thoracic nerve; Td, thoracodorsal nerve; Tlo, long thoracic nerve; U, ulnar nerve. Abbreviations in Artery: A, axillary artery; B, brachial artery; Bp, deep brachial artery; BS, superficial brachial artery; Chp, posterior humeral circumflex artery; Cs, circumflex scapular artery; Ip, inferior pectoral artery; Sb-a, subscapular artery; Sss, superficial subscapular aretery; Ta-p, thoracoacromial artery (pectoral branch); Tba, third branch of axillary artery; Td-a, thoracodorsal artery; Il, lateral thoracic artery. Abbreviations in muscle: LD, latissimus dorsi; Oh, omohyoideus; Pect, pectoralis; SA, serratus anterior; ScA, scalenus anterior; ScM, scalenus medius; SS, subscapularis; TM, teres major.

Table 1. Abbreviations of the nerves, arteries and muscles in this study

Abbreviations	Nerve	Abbreviations	Artery	Abbreviations	Muscle
C	Cervical nerve	A	Axillary artery	LD	Latissimus dorsi
Ap	Ansa pectoralis	B	Brachial artery	Oh	Omohyoideus
Ax	Axillary nerve	Bp	Deep brachial artery	Pect	Pectoralis
Cam	Medial antebrachial cutaneous nerve	BS	Superficial brachial artery	SA	Serratus anterior
Cba	Anterior brachial cutaneous nerve	Chp	Posterior humeral circumflex artery	ScA	Scalenus anterior
Cbm	Medial brachial cutaneous nerve	Cs	Circumflex scapular artery	ScM	Scalenus medius
Icb	Intercostobrachial nerve	Ip	Inferior pectoral artery	SS	Subscapularis
M	Median nerve	Sb-a	Subscapular artery	TM	Teres major
Mc	Musculocutaneous nerve	Sss	Superficial subscapular artery		
Pl	Lateral pectoral nerve	Ta	Thoracoacromial artery		
Pm	Medial pectoral nerve	Ta-p	Thoracoacromial artery (pectoral branch)		
R	Radial nerve	Tba	Third branch of axillary artery		
Sb	Subscapular nerve	Td-a	Thoracodorsal artery		
Ss	Suprascapular nerve	Tl	Lateral thoracic artery		
T	Thoracic nerve				
Td	Thoracodorsal nerve				
Tlo	Long thoracic nerve				
U	Ulnar nerve				

The dorsal divisions

The long thoracic nerve (Tlo) branched from C6 and C7 dorsally and then ramified into several branches. The first branch distributed into the most upper part of the serratus anterior muscle (SA1). The other branches innervated lower parts of the SA one by one. The thoracodorsal nerve (Td) ramified from the posterior cord and passed through the most dorsal part of the branches of the brachial plexus. The first, second and third subscapular nerve (Sb) ramified from the posterior division of the superior trunk, and the first and second branches communicated with each other. The axillary nerve (Ax) ramified from the posterior cord and divided the subscapular nerve [Sb(TM)] distributing the teres major muscle. The radial nerve (R) originated from posterior cord, which the T1 did not attend.

The cutaneous nerve

The medial brachial cutaneous nerve (Cbm) originated from the T1. And then, this nerve composed the intercostobrachial nerve (Icb) communicating with the intercostal nerve from the second thoracic nerve (T2). The medial antebrachial cutaneous nerve (Cam) ramified from the T1.

Axillary artery

The first branch of the axillary artery (A) passed anterior to the lateral and medial pectoral nerves (Pl and Pm). Then, this branch distributed upper portion of the major and minor pectoral muscles (Pect. major and Pect. minor). Therefore, this branch should be the pectoral branch of the thoracoacromial artery (Ta-p). The second branch of the axillary artery, so-called the superficial subscapular artery (Sss), bifurcated and distributed subscapular muscle (SS) passing posterior to the all branches of the brachial plexus except for the second and third subscapular nerves (Sb). The third branch (Tba) passed behind to the two pectoral nerves (Pl and Pm) and ventral side to the anterior brachial cutaneous nerve. Then, this branch distributed around the coracoid process of the scapula. The fourth branch [Ip(Ta)] had similar pattern of the thoracoacromial artery and also ran behind the two pectoral nerves and ventral side to the anterior brachial cutaneous nerve. This branch had three branches i.e. pectoral branch, acromial branch and deltoid branch. Moreover, this artery branched to the abdominal part of the major pectoral muscle, which should be 'inferior pectoral artery' (Kodama, 2000; asterisk mark in Fig. 1). The axillary artery finally bifurcated two arteries. One was the superficial brachial artery (BS) and the other was the common trunk of the subscapular artery (Sb-a) and deep brachial artery (Bp). First, the thoracodorsal artery (Td-a) was branched from Sb-a. Then, the subscapular artery bifurcated two branches, i.e. the circumflex scapular artery (Cs) and the posterior humeral circumflex artery (Chp). The thoracodorsal artery passed through behind the deep brachial artery and anterior to the thoracodorsal nerve. The circumflex scapular artery (Cs) distributed the serratus anterior muscle passing the most posterior position of the axilla. Thus, the vascular should be compensated by lateral thoracic artery (Tl) (Fig. 1).

In this specimen, the axillary artery is continued by the BS. Therefore, the axillary artery did not went through

the brachial plexus from ventral to dorsal at all, but ran ventrally along the brachial plexus at all times.

Discussion

Some works have been carried out for the hominoid brachial plexus (Kusakabe et al., 1965: both arms from one chimpanzee; Nishimura et al., 1965: both arms from one gibbon; Mizoguchi et al., 1967: eight arms from four orang-utans; Koizumi, 1980: 26 arm from 13 gibbons) and both brachial plexus and axillary artery [Koizumi and Sakai, 1995: four arms from four chimpanzees, both arms of one gorilla, four arms from four gibbons; Kawashima et al., 2007: one arm of one orang-utan]. Still there are not enough data for hominoid brachial plexus and axillary artery to discuss their variations. Especially, these plexus and artery of bonobo have not been investigated yet. This is the first report of a distribution pattern of bonobo brachial plexus and axillary artery. We could get only one arm from a cadaver for this research. Thus, we could not represent any of variation data, but case study. Here, we represent a brachial plexus and an axillary artery distribution pattern of a male bonobo and compare the pattern with other hominoid species including human.

Eighty-five per cent of human axillary artery went through the roots or trunks of brachial plexus towards ventrally on the position between C7 and C8 of the spinal nerve (Kodama, 2000). But the position where the axillary artery went through the roots or trunks of brachial plexus was varied (ibid.); i.e. between C6 and C7 (0.3%); C7 and C7 (3.6%); C7/C8 and C7/C8 (0.3%); C8 and C8 (3.9%); C8 and T1 (1.0%); T1 and T1 (1.3%). Furthermore, there were two cases that the axillary artery did not get through into the brachial plexus at all, but passed through between medial brachial cutaneous nerve and ulnar nerve (2.9%), or T1 and T2 (2.0%).

Miller reported the interrelationship between the brachial plexus and axillary artery of 17 species of primates (Miller, 1939). Although, according to his report, there are many variations in the interrelationships between the brachial plexus and axillary artery among the primate species, he did not describe the detail origins (cervical nerve and thoracic nerve) of the brachial plexus. Another study objecting gorilla reported that in this animal, the axillary artery seemed to penetrate the roots or trunks of brachial plexus towards ventrally on the position between C7 and C8 of the spinal nerve (Raven, 1950) according to his figure. Because the root and the way of C8 of his figure, however, were not clear, the detail discussion is not impossible. Moreover, according to Bolk's (1902) figures, the axillary artery penetrates form anterior to posterior between C7 and C8 both in chimpanzee and orang-utan, but, in gibbon, the axillary artery and the brachial plexus did not cross over.

Kawashima et al. (2007) showed that the axillary artery of an orang-utan went through the brachial plexus on the position between C6 and C7. This pattern was observed in two gorilla arms as well (Koizumi and Sakai, 1995). In four chimpanzees and four gibbons from Koizumis' study, however, the axillary artery and the brachial plexus did not cross over, but the axillary artery positioned anterior to the brachial plexus all the way along. Swindler and Wood (1973) also report the same manner concerning the interrelationship between the brachial plexus and axillary artery in chimpanzee. A bonobo in this study had a similar type of interrelation between the brachial plexus and axillary artery to these chimpanzees and gibbons.

However, as we cannot say that the type of the brachial plexus and axillary artery in this study is constant for bonobo, more research is needed.

Acknowledgements

We appreciate two anonymous reviews for giving nice advices. This study was supported by KAKENHI (21370110).

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