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**Various Patterns of Branching and Connections
of the Phrenic Nerve in Man and in *Macacus***

Zmienność odejścia i połączeń n. przeponowego u człowieka i makaków

The phrenic nerve is of interest to many workers, both from a theoretical and a practical point of view, as evidenced by the numerous studies dealing with the morphology and topography of this nerve. The above mentioned problems have been dealt with on abundant human material (1, 4, 9, 10, 12, 14, 15). The literature concerning the phrenic nerve in other *Primates* (3, 5, 8, 9, 11) is rather scanty. In *Macacus* studies were carried out on a scanty material, so it was difficult to decide what characters in the monkeys were typical and what were only variants. The lack of those data do not permit to make a comparison of the phrenic nerve in *Macacus* with that in other monkeys and in man. Such a comparison in an anthropogenetic order would allow a division of features of this nerve into progressive and regressive. This would also enable to elucidate some variations of the phrenic nerve in man.

The subject of this paper is to examine the phrenic nerve in *Macacus* and compare it with that in man.

MATERIAL AND METHODS

Bilateral investigations on 100 *Macacus rhesus* and 50 *Macacus cynomolgus* were carried out concurrently with bilateral comparative studies on 25 human corpses. Dissection method was used and observations were performed with a binocular magnifying lens. Results of observations were recorded, figures made and dissections photographed. Special attention was paid to the number and thickness of the roots of the phrenic nerve, their origin, connections, and the relationship to spinal nerves.

The roots forming the phrenic nerve, and their number

In our material the phrenic nerve was formed by one, two or three roots. According to the number of roots the phrenic nerve was divided into types: I, II and III.

In man, type I was found in 18 cases ($36.0\% \pm 6.79$), type II — in 27 cases ($54.0\% \pm 7.05$), type III — in 5 cases ($10.0\% \pm 4.24$).

In *Macacus rhesus* type I was found in 14 cases ($7.0\% \pm 1.80$), type II — in 49 cases ($24.5\% \pm 3.04$), and type III — in 137 cases ($68.5\% \pm 3.28$).

In *Macacus cynomolgus* type I was found in 5 cases ($5.0\% \pm 2.18$), type II — in 30 cases ($30.0\% \pm 4.58$), type III — in 65 cases ($65.0\% \pm 4.77$).

The origin of the roots of the phrenic nerve

In man the phrenic nerve in type I was always observed to arise from C_4 , in type II — from C_3 and C_4 in 4 cases ($8.0\% \pm 3.84$) and from C_4 and C_5 in 23 cases ($46.0\% \pm 7.05$). In type III the roots of the phrenic nerve extended from C_3 , C_4 and C_5 in 4 cases ($8.0\% \pm 3.84$); in one case 2 roots arose from C_4 and one root from C_5 ($2.0\% \pm 1.41$).

In *Macacus rhesus* the phrenic nerve (type I) arose from C_4 in 4 cases ($2.0\% \pm 0.99$) and from C_5 in 10 cases ($5.0\% \pm 1.54$). In type II the phrenic nerve took separate roots from C_4 and C_5 . This type was found in 29 cases ($14.5\% \pm 2.49$). In 3 cases ($1.5\% \pm 0.85$) one root of the phrenic nerve arose from C_4 , while another arose from the subclavian nerve (Fig. 14). In 17 cases ($8.5\% \pm 1.97$) one root arose from C_5 , another from the subclavian nerve (Fig. 15). In type III the phrenic nerve had three roots arising separately from C_4 , C_5 and the subclavian nerve (Fig. 11).

In *Macacus cynomolgus* (type I) the phrenic nerve arose from C_4 in one case ($1.0\% \pm 0.99$) and from C_5 in 4 cases ($4.0\% \pm 1.96$). In type II the phrenic nerve in 20 cases ($20.0\% \pm 4.00$) took one root from C_4 while another extended from C_5 (Fig. 13). In 10 cases ($10.0\% \pm 3.00$) one root of the phrenic nerve arose from C_5 , another from the subclavian nerve. The roots of the phrenic nerve (type III) arose from C_4 , C_5 and the subclavian nerve in all cases (Fig. 12).

Table 1 presents the origin of the roots of the phrenic nerve in man and *Macacus* monkeys with reference to sex and side of body.

Spinal nerves forming the phrenic nerve

In man the phrenic nerve is formed by fibres which arise from C_3 in 8 cases ($16.0\% \pm 5.18$), C_4 — in 50 cases (100.0%) and C_5 — in 28 cases ($56.0\% \pm 7.02$).

In *Macacus rhesus* this nerve is composed of fibres arising from C_4 in 173 cases ($86.5\% \pm 2.42$), C_5 — in 196 cases ($98.0\% \pm 0.99$), and C_6 — in 157 cases ($78.5\% \pm 2.90$).

Table 1. The origin of the roots of the phrenic nerve in man and *Macacus*

Type	The roots forming the phrenic nerve						MACACUS RHESUS						MACACUS CYNOMOLGUS					
	♂			♀			♂			♀			♂			♀		
	R %	L %	Tog- ther %	R %	L %	Tog- ther %	R %	L %	Tog- ther %	R %	L %	Tog- ther %	R %	L %	Tog- ther %	R %	L %	Tog- ther %
I	C ₄	8.0	10.0	36.0	0.5	0.5	0.5	0.5	2.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0
	C ₅				1.5	1.0	1.5	1.0	1.5	1.0	1.5	5.0	2.0	1.0	4.0	2.0	1.0	4.0
II	C ₃ , C ₄	4.0	2.0	8.0														
	C ₄ , C ₅	14.0	10.0	46.0	3.5	6.0	3.0	3.0	2.0	6.0	2.0	14.5	2.0	6.0	5.0	7.0	20.0	
	C ₄ and from n. <i>subclavius</i>				0.5		1.0					1.5						
	C ₅ and from n. <i>subclavius</i>				2.0	2.5	2.0	2.0	2.0	2.0	2.0	8.5	5.0	2.0	2.0	1.0	10.0	
III	C ₃ , C ₄ , C ₅		2.0	8.0	2.0	4.0												
	C ₄ , C ₅	2.0		2.0														
	C ₄ , C ₅ and from n. <i>subclavius</i>				18.0	16.0	16.5	18.0	68.5	15.0	15.0	18.0	18.0	15.0	17.0	65.0		

In *Macacus cynomolgus* the fibres of the phrenic nerve arose from C₄ in 86 cases ($86.0\% \pm 3.47$), C₅ — in 99 cases ($99.0\% \pm 0.09$) and C₆ — in 75 cases ($75.0\% \pm 4.33$).

In *Macacus* monkeys the fibres of the phrenic nerve from C₆ emerged by the root arising from the subclavian nerve.

The thickness of the roots of the phrenic nerve

When the phrenic nerve in man was formed by the roots arising from C₃ and C₄, the root from C₄ was always thicker than that from C₃. If the phrenic nerve was formed by the roots from C₄ and C₅, the root from C₄ was thicker in 22 cases and that from C₅ — only in one case. In 15 cases out of the 22 mentioned above, the root from C₅ was very thin. The thickest root of the phrenic nerve, formed by the fibres arising from C₃, C₄ and C₅, was that which arose from C₄. The second in thickness was the root from C₅ in 3 cases, and that from C₃ in one case. In one case when the phrenic nerve was formed by two separate roots from C₄ and by one root from C₅, the thinnest one was also from C₄.

In conclusion, the human phrenic nerve or its main root was made up by the fibres arising from C₄ in 49 cases ($98.0\% \pm 1.41$), while in one case ($2.0\% \pm 1.41$) the fibres from C₅ formed the main root of the phrenic nerve.

In *Macacus rhesus* the phrenic nerve formed by fibres arising from C₄ and C₅, had the roots thicker in 8 and 18 cases from C₄ and C₅, respectively. In three cases the roots from C₄ and C₅ were equal in thickness. The phrenic nerve formed by the fibres arising from C₄ and the subclavian nerve had that root thicker which arose from C₄. The phrenic

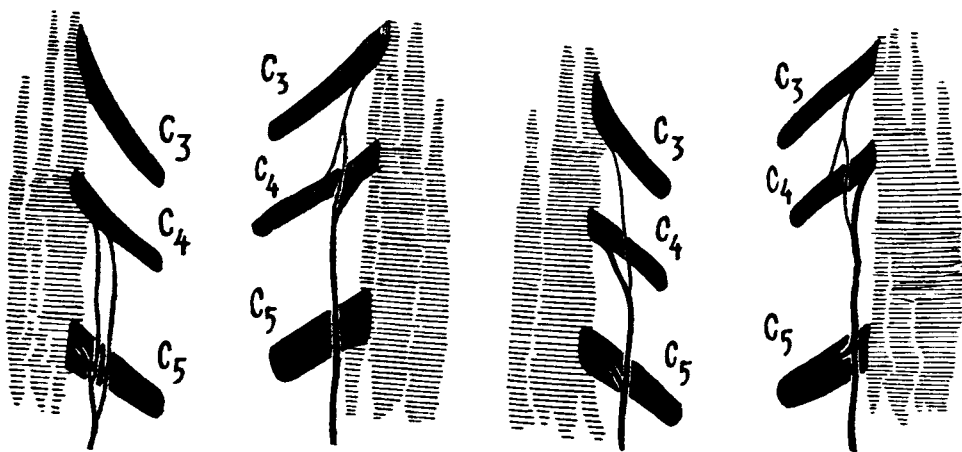


Fig. 1—4. Variations of the phrenic nerve in man

nerve, formed by the fibres arising from C_5 and the subclavian nerve, had that root thicker which arose from C_5 . The above mentioned nerve, formed by the roots arising from C_4 and C_5 and the subclavian nerve, had those roots thicker which arose from C_5 and C_4 in 117 and 5 cases, respectively. In 15 cases the roots from C_4 and C_5 were equal in thickness. The next in thickness was the root from C_4 found in 58 cases and the root from the subclavian nerve, observed in 34 cases. In 30 cases the roots from C_4 and the subclavian nerve were equal in thickness.

In *Macacus rhesus* the phrenic nerve or its main root were found to set off fibres from C_4 and C_5 in 20 ($10.0\% \pm 2.12$) and 162 cases ($81.0\% \pm 2.77$), respectively.

In *Macacus cynomolgus* the phrenic nerve, formed by the fibres from C_4 and C_5 , had its thicker roots arising from C_4 in 4 cases and those from C_5 in 10 cases. In 6 cases the roots arising both from C_4 and C_5 were equal in thickness. The phrenic nerve formed by the roots arising from C_5 and the subclavian nerve had that root thicker which extended from C_5 . The phrenic nerve, formed by the roots extending from C_4 , C_5 and the subclavian nerve, in 56 cases had the thickest root arising from C_5 , in 3 cases — from C_4 . In 6 cases the roots from C_4 and C_5 were equal in thickness. The next in thickness was the root from C_4 in 30 cases, and that arising from the subclavian nerve in 15 cases. In 14 cases the roots from C_4 and the subclavian nerve were equal in thickness.

In *Macacus cynomolgus* the phrenic nerve or its main root set off fibres from C_4 in 8 cases ($8.0\% \pm 2.71$) and C_5 in 80 cases ($80.0\% \pm 4.00$).

Topography of the roots of the phrenic nerve

In man the root of the phrenic nerve, which arose from C_3 ran downwards, passed anteriorly off the ventral ramus of the fourth spinal cervical nerve, and in 7 cases, at a distance of 0.5—1.0 cm below this nerve, communicated with the root arising from C_4 . In one case the root from C_3 ran laterally off the anterior slanting muscle, continued to pass in front of the subclavian vein, and at a distance of 2 cm below it the root from C_3 united with the root from C_4 . The root of the phrenic nerve which originated from C_4 ran laterally off the anterior slanting muscle, continued in front of the ventral ramus of the spinal fifth cervical nerve, entered on the anterior slanting muscle, and penetrated the thorax outside the subclavian vein. In one case another root from C_4 united with the phrenic nerve. It ran laterally from the main root of the phrenic nerve, continued on the anterior slanting muscle and came into union with combined roots from C_4 and C_5 , at the level of the sixth cervical nerve (Fig. 1). The phrenic root from C_5 was the shortest. In 23 cases it united with the root from C_4 (Fig. 2) and in two cases with combined

C₃ and C₄ roots (Fig. 3), at the level of the ventral ramus of the fifth spinal cervical nerve or at a distance of 0.5—1.0 cm below it. In one case the root from C₅ reached the root from C₄, and in one case it fused with the combined roots from C₃ and C₄ on the slanting anterior muscle. In one case the phrenic root from C₅ came into fusion with joint roots from C₃ and C₄ in the upper part of the thorax.

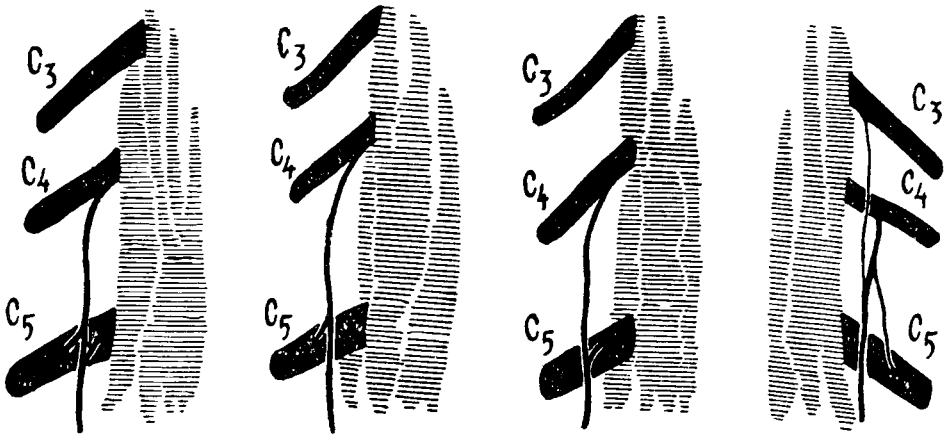


Fig. 5—8. Variations of the phrenic nerve in man

In *Macacus* monkeys the phrenic root from C₄ ran on the slanting anterior muscle and entered the thorax (Fig. 14) outside the subclavian vein. The root from C₅ was observed to lie below the slanting anterior muscle; next, it emerged out of it and ran at a shorter or longer distance laterally off the slanting anterior muscle, in the majority of cases entered on it and penetrated the thorax outside the subclavian vein (Figs. 11, 12, 15). In *Macacus rhesus*, in one case, the phrenic root from C₅ penetrated the anterior slanting muscle and entered on its anterior surface. In some cases, in *Macacus rhesus* and *Macacus cynomolgus*, the root from C₅ ran laterally off the anterior slanting muscle, joined the root arising from the subclavian nerve and entered the thorax outside the subclavian vein. The root of the phrenic nerve arising from the subclavian nerve ran downwards and medially, passed in front of the ventral branches of the spinal C₇ and C₈ nerves, and entered the thorax, mostly, in front of the subclavian vein (Figs. 11, 15).

The fusion of the phrenic roots into a common trunk in *Macacus* monkeys was noted mostly just below the subclavian vein or inside the upper part of the thorax.

The root from C₄ fused with the root from C₅ above the subclavian vein in 115 cases (57.5% ± 3.49) in *Macacus rhesus*, and in 61 cases

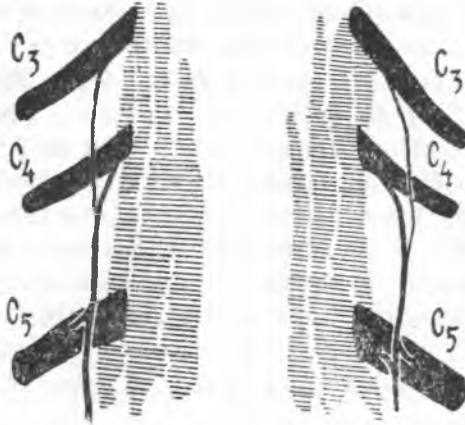


Fig. 9—10. Variations of the phrenic nerve in man

(61.0% \pm 4.86) in *Macacus cynomolgus*. It fused with the root from C₃ at the level of the subclavian vein in 4 cases (2.0% \pm 0.99) in *Macacus rhesus*, and in 3 cases (3.0% \pm 1.70) in *Macacus cynomolgus*. It united with the root from C₅ just below the subclavian vein in 10 cases



Fig. 11. The phrenic nerve in *Macacus rhesus* formed by the roots from C₄, C₅ and from subclavius nerve. Explanations: 1 — *nervus phrenicus*, 2 — *radix nervi phrenici ex C₄*, 3 — *radix nervi phrenici ex C₅*, 4 — *radix nervi phrenici ex nervo subclavio*, 5 — *vena subclavia*

(5.0% \pm 1.54) in *Macacus rhesus* and in 4 cases (4.0% \pm 1.96) in *Macacus cynomolgus*, and in the upper part of the thorax in 6 cases (3.0% \pm 1.20) in *Macacus rhesus*, and in 2 cases (2.0% \pm 1.40) in *Macacus cynomolgus*. Besides, the root from C₄ united with the root, arising from the subclavian nerve, just below the subclavian vein in 3 cases (1.5% \pm 0.85) in *Macacus rhesus*. The root from C₄ came into union with the joint roots arising from C₅ and the subclavian nerve above the subclavian vein in 3 cases (1.5% \pm 0.85) in *Macacus rhesus*, and in one case (1.0% \pm 0.99) in *Macacus cynomolgus*; at the level of the subclavian vein — in 2 cases (1.0% \pm 0.70) in *Macacus rhesus*, and in one case (1.0% \pm 0.99) in *Macacus cynomolgus*; and just below the subclavian vein in 5 cases (2.5% \pm 1.10) in *Macacus rhesus*, and in 4 cases (4.0% \pm 1.96) in *Macacus cynomolgus*.

The root from C₅ united with the root arising from the subclavian nerve above the subclavian vein in 4 cases (2.0% \pm 0.99) in *Macacus rhesus*, and in 2 cases (2.0% \pm 1.40) in *Macacus cynomolgus*; just below the subclavian vein — in 10 cases (5.0% \pm 1.54) in *Macacus rhesus*, and in 6 cases (6.0% \pm 2.37) in *Macacus cynomolgus*; and in the upper part



Fig. 12. The phrenic nerve in *Macacus cynomolgus* formed by the roots from C₄, C₅ and from the *subclavius* nerve. For explanations see Fig. 11

of the thorax — in 3 cases ($1.5\% \pm 0.85$) in *Macacus rhesus*, and in 2 cases ($2.0\% \pm 1.40$) in *Macacus cynomolgus*.

The root of the phrenic nerve extending from the subclavian nerve came into union with the combined roots of the same phrenic nerve arising separately from C₄ and C₅ in 106 cases ($53.0\% \pm 3.53$) in *Macacus rhesus*, and in 50 cases ($50.0\% \pm 5.0$) in *Macacus cynomolgus*. This union took place just below the subclavian vein in 82 cases ($41.0\% \pm 3.47$) in *Macacus rhesus*, and in 40 cases ($40.0\% \pm 4.90$) in *Macacus cynomolgus*. It also took place in the upper part of the thorax in 24 cases ($12.0\% \pm 2.30$) in *Macacus rhesus* and in 10 cases ($10.0\% \pm 3.0$) in *Macacus cynomolgus*.

The phrenic nerve was formed by the simultaneous fusion of 3 roots: those arising from C₄, C₅ and the subclavian nerve in 21 cases ($10.5\% \pm 2.16$) in *Macacus rhesus*, and in 9 cases ($9.0\% \pm 2.86$) in *Macacus cynomolgus* (Fig. 12). The fusion took also place below the subclavian vein in 11 cases ($5.5\% \pm 1.61$) in *Macacus rhesus*, and in 6 cases ($6.0\% \pm 2.37$) in *Macacus cynomolgus*; and in the upper part of the thorax in 10 cases ($5.0\% \pm 1.54$) in *Macacus rhesus*, and in 3 cases ($3.0\% \pm 1.70$) in *Macacus cynomolgus*.

Connections of the phrenic nerve with spinal nerves

In man, the phrenic nerve or its roots gave off branches to spinal nerves in 20 cases ($40.0\% \pm 6.93$). Out of these 20 cases, the branches were sent off to the ventral ramus of the spinal nerve C₄ in one case (Fig. 6); to C₄ and C₅ — in 3 cases (Fig. 4); to C₅ — in 14 cases (Figs. 5, 7); to the suprascapular nerve — in one case, and to the suprascapular nerve and the posterior branch of the superior trunk of the branchial plexus — in one case.

The branch communicating to C₄ separated from the phrenic root arising from C₃, at a distance of 1 to 2 cm below its emergence, ran laterally and entered the ventral ramus of the fourth cervical nerve. In these cases the phrenic nerve was formed by two roots: one from C₃ and another from C₄ (Fig. 6).

In seven cases, the branch communicating to C₅ separated from the phrenic nerve formed exclusively by C₄ (Fig. 7), and in 6 cases — from the root of this nerve originating from C₄. In these 6 cases the phrenic nerve was formed by combined roots from C₃ and C₄ in one case (Fig. 8), and from C₄ and C₅ — in 5 cases (Fig. 5). Out of the other remaining 4 cases, the branch communicating to C₅ separated from the phrenic nerve formed by C₃ and C₄ in 3 cases (Fig. 9), and from the combined roots of C₃ and C₄ — in one case (Fig. 10). In this last case, the phrenic nerve was formed by roots of C₃, C₄ and C₅. In the above mentioned 4 cases, the branch communicating to the ventral ramus of C₅ contained

the fibres from C₄ only. The branch communicating to C₅ separated from the phrenic nerve, or its roots, at the level of the ventral ramus of C₅, or somewhat above, deviated laterally, ran along this nerve and, finally, entered it.



Fig. 13. The phrenic nerve in *Macacus cynomolgus* formed by the roots from C₄ and C₅.
For explanations see Fig. 11

The branch communicating to the suprascapular nerve as well as to the posterior branch of superior trunk of the brachial plexus separated from the phrenic nerve formed only by C₄.

The connection of the phrenic nerve with the subclavian nerve is characteristic of *Macacus* monkeys, as reported in our previous paper (13). In 232 out of 300 examined cases ($77.0\% \pm 2.42$), one of the roots of the phrenic nerve originated from the subclavian nerve. In most cases, this root of the phrenic nerve was larger than the subclavian nerve. Therefore, the definition: "the root of the phrenic nerve reaches the subclavian nerve" is not always correct. It is better to speak of common separation of these nerve branches.

DISCUSSION

The phrenic nerve may form roots of the spinal nerves from C₂ to C₇. Table 2 presents the participation of the spinal nerves in the structure of the human phrenic nerve.

Table 2. The participation of spinal nerves in the formation of the phrenic nerve in man

Authors	Number of the cases examined	Spinal nerves			
		C ₂	C ₃	C ₄	C ₅
		%	%	%	%
FRANK	5		20.0	100.0	100.0
LUSCHKA	32		40.6	100.0	43.8
TROJANOWSKI	100	4.0	11.0	100.0	64.0
URBANOWICZ and ZAŁUSKA	50		16.0	100.0	56.0
YANO	22		4.5	100.0	59.1
Together	209	2.0	16.3	100.0	59.3

It results from Table 2 that, in man, the phrenic nerve may consist of the fibres of the spinal nerves from C₂ to C₅. The fibres from C₄ always take part in the structure of this nerve. The fibres from C₅ take part relatively often in its structure, i.e. in 59.3% of cases, but, according to us, they form the main root of the phrenic nerve only in 2.0% of cases.

Table 3. The phrenic nerve in man

Authors	TROJANOWSKI	LUSCHKA	FRANK	YANO	URBANOWICZ ZAŁUSKA	TOGETHER
	No. of cases	%	%	%	%	%
Spinal nerves forming the phrenic nerve	100	32	5	22	50	209
C ₂ , C ₃ , C ₄	2.0					1.0
C ₃ , C ₄	4.0	18.7		4.5	8.0	7.1
C ₄	30.0	37.5		36.4	36.0	32.5
C ₂ , C ₃ , C ₄ , C ₅	2.0					1.0
C ₃ , C ₄ , C ₅	3.0	21.9	20.0		8.0	7.1
C ₄ , C ₅	59.0	15.6	80.0	59.1	48.0	50.2
C ₄ , C ₅ + <i>plex. brach.</i>		6.3				1.0

Reports concerning the frequency of occurrence of the fibres from C_3 in the phrenic nerve are controversial. Luschka (10) found them in 40.6%, while Yano (14) only in 4.5% of cases. We found them in 16.0% of cases. The fibres from C_2 rarely participate in the formation of the phrenic nerve. Trojanowski found them only in 4.0% of cases (12).

The human phrenic nerve may consist of one, two, three or four roots. Table 3 presents the frequency of patterns of the phrenic nerve in man with respect to the number of roots and their origin.

Table 3 shows that the human phrenic nerve is made up mostly by two roots: from C_4 and C_5 or by one root: from C_4 . Other patterns are less frequently found, as confirmed by our investigations.

Apart from the human phrenic nerve, the occurrence of an additional phrenic nerve is often noted in man. It consists of fibres from the C_3 , C_4 and C_5 nerves or from the subclavian nerve (2, 15). This additional phrenic nerve was observed by Yano (15) in 61.8% of cases out of 220 subjects examined. The phrenic nerve in *Bovidae* and *Equidae* is formed



Fig. 14. The phrenic nerve in *Macacus rhesus* formed by the roots from C_4 and subclavius nerve. For explanations see Fig. 11

Table 4. The roots which form the phrenic nerve in *Primates*

Animals	The branches forming the nerve	Authors
<i>PROSIMIAE</i> <i>Lemur</i>	C ₄ , C ₅ C ₄ , C ₅ , C ₆ C ₅ , C ₆	Narkiewicz Bolk, Narkiewicz Narkiewicz
<i>Lepilemur</i>	C ₄ , C ₅ , C ₆	Bolk
<i>Propithecus</i>	C ₅ , C ₆	Bolk
<i>Perodicticus</i>	C ₄ , C ₅ , C ₆	Bolk
<i>Galago</i>	C ₄ , C ₅ , C ₆	Kanagasuntheram and Mahran
<i>SIMIAE</i> <i>PLATYRRHINA</i> <i>Aotes</i>	C ₄ , C ₅ , C ₆	Bolk
<i>Alouatta</i>	C ₄ , C ₅ , C ₆	Bolk
<i>Saimiri</i>	C ₄ , C ₅	Bolk
<i>Cebus</i>	C ₄ C ₄ , C ₅ C ₄ , C ₅ , C ₆	Narkiewicz Narkiewicz Bolk
<i>Ateles</i>	C ₄ , C ₅ C ₄ , C ₅ , C ₆	Narkiewicz Bolk, Narkiewicz
<i>Leontocebus</i>	C ₃ , C ₄ , C ₅ , C ₆	Bolk
<i>CATARRHINA</i> <i>Macacus</i>	C ₄ C ₄ , C ₅ C ₄ , C ₅ , C ₆ C ₅ C ₅ , C ₆	Urbanowicz and Załuska Narkiewicz, Urbanowicz and Załuska Bolk, Kurz, Narkiewicz, Urbanowicz and Załuska Urbanowicz and Załuska Narkiewicz, Urbanowicz and Załuska
<i>Papio</i>	C ₄ C ₄ , C ₅ C ₄ , C ₅ , C ₆ C ₅ , C ₆	Narkiewicz Narkiewicz Bolk Bolk
<i>Cercopithecus</i>	C ₄ C ₄ , C ₅ C ₅ , C ₆ , C ₇	Narkiewicz Bolk, Narkiewicz Narkiewicz
<i>Semnopithecus</i> <i>Colobus</i> <i>Hylobates</i> <i>Pongo</i> <i>Pan</i> <i>Gorilla</i>	C ₄ , C ₅ , C ₆ C ₄ , C ₅ , C ₆ C ₄ , C ₅ C ₄ , C ₅ C ₃ , C ₄ , C ₅ C ₃ , C ₄ , C ₅	Bolk, Narkiewicz Bolk Bolk Bolk Bolk Raven

by the roots from C₅, C₆ and C₇ (9). In the rat the phrenic nerve is made up by the roots from C₄, C₅ and C₆ (6). The arrangement of roots of spinal nerves in monkeys is presented in Table 4.

It results from Table 4 that the highest root of the phrenic nerve in lower monkeys has the fibres from C₄, the lowest — from C₆. Bolk (3) found only in *Leontocebus* a concurrent occurrence of the fibres from C₃ and C₆ in the structure of the phrenic nerve. In higher monkeys the phrenic nerve may be made up by the fibres from C₄, C₅ and C₆, with the absence of the root from C₆ in some species. The absence of the root from C₆ is a common feature of the anthropoid monkeys in which the root from C₃ may occasionally occur.



Fig. 15. The phrenic nerve in *Macacus rhesus* formed by the roots from C₅ and *subclavius* nerve. For explanations see Fig. 11

In domestic animals the phrenic nerve extends only from the brachial plexus, and its origin starts from C₇. In lower monkeys the root from C₇ disappears and the root from C₄ occurs. As a result of this, the phrenic nerve in those monkeys arises both from the brachial plexus and from the cervical plexus. In higher monkeys the occasional absence of the root from C₆ is observed with the occurrence of the root from C₃. In man the continuation of "the ascending" of the origin of the phrenic nerve is also observed. It means a considerable reduction of the root from C₅ and the occurrence of these from C₃ and C₂. Thus the phrenic nerve in man arises only from the cervical plexus, as stated in 40.6% of cases.

It results from the above studies that the participation of the roots from C₇ and C₆ in formation of the phrenic nerve is found to be a primitive feature, while the absence of those roots and a certain amount of reduction of the roots from C₅, as well as the occurrence of the root from C₃ and C₂, are to be regarded as progressive features. The phrenic nerve in *Macacus* monkeys is found to be of primitive type.

CONCLUSIONS

1. In our investigations the phrenic nerve in man was mostly formed by one or two roots, rarely by three roots.
2. The fibres from C₄, C₅ and C₃ had respectively high, low and very low participation in the structure of the human phrenic nerve.
3. The morphology and topography of the phrenic nerve in *Macacus rhesus* and *Macacus cynomolgus* were found to be alike.
4. The phrenic nerve in *Macacus* was usually formed by three roots, less frequently by two roots and, exceptionally rarely, by one root.
5. The fibres from C₅, C₄ and C₆ had respectively high, low and very low participation in the structure of the phrenic nerve in *Macacus* monkeys.
6. The phrenic nerve in *Macacus* was primitive in type.
7. The connection of the phrenic nerve with the subclavian nerve was often noted in the *Macacus* monkeys.
8. No significant differences in respect to sex and body side were observed in the structure of the phrenic nerve in man and of that in *Macacus* monkeys.

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Zmienność odejścia i połączeń n. przeponowego u człowieka i makaków

Streszczenie

Na 25 zwłokach ludzkich, 100 osobnikach *Macacus rhesus* i 50 osobnikach *Macacus cynomolgus* zbadano obustronnie zmienność odejścia i połączeń n. przeponowego.

U człowieka n. przeponowy w większości przypadków tworzyły dwa korzenie, rzadziej — jeden i niekiedy trzy korzenie, a największy udział w jego budowie miały włókna z C₄, mniejszy — z C₅ i najmniejszy — z C₃.

U *Macacus rhesus* i *Macacus cynomolgus* morfologia i topografia n. przeponowego były podobne. Nerw przeponowy u makaków w większości przypadków tworzyły trzy korzenie, rzadziej — dwa i wyjątkowo — jeden korzeń, a największy udział w jego budowie miały włókna z C₅, mniejszy — z C₄ i najmniejszy — z C₆. Jeden z korzeni n. przeponowego u makaków wychodził zazwyczaj ze splotu ramiennego wspólnie z n. podobojczykowym.

Ryc. 1—10. Odmiany n. przeponowego u człowieka.

Ryc. 11. Nerw przeponowy u *Macacus rhesus* utworzony przez korzenie od C₄, C₅ i od n. podobojczykowego.

Ryc. 12. Nerw przeponowy u *Macacus cynomolgus* utworzony przez korzenie od C₄, C₅ i od n. podobojczykowego.

Ryc. 13. Nerw przeponowy u *Macacus cynomolgus* utworzony przez korzenie od C₄ i C₅.

Ryc. 14. Nerw przeponowy u *Macacus rhesus* utworzony przez korzenie od C₄ i od n. podobojczykowego.

Ryc. 15. Nerw przeponowy u *Macacus rhesus* utworzony przez korzenie od C₅ i od n. podobojczykowego.

Tab. 1. Pochodzenie korzeni n. przeponowego u człowieka i makaków.

Tab. 2. Udział nerwów rdzeniowych w utworzeniu n. przeponowego u człowieka.

Tab. 3. Nerw przeponowy u człowieka.

Tab. 4. Korzenie tworzące n. przeponowy u naczelných.

Вариабильность ухода и соединений диафрагмального нерва у человека и макака

Резюме

Билатерально исследована вариабильность ухода и соединений диафрагмального нерва на 25 трупах человека, 100 особях *Macacus rhesus* и 50 *Macacus cynomolgus*.

У человека диафрагмальный нерв в большинстве случаев образовывал два корня, реже — один, иногда три корня, а самое большое участие в его строении принимали волокна, состоящие из C_4 , меньшее — из C_5 , и самое малое — из C_3 .

У *Macacus rhesus* и *Macacus cynomolgus* морфология и топография диафрагмального нерва были похожи. Диафрагмальный нерв у макака в большинстве случаев образовывал три корня, реже — два, в редких случаях — один корень, самое большое участие в его строении принимали волокна, состоящие из C_5 , меньшее — из C_4 и самое малое — из C_6 . Один из корней диафрагмального нерва у макака выходил преимущественно из плечевого сплетения вместе с подключичным нервом.

Рис. 1—4. Варианты диафрагмального нерва у человека.

Рис. 5—8. Варианты диафрагмального нерва у человека.

Рис. 9—10. Варианты диафрагмального нерва у человека.

Рис. 11. Диафрагмальный нерв у *Macacus rhesus*, образованный корнями от C_4 и C_5 и от подключичного нерва.

Рис. 12. Диафрагмальный нерв у *Macacus cynomolgus*, образованный корнями от C_4 и C_5 и от подключичного нерва.

Рис. 13. Диафрагмальный нерв у *Macacus cynomolgus*, образованный корнями от C_4 и C_5 .

Рис. 14. Диафрагмальный нерв у *Macacus rhesus*, образованный корнями от C_4 и от подключичного нерва.

Рис. 15. Диафрагмальный нерв у *Macacus rhesus*, образованный корнями от C_5 и от подключичного нерва.

Табл. 1. Происхождение корней диафрагмального нерва у человека и макака.

Табл. 2. Участие спинномозговых нервов в образовании диафрагмального нерва у человека.

Табл. 3. Диафрагмальный нерв у человека.

Табл. 4. Корни, образующие диафрагмальный нерв у приматов.

