On the Plexus brachialis of Macacus cyclopsis

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An investigation of the Plexus brachialis of Formosan monkey, Macacus cyclopsis, was done in which the nerve roots which contribute to its formation, and the primary and secondary nerve cords (Truncus and Fasciculus) were studied along with the classification of the types of Plexus brachialis. The most frequent type, that is the typical type of plexus in Macacus cyclopsis was the same as in other macaques and man, but the range of roots which contribute to the formation of the plexus in Macacus cyclopsis may be said to be of the postfixed type in comparison with man.

The general pattern of the Plexus brachialis in Genus Macaca in particular, may be considered to have been elucidated by the many studies that have been done on monkey, including the statistical observation of a large number of cases, by M. ONO (1936), R.E. CHASE and C.F. DE GARIS (1940), S. HORIUCHI (1942), etc.

Nevertheless, the author having had the opportunity to conduct statistical investigation of the Plexus brachialis in a comparatively large number of cases, as part of the statistical anatomical study of Macacus cyclopsis in progress at this department shall report on the findings obtained and, in addition, discuss the low position of the nerve roots that form the Plexus brachialis in relation to the various patterns of the Plexus brachialis as well as describe the differences between man and other monkeys and apes, in order to supplement the previous reports.

MATERIAL AND METHOD

The material for this study consisted of both sides of the body of 30 adult Formosan monkeys, Macacus cyclopsis (male 18, female 12).
selected at random among the collection of Prof. Satoh. These specimen, after capture and strangulation, had been fixed immediately by the injection of 10% formalin solution into the A. femoralis and preserved in this solution.

The method of inspection involved gross anatomical observation and whenever necessary 3 × and 5 × magnifying lenses were used to insure accuracy of the findings.

FINDINGS AND CONSIDERATION

I. Nerve roots forming the Plexus brachialis

1) There are 34 pairs of spinal nerves in Macacus cyclops including 8 cervicals, 12 thoracics, 7 lumbar, 3 sacral and 4 caudal, but the nerve roots that form the Plexus brachialis range from C₄ to T₂. Among these, the 5 nerve roots from C₅ to T₁ always contribute to the plexus, while T₂ contributes in most cases (91.2%), but C₄ is rarely associated (8.3%).

As suggested in such previous studies as the investigation of Fig. 1
mammals by Reimer and the study of non-mammals by Furbringer, contributions to the formation of the Plexus brachialis are by higher position nerve roots as the animal becomes more advanced, phylogenetically (cephalic migration). Sherrington, Todd, etc. have also reported a similar relation in primates.

In other words, a summary of the situation in primates indicates that C₅—T₁ are always involved in prosimians and platyrrhini with additional contribution by T₂ in very rare instances, but C₄ never contributes. In catarrhini, however, participation of C₄ and T₂ begins to appear. Todd claims that it is rare in Cercopithecidae for the contribution by T₂ to be absent and Bolk reports that contribution by T₂ is characteristic of lower catarrhini. Furthermore, Hirasawa mentions that Kohlbrugge has noted the participation of C₃ in Semnopithecus, but unfortunately the original manuscript could not be obtained so that the frequency of this is unknown. Nevertheless, this is a noteworthy finding.

In macaques, which have been studied statistically in comparatively large numbers (De Garis, Horiuchi, Ono), C₅—T₁ are received consistently in all species while contribution by C₄ is infrequent. In particular, in the study by Ono, C₄ is absent in Macacus cyclops, M. cynomolgus and M. irus, on the contrary the frequency of the appearance of T₂ in Macacus irus is 100%. In the study by Horiuchi, the frequency of C₄ in Macacus fuscatus is 50%.

Such marked differences have been seen not only by Ono but also in the Macacus fuscatus by Horiuchi and further the absence of T₂ has been noted by Brooks in contrast to the finding in the cases of Todd. However, it should be noted that such differences have been seen when the number of cases examined is small. In other words, these differences should be regarded as variations due to the small number of cases examined and it is appropriate to consider that for Genus maeaca at least C₅—T₁ are always received with the presence of T₂ in most cases, while C₄ rarely contributes to the formation of the plexus as seen in Macacus cyclops of Horiuchi and myself, and in Macacus rhesus of Horiuchi and De Garis.

In anthropoid apes, there is greater contribution by C₄ and there are some who claim that the formation in gibbon is by only C₆—C₈ (Chemén and Iribonau, Kohlbrugge), but it is usually said to be formed by C₅—T₁ (Bolk) with contribution by C₄, T₂ in rare cases (Bolk, Hill).

In orang utan, the formation is by C₄—T₂ but by C₄—T₁ in gorilla and chimpanzee. Moreover, the contribution by T₁ is minor.

For these anthropoid apes, the number of cases examined and frequency, etc., are unknown and although a definite statement is not possible, it is felt that the contribution by C₄ is still inconsistent in gibbon and gradually begins to increase from other anthropoid apes.
On the other hand, in man, the 8 roots from C₃ to Th₃ usually contribute. Of these, the 5 roots from C₃ to T₁ always are involved in the formation of the nerve plexus, but in contrast to the situation in monkey, there is greater participation by C₆ with lesser contribution by T₃ and in some instances T₂ is not found at all. Further, contribution by C₃ to the formation of the plexus has been reported by some to be absent (Koreans, Kawasaki; Americans, Kerr), or very infrequent (Japanese, Mori and Matsushita, Hirase, ARAKAWA) while others have noted it at a considerably high rate (Poles, Jachimowicz), but it rarely seems to participate to a greater degree than C₄.

With regard to these roots of origin, there are some reports such as by Jachimowicz in which the contribution by C₃ to the formation of the plexus is said to be quite frequent whereas in others it is said to be absent. It also has been reported that the frequency of contribution by C₄ in Western countries (Cunningham, Jachimowicz, etc.) is about twice as frequent as in Japanese or Koreans (Hirasawa, ARAKAWA, Kawasaki), and at the same time, the frequency of contribution by T₂ is on the contrary extremely high which is similar to the condition in monkeys. These findings suggest that there may be considerable difference by race, but this problem will not be discussed here.

I shall only mention that in the formation of the plexus in man there is contribution by C₃, which is not seen in monkey, and a greater degree of participation by C₄, which is very infrequent in monkey, while on the contrary, contribution by T₂ frequently seen in monkey is infrequent.

In other words, the condition in man is prefixed in comparison with monkey, ape, etc., as indicated by Sherring, Todd, etc. In summary, in primates in the broad sense including man, the nerve roots which contribute to the formation become higher extending to C₄ and even to C₃ along with phylogenetic advance, and there is a change in the brachial plexus from the postfixed type to the prefixed type.

2) S. Horiuchi has made a classification into the following 4 types according to the number of roots which are involved in the formation of the Plexus brachialis of macaques monkey.

Type 1. Formation of the Plexus brachialis by 6 roots from C₄ to T₁
Type 2. Formation by 7 roots from C₄ to T₂
Type 3. Formation by 5 roots from C₃ to T₁
Type 4. Formation by 6 roots from C₃ to T₁

This classification was applied to my cases of Macacus cyclops. Most frequent is type 4 (86.7%) while the others, types 3 (5.0%), 2 (5.0%) and 1 (3.3%), were very infrequent (table 1).
Table 1. Classification of the types by the root contributing to the formation of the plexus

<table>
<thead>
<tr>
<th>Types</th>
<th>n (%)</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>C4 ~ T1</td>
<td>2 (3.3)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>C4 ~ T2</td>
<td>3 (5.0)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>III</td>
<td>C5 ~ T1</td>
<td>3 (5.0)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>IV</td>
<td>C5 ~ T2</td>
<td>52 (86.7)</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
</tbody>
</table>

Unfortunately, the findings of CHASE and De GARIS for *Macacus rhesus* cannot be classified by this method for comparison, but in the study of HORIUCHI on *Macacus cyclopsis* (100 sides) and *Macacus rhesus* (100 cases), type 4 was the most frequent (60.0%) followed in frequency by type 3 (32.0%) whereas in *Macacus fascicularis* (32 sides) type 3 predominated followed by type 4. In *Macacus fuscatus* (8 sides), type 1 was the most frequent with an equal rate of appearance of types 3 and 4 with no case of type 2. In the 6 cases of macaques monkey of BROOKS, the range was from C4 to T1, i.e., type 1. The species of macaque in his study is unknown. Nevertheless, there is a marked difference.

Table 2. Frequency of each root contributing to the formation of the plexus.

<table>
<thead>
<tr>
<th>Author</th>
<th>Species</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugiyama</td>
<td><em>Macacus cyclopsis</em></td>
<td>5 (8.3)</td>
<td>60 (100)</td>
<td>60 (100)</td>
<td>60 (100)</td>
<td>60 (100)</td>
<td>60 (100)</td>
<td>55 (91.2)</td>
<td></td>
</tr>
<tr>
<td>Chase and De Garis</td>
<td><em>M. rhesus</em></td>
<td>97 (36.9)</td>
<td>300 (100)</td>
<td>300 (100)</td>
<td>300 (100)</td>
<td>300 (100)</td>
<td>300 (100)</td>
<td>185 (86.4)</td>
<td></td>
</tr>
<tr>
<td>Horiuchi</td>
<td><em>M. cyclopsis</em></td>
<td>4 (8.0)</td>
<td>50 (100)</td>
<td>50 (100)</td>
<td>50 (100)</td>
<td>50 (100)</td>
<td>50 (100)</td>
<td>31 (62.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. rhesus</em></td>
<td>4 (8.0)</td>
<td>50 (100)</td>
<td>50 (100)</td>
<td>50 (100)</td>
<td>50 (100)</td>
<td>50 (100)</td>
<td>43 (86.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. fascicularis</em></td>
<td>3 (18.8)</td>
<td>16 (100)</td>
<td>16 (100)</td>
<td>16 (100)</td>
<td>16 (100)</td>
<td>16 (100)</td>
<td>7 (43.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. fuscatus</em></td>
<td>2 (50.0)</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>1 (25.0)</td>
<td></td>
</tr>
<tr>
<td>Ono</td>
<td><em>M. cyclopsis</em></td>
<td>8 (100)</td>
<td>8 (100)</td>
<td>8 (100)</td>
<td>8 (100)</td>
<td>8 (100)</td>
<td>8 (100)</td>
<td>2 (25.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. cynomologus</em></td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>4 (100)</td>
<td>2 (50.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. irus</em></td>
<td>6 (100)</td>
<td>6 (100)</td>
<td>6 (100)</td>
<td>6 (100)</td>
<td>6 (100)</td>
<td>6 (100)</td>
<td>6 (100)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>M. rhesus</em></td>
<td>4 (18.2)</td>
<td>22 (100)</td>
<td>22 (100)</td>
<td>22 (100)</td>
<td>22 (100)</td>
<td>22 (100)</td>
<td>19 (86.4)</td>
<td></td>
</tr>
</tbody>
</table>
from the former 2 reports and my own observations, but this is felt to be due to the small number of cases investigated rather than a difference by species.

This can also be said of the difference in the findings obtained by Ono who examined a comparatively small number of cases. According to Ono, the type most frequently seen is type 3 in *Macacus cyclops* (8 sides), types 3 and 4 in *Macacus cynomologus* (4 sides) and type 4 followed by type 3 in *Macacus irus* (6 sides) and *Macacus rhesus* (22 sides).

Thus, the inference drawn from these findings is that at least in macaques type 4 is the most commonly seen typical type followed in frequency by type 3.

On the other hand, in man, type 3 is reported to be predominant in Japanese fetus (Mori, Matsushita, 200 sides), Japanese adults (Hirasawa and Arakawa combined, 450 sides) and in Koreans (Kawasaki, 180 sides) while type 1 is most frequent in American whites (Kerr, 85 cases) and American negroes (Kerr, 90 cases) while type 2 is the greatest in Poles (Jachimowicz, 218 cases).

The observed difference from monkey is to be expected because, as mentioned previously, there is cephalic migration of the roots of origin and disappearance of the caudal portion with increasing phylogenetic advance.

II. Formation of the respective truncus and fasciculus of the Plexus brachialis

The various nerves which emerge from the cervical and thoracic nerve roots immediately unite or directly from a single trunk. This trunk separates into 3 trunks, namely, the Truncus superior, medius and inferior. Each trunk further separates into anterior and posterior branches. According to the combination of the various branches, the Fasciculus lateralis, Fasciculus posterior and Fasciculus medialis are formed.

First, the formation of the trunks are classified by the nerve roots which contribute and the condition of separation and union.

<p>| Table 3. Truncus superior |</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Cr, C5, C6</th>
<th>Cr, C7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>3 (5.0)</td>
<td>42 (70.0)</td>
<td>45 (75.0)</td>
</tr>
<tr>
<td>Group 2</td>
<td>7 (11.7)</td>
<td>7 (11.7)</td>
<td></td>
</tr>
<tr>
<td>Group 3</td>
<td>2 (3.3)</td>
<td>6 (10.0)</td>
<td>8 (13.3)</td>
</tr>
<tr>
<td>Total</td>
<td>5 (8.3)</td>
<td>55 (91.7)</td>
<td>60</td>
</tr>
</tbody>
</table>

A) Trunci superior, medius and inferior

1) Truncus superior (table 3, figure 2)

Truncus superior may be classified into the following 3 groups according to the pattern of the roots that contribute to their formation.
i) Group 1

The Truncus superior is formed by the union of C₅, C₆ and occasionally C₄. This trunk separates into anterior and posterior branches of which the anterior branch contributes to the formation of the Fasciculus lateralis while the posterior branch contributes to the Fasciculus posterior.

In my Macacus cyclops, this type was seen in 45 cases (75.0%) among which the participation of C₄ was seen in 3 cases (5.0%).

Horiuchi also has made a classification into 3 groups and this type corresponds to his Group I. In his findings also this type was seen in 42 cases (70.0%) of Macacus cyclops, 39 cases (78.0%) of Macacus rhesus, 15 cases (93.8%) of Macacus fascicularis and in 3 cases (75.0%) of Macacus fuscatus so that this may be regarded to be the most typical type in macaques.

In man, also, this type has been reported in 182 cases (91.0%) of Japanese fetus (Mori and Matsushita), 177 cases (88.5%) of Japanese adult (Hirasawa) and in 168 cases (93.3%) of adult Koreans (Kawasaki) so that it appears that the typical type in man is the same as in macaques.

ii) Group 2

In this group, the Truncus superior is formed by C₅ and C₆, but first C₅ separates into 2 branches of approximately equal size, one of which runs to the Fasciculus lateralis and the other unites with C₆. Moreover, the branch which joined C₆ separates further into anterior and posterior branches of which the posterior branch unites with the Fasciculus posterior and the anterior branch unites with the other branch from the C₅ to form the Fasciculus lateralis.

In the Macacus cyclops of the author, 7 cases (11.7%) were found.

This type was found by Horiuchi in 4 cases (6.7%) of Macacus cyclops and in 2 cases (4.0%) of Macacus rhesus but was absent in Macacus fascicularis and fuscatus. There is no mention of this type in man.
iii) Group 3

Strictly speaking, cases belonging to this group lack the Truncus superior. C₃, C⁶ and occasionally C₄ contribute to its formation, but C₅ and C₆ separate into anterior and posterior branches prior to their union. The two anterior branches join to form the Ramus anterior superior while the 2 posterior branches likewise unite to form the Ramus posterior.

This type was seen in 8 cases (13.3%) of my Macacus cyclopsis including 2 cases (3.3%) in which the participation by C₄ was noted.

This type corresponds to Group III of Horiuchi who has noted it in 12 cases (20.0%) of Macacus cyclopsis, 5 cases (10.0%) of Macacus rhesus and in 1 case (25.0%) of Macacus fuscatus while it was absent in Macacus fascicularis. In man, it has been reported in 13 cases (6.5%) of Japanese fetus (Mori and Matsushita), 6 cases (3.0%) of adult Japanese (Hirasawa), 3 cases (1.7%) of adult Koreans (Kawasaki) and in 14 cases (8.0%) of American whites and negroes (Kerr).

2) Truncus medius (figure 3)

Horiuchi has classified the structure of the Truncus medius in macaques into 6 groups, but no variation was seen in the Macacus cyclopsis of the author. That is, in all cases it is formed solely by C₇ which separates into anterior and posterior branches, of which the anterior branch becomes the Ramus anterior medius that unites with the Ramus anterior superior to form the Fasciculus lateralis while the posterior branch becomes the Ramus posterior medius which contributes to the formation of the Fasciculus posterior. No abnormality of bifurcation was seen.

Such a condition has been found by Horiuchi in 56 cases (93.3%) of Macacus cyclopsis, 44 cases (88.0%) of Macacus rhesus, 14 cases (87.5%) of Macacus fascicularis and in 4 cases (100.0%) of Macacus fuscatus. In man, it has been noted in 155 cases (77.5%) of Japanese fetus (Mori and Matsushita), 172 cases (86.0%) of adult Japanese (Hirasawa) and in 161 cases (89.4%) of adult Koreans (Kawasaki).

3) Truncus inferior (table 4, figure 4)

Horiuchi has made a classification into 4 groups of which groups 2 and 4 have further been subdivided into 7 and 2 subgroups, respectively. In the case of the author, it was possible to make a classification into
only 4 groups.

i) Group 1

In this type, formation is by C₈, T₁ and T₂, but there may be occasional absence of T₂. These 3 roots unite to form a single trunk which separates into 2 branches. The anterior branch termed the Ramus anterior inferior contributes to the formation of the Fasciculus medialis while the posterior branch which becomes the Ramus posterior contributes to the Fasciculus posterior.

In my *Macacus cyclopsis*, this type was seen in 49 cases (81.7%) including 2 cases (3.3%) in which T₂ did not participate in the formation of the main trunk.

This type corresponds to Group I of HORIUCHI who had noted it in 50 cases (83.3%) of *Macacus cyclopsis*, 39 cases (78.0%) of *Macacus rhesus*, 15 cases (93.8%) of *Macacus fascicularis* and in 4 cases (100%) of *Macacus fuscatus* so that this may be regarded as the typical type in macaque.

In man, it has been reported in 176 cases (88.0%) of Japanese fetus (MORI and MATSUISHITA), 179 cases (89.5%) of Japanese adults (HIRASAWA), 153 cases (85.0%) of adult Koreans (KAWASAKI) and in 166 cases (95.0%) of American whites and negroes (KERR).
Therefore, this may be regarded as being the typical type in man also with little difference in frequency between the two.

ii) Group 2

This type is formed by C₄, T₁, and T₂, but in the strict sense, the Truncus inferior is absent.

That is, both of C₄ and T₁ first separate into 2 branches, respectively, and the 2 anterior branches unite to form the Ramus anterior inferior which becomes the Fasciculus medialis while the 2 posterior branches unite to form the Ramus posterior inferior which contributes to the formation of the Fasciculus posterior.

This type was seen in 4 cases (6.7%) of the author’s Macacus cyclopis.

The corresponding type has been seen by Horiuchi in only 5 cases (8.5%) of Macacus cyclopis and in 1 case (2.0%) of Macacus rhesus with no case in Macacus fascicularis andfuscatus.

On the other hand, in man this type does not seem to occur except for the report of 1 case (0.5%) in an adult Korean (Kawasaki).

iii) Group 3

This type is composed by C₄ and T₁, but C₄, prior to its union with T₁, separates into anterior and posterior branches. The anterior branch unites with T₁ to form the Fasciculus medialis, while the posterior branch independently becomes the Ramus posterior inferior which contributes to the formation of the Fasciculus posterior.

This type was seen in 3 cases (5.0%) of the author’s Macacus cyclopis.

This type corresponds to Group IV of Horiuchi who has found it in only 1 case (1.7%) of Macacus cyclopis and not at all in other macaques.

In man, it has been reported in 10 cases (5.0%) of Japanese fetus (Mori and Matsushita) and in 11 cases (6.1%) of adult Koreans (Kawasaki).

iv) Group 4

This type is formed by C₄, T₁ and T₂, but the formation of the Truncus inferior is quite incomplete. That is, C₄ directly separates into 2 branches and the anterior branch immediately anastomoses with the lateral root of the N. medianus. On the other hand, the posterior branch unites with the posterior branch of T₁ to become the Ramus posterior inferior which contributes to the formation of the Fasciculus posterior. The anterior branch of T₁ directly becomes the Fasciculus
medialis.
This type was seen in 2 cases (3.3%) of my Macacus cyclopsis but has not been reported elsewhere.

B) Fasciculi lateralis, medialis and posterior

1) Fasciculus lateralis (table 5)

HORIUCHI has made a classification into 10 groups in macaques according to the branches that form this fasciculus, but the author has made a general classification into 3 types.

i) Type 1

The ventral branches, the Rami anterior superior, form C₅, C₆ and occasionally C₄ unite with the Ramus anterior medius of C₇ to form the Fasciculus lateralis which separates into the lateral root of the N. medianus and the N. musculocutaneus.

In the Macacus cyclopsis of the author, this type was seen in which 45 cases (75.0%) including 3 cases (5.0%) in which C₄ contributed to the formation.

This type has been reported by HORIUCHI in 39 cases (65.0%) of Macacus cyclopsis, 31 cases (62.0%) of Macacus rhesus, 13 cases (81.3%) of Macacus fascicularis and in 3 cases (75.0%) of Macacus fuscatus while in man, it has been noted in 181 cases (90.5%) of Japanese fetus (MORI and MATSUSHITA), 164 cases (82.0%) of adult Japanese (HIRASAWA) (both of the latter include type III of the author) and in 148 cases (82.2%) of adult Koreans (KAWASAKI). Thus, this may be regarded as the typical type in both monkey and man although the incidence is lower in monkey as compared with man.

ii) Type 2

This type, similar to Type 1, is formed by C₅, C₆ and C₇, but the condition of the Ramus anterior superior is different from Type I. That is, C₅ separates into branches a and b of which branch b forms a single trunk with C₆ which immediately divides into anterior and posterior branches. The posterior branch becomes the Ramus posterior superior which contributes to the formation of the Fasciculus posterior while the anterior branch unites with branch a to become the Ramus anterior superior which unites with the Ramus anterior medius (C₇) to form the Fasciculus lateralis.
This type was seen in 7 cases (11.7%) of my *Macacus cyclopsis*.

This type corresponds to Group II, of Horiuchi who had reported it in 4 cases (6.7%) of *Macacus cyclopsis* and in 1 case (2.0%) of *Macacus rhesus* but in no case of *Macacus fascicularis* or *fuscatus*. There is no report of this type in man.

iii) Type 3

This is similar to Type 1, but C₅ and C₆ respectively separate into anterior and posterior branches of which the 2 anterior branches unite and join with the anterior branch of the Truncus medius to form the Fasciculus lateralis.

This type was seen in 8 cases (13.3%) of my *Macacus cyclopsis* including 2 cases (3.3%) in which C₄ also participated.

This corresponds to type II, of Horiuchi who has reported it in 9 cases (15.0%) of *Macacus cyclopsis*, 5 cases (10.0%) of *Macacus rhesus* and in 1 case (25.0%) of *Macacus fuscatus*. In contrast, it has been reported in only 2 cases (1.1%) of adult Koreans (Kawasaki).

2) Fasciculus medialis (table 6)

Horiuchi has made a classification into 8 types in macaques but the author has made a division into 4 types according to the branches that are involved in its formation and the condition of bifurcation.

<table>
<thead>
<tr>
<th>Type</th>
<th>C₅, T₁</th>
<th>C₆, T₁, T₂</th>
<th>T₁, T₂</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>2(3.3)</td>
<td>49(81.7)</td>
<td>51(85.0)</td>
<td></td>
</tr>
<tr>
<td>Type 2</td>
<td>4(6.7)</td>
<td>4(6.7)</td>
<td>5(8.3)</td>
<td></td>
</tr>
<tr>
<td>Type 3</td>
<td>3(5.0)</td>
<td>3(5.0)</td>
<td>6(10.0)</td>
<td></td>
</tr>
<tr>
<td>Type 4</td>
<td>2(3.3)</td>
<td>2(3.3)</td>
<td>4(6.7)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6(10.0)</td>
<td>52(88.3)</td>
<td>2(3.3)</td>
<td>60</td>
</tr>
</tbody>
</table>

i) Type 1

This type consists of the anterior branch, that is, the Ramus anterior inferior of the Truncus inferior, which is formed by C₅, T₁ and frequently T₂. It separates into the medial root of the N. medianus and the N. ulnaris.

This type was found by the author in 51 cases (85.0%) of *Macacus cyclopsis* of which there were only 2 cases (3.3%) in which T₂ was not involved.

This type corresponds to Group I of Horiuchi which has been reported in 50 cases (83.3%) of his *Macacus cyclopsis*, 39 cases (78.0%) of *Macacus rhesus*, 15 cases (93.8%) of *Macacus fascicularis* and in 4 cases (100%) of *Macacus fuscatus*.

In man, it is reported in 176 cases (88.0%) of Japanese fetus (Mori...
ii) Type 2

C₈, T₁, and T₂ contribute to the formation of this type, but each of these roots first separate into anterior and posterior branches after which the 2 anterior branches unite to form the Fasciculus medialis.

This type was seen in 4 cases (6.7%) of the Macacus cyclopsis of the author.

This type corresponds to Type III₁ of Horiuuchi in which T₂ also is involved. He has found it in 5 cases (8.3%) of Macacus cyclopsis and in 1 case (2.0%) of Macacus rhesus while in man it has been reported in 1 case (0.6%) of adult Korean (Kawasaki).

iii) Type 3

This type is formed by C₈ and T₁. C₈ before it unites with T₁ separates into anterior and posterior branches of which the anterior branch joins with T₁ to form the Fasciculus medialis. That is, in this type, T₁ does not separate but contributes directly to the formation of this fasciculus, but the N. ulnaris is poorly developed.

This type was seen in 3 cases (5.0%) of the author’s Macacus cyclopsis.

This corresponds to Type III₂ (in which T₂ contributes) and Type III₃ of Horiuuchi who has reported the former type in only 1 case (2.0%) of Macacus rhesus and the latter in only 1 case (1.7%) of Macacus cyclopsis.

In man, it has been reported in 9 cases (5.0%) of adult Koreans (Kawasaki), but Mori, Matsushita and HirasaWA have included this in the condition regarded as Type I by the author.

iv) Type 4

This type is formed by T₁ and T₂. That is, after the union of T₁ and T₂, there is separation into anterior and posterior branches of which the anterior branch directly becomes the Fasciculus medialis. In this case, the N. ulnaris is well developed. This was seen in 2 cases (3.3%) of the author’s Macacus cyclopsis, but Horiuuchi has noted this in 1 case (1.7%) of his Macacus cyclopsis only.

3) Fasciculus posterior (table 7)
Table 7. Fasciculus posterior

<table>
<thead>
<tr>
<th>Type</th>
<th>C₄~T₁</th>
<th>C₄~T₂</th>
<th>C₅~C₇</th>
<th>C₇~T₁</th>
<th>C₈~T₁</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>3 (5.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39 (65.0)</td>
</tr>
<tr>
<td>Type 2</td>
<td></td>
<td>7 (11.7)</td>
<td></td>
<td></td>
<td>7 (11.7)</td>
<td></td>
</tr>
<tr>
<td>Type 3</td>
<td>2 (3.3)</td>
<td></td>
<td>3 (5.0)</td>
<td></td>
<td>5 (8.3)</td>
<td></td>
</tr>
<tr>
<td>Type 4</td>
<td></td>
<td>3 (5.0)</td>
<td>3 (5.0)</td>
<td></td>
<td>3 (5.0)</td>
<td></td>
</tr>
<tr>
<td>Type 5</td>
<td></td>
<td></td>
<td>3 (5.0)</td>
<td></td>
<td>3 (5.0)</td>
<td></td>
</tr>
<tr>
<td>Type 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 (5.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2 (3.3)</td>
<td>3 (5.0)</td>
<td>3 (5.0)</td>
<td></td>
<td>52 (86.7)</td>
<td>60 (n%)</td>
</tr>
</tbody>
</table>

i) Type 1

The Ramus posterior superior formed by C₄, C₅, and C₇, the Ramus posterior medius from C₇ and the Ramus posterior inferior formed by C₈, T₁ (and T₅) compose this type. In the union of these fasciculi, first, the Ramus posterior superior and Ramus posterior medius unite to form a single trunk which is joined by the Ramus posterior inferior.

This type was found by the author in 39 cases (65.0%) of Macacus cyclopsis including 3 sides (5.0%) in which C₄ was involved.

This corresponds to Group I of the classification of Horiuchi, but in his investigation he found 34 cases (56.7%) in Macacus cyclopsis, 31 cases (62.0%) in Macacus rhesus, in 14 cases (87.5%) in Macacus fascicularis and 75.0% in Macacus fuscatus.

Corresponding types seen in man would include 160 cases (80.0%) of type I in Japanese fetus (Mori and Matsushita), 152 cases (76.0%) of alpha type in adult Japanese (Hirasawa) and 128 cases (71.1%) of type I in adult Koreans (Kawasaki), but the state of union between the various fasciculi is not necessarily the same as in my cases.

ii) Type 2

In this type, the state of formation of the Ramus posterior superior differs from Type 1. That is, C₅ first separates into branches a and b. Branch a unites with C₈ to form a single trunk. This immediately divides into anterior and posterior branches of which the posterior branch joins with the Ramus posterior medius to form a small trunk which unites next with the Ramus posterior inferior to form the Fasciculus posterior.

This type was seen in 7 cases (11.7%) of my Macacus cyclopsis.

Horiuchi has reported it in 4 cases (6.7%) of Macacus cyclopsis and in 2 cases (4.0%) of Macacus rhesus, but there is no report of this type elsewhere.
iii) Type 3

In this type, the Ramus posterior superior is formed by the 2 posterior branches that are sent off from C₅ and C₆ prior to their union so that in the strict sense it does not emerge from the Truncus superior. The Rami medius and inferior are the same as in Type a.

This type was noted in 5 cases (8.5%) of my *Macacus cyclopsis* including 2 cases (3.3%) in which C₄ contributed. This number also include cases in which T₂ did not participate.

This corresponds to type III₃ of Horiuchi who has reported it in 9 cases (15.0%) of his *Macacus cyclopsis*, 4 cases (10.8%) of *Macacus rhesus* and in 1 case (25.0%) of *Macacus fuscatus*, but contribution by C₄ is not found.

In man, it has been reported in 3 cases (1.5%) of Japanese fetus (Mori and Matsushita), 6 cases (3.0%) of adult Japanese (Hirasawa) and in 6 cases (3.3%) of adult Koreans (Kawasaki).

iv) Type 4

In this type, the composition of the Ramus posterior superior (C₅, C₆) and Ramus posterior (C₇) is the same as in Type I, but the Ramus posterior inferior is formed by the union of the posterior branch of C₅ and the posterior branches of T₁ and T₂.

This type was seen in 3 cases (5.0%) of the *Macacus cyclopsis* of the author.

Horiuchi has reported 4 cases (6.7%) in his *Macacus cyclopsis* and in 3 cases (6.0%) of *Macacus rhesus* while in man it has been noted in 3 cases (1.5%) of Japanese fetus (Mori and Matsushita) and in 1 case (0.6%) of Korean adult.

v) Type 5

This type can be considered to be a mixture of Types III and IV. The Ramus posterior superior is formed by the posterior branches sent off from C₅ and C₆, while the Ramus posterior inferior is formed by the posterior branches from C₅ and T₁ plus T₂. First, the Ramus superior and Ramus medius unite followed by the addition of the Ramus inferior.

This type was seen in 3 cases (5.0%) of my *Macacus cyclopsis*, but in other studies it has been found by Horiuchi in 2 cases (4.0%) of *Macacus rhesus* only.

vi) Type 6

In this type, the components of the Ramus posterior are the same as in Type 1, but the condition of union is different. In other words, first, the Ramus medius and Ramus inferior unite after which the
Ramus superior joins this trunk. In this type, the Ramus inferior originates from C₈ while T₁ is not involved.

This type was seen in 3 sides (5.0%) of my Macacus cyclopsi/s while HORIUCHI has noted it in 1 case (2.0%) of Macacus rhesus only.

In man, a corresponding type has been reported in 10 cases (5.0%) of Japanese fetus (MORI and MATSUMITA) and in a few Koreans adults.

III. Classification of Plexus brachialis

In the proceeding section, the Truncus superior, inferior and medius, and the Fasciculi lateralis, medialis and posterior which form the Plexus brachialis were described in relation to their nerve root of origin, bifurcation of the truncus and the composition of the fasciculus formed by the union of the trunks. A classification of the plexus into a number of different types is, of course, possible depending upon the composition and combination of these truncus and fasciculus. HORIUCHI has made a classification into 18 types while DE GARIS has made a classification into 8 types with subdivisions, for a total of 15 types. However, when a classification is made according to the general pattern regardless of minor differences, it was possible for the author to make a gross classification into the following 7 types.

1) Type I (fig. 5-1)

In this type, the Truncus superior is formed by the union of C₅ and C₆ (and occasionally C₄ also), the Truncus medius directly by C₇, and the Truncus inferior by C₈, T₁ and T₂. Each of these are separate trunks. When C₄ contributes to the Truncus superior, however, C₄ and C₅ first unite followed by the addition of C₆ and for the Truncus inferior,
T₁ and T₂ first unite to which C₈ is added. Each truncus further separates into 2 branches (Rami anterior and posterior). The Ramus anterior superior and Ramus anterior medius unite to form the Fasciculus lateralis, the Ramus anterior inferior directly forms the Fasciculus medialis while Rami posterior superior, medius and inferior unite to form the Fasciculus posterior. The Fasciculus lateralis divides into the lateral root of the N. medianus and the N. musculocutaneous while the Fasciculus medialis separates into the medial root of the N. medianus and the N. ulnaris. The 2 roots of the N. medianus are on each side of the A. axillaris. The Fasciculus posterior, after giving off many branches, continues with the N. radialis.

This type was the most frequent being found in 39 cases (65.0%) of my Macacus cyclopsis. Of these, participation of C₈ in the structure was seen in 3 cases (5.0%).

This type corresponds to Type I of HORIUCHI who observed 33 cases (55.0%) in his Macacus cyclopsis, 23 cases (46.0%) in Macacus rhesus, 13 cases (81.3%) in Macacus fascicularis and in 3 cases (75.0%) of Macacus fuscatus. This corresponds to Type A of CHASE and DE GARIS who have reported 246 cases (82.0%) in Macacus rhesus. In both instances, this was the most frequent type.

Furthermore, this has been reported in 150 cases (75.0%) of Japanese fetus (MORI and MATSUSHITA), 327 cases (72.6%) of Japanese adult (HIRASAWA, ARAKAWA), 109 cases (60.5%) of adult Koreans (KAWASAKI) and in 175 cases (93.7%) of American whites and negroes (KERR).

Therefore, this is the most frequent so-called typical type not only in macaques but in man also.

2) Type II (fig. 5-2)

This is similar to Type I except that it is composed by C₈—T₂ and the stage of union of C₈ and C₈ is different. That is, C₈ first separates into branches a and b, of which branch b unites with C₈ to form a small trunk which shortly divides into anterior and posterior branches. The anterior branch unites with branch a from C₈ to form the Fasciculus lateralis while the posterior branch becomes the Ramus posterior superior which contributes to the formation of the Fasciculus posterior.

This type was found in 7 cases (11.7%) of my Macacus cyclopsis.

This type corresponds to Type II in the classification by HORIUCHI who reports it in 4 cases (6.7%) of his Macacus cyclopsis and in 1 case (2.0%) of Macacus rhesus with no case noted in Macacus fascicularis or Macacus fuscatus. This does not appear either in the Macacus rhesus of CHASE and DE GARIS or in Japanese fetus (MORI and MATSUSHITA), adult Japanese (HIRASAWA, ARAKAWA) or adult Koreans (KAWASAKI).
3) Type III (fig. 5-3)

This is similar to Types I and II except that both C₈ and C₉ first separate into anterior and posterior branches to form 4 branches of which the 2 anterior branches unite to become the Ramus anterior superior and the 2 posterior branches unite to become the Ramus posterior superior. Therefore, in this case, the Truncus superior in the strict sense is absent.

This type was noted in 5 cases (8.3%) of my *Macacus cyclopsis* of which 2 cases (3.3%) were composed by C₄–T₁ while 3 cases (5.0%) consisted of C₅–T₂.
This corresponds to Type III in the classification by Horiuchi who has found 7 cases (11.7%) in his Macacus cyclops, 5 cases (10.0%) in Macacus rhesus and in 1 case (25.0%) in Macacus fuscatus while this type was not found in Macacus fascicularis. Neither has it been noted in the Macacus rhesus of Chase and De Garis. In man, it has been reported in 15 cases (3.3%) of Japanese adults (Hirasawa, Arakawa), 3 cases (1.6%) of adult Koreans (Kawasaki) and in 6 cases (3.0%) of Japanese fetus (Mori and Matsushita).

4) Type IV (fig. 5–4)

This type is composed by C₅–T₂. It is similar to Type I, but the roots from C₅ and T₁ each separate into 2 branches and the 2 anterior branches unite to become the Fasciculus medialis while the 2 posterior branches unite to form the Ramus posterior inferior and, therefore, the Truncus inferior in the strict sense is absent.

This type was observed in 3 cases (5.0%) of my Macacus cyclops.

Fig. 5–4, Type IV

This corresponds to Type IV of the classification of Horiuchi who found 4 cases (6.7%) in Macacus cyclops and only 1 case (2.0%) in Macacus rhesus, but Chase and De Garis have not noted it in their Macacus rhesus.

In man, it has been found only in 1 case (0.5%) of adult Koreans (Kawasaki) and is not present in Japanese fetus or adult.

5) Type V (fig. 5–5)

This type is composed by C₅–T₂ and is a combination of Types III
and IV. C₈ and C₉ as well as C₈ and T₁ do not demonstrate the usual union into the Truncus superior or Truncus inferior but separate first into anterior and posterior branches. Thus, in this type, there are 5 anterior and posterior branches, respectively. The 2 upper posterior branches from the Ramus posterior superior, the 2 lower posterior branches from the Ramus posterior inferior while the 2 upper anterior branches form the Ramus anterior superior and the 2 lower anterior branches form the Ramus anterior inferior.

This type was noted in only 1 case (1.7%) of my Macacus cyclopsis.

This corresponds to Type V of Horiuchi who has found it in only 1 case (1.7%) of Macacus cyclopsis while it is not present in the Macacus rhesus of Chase and De Garis. It is not found in man either.

6) Type VI (fig. 5–6)

This type consists of C₈–T₂. It is similar to Type V, but each root from C₈, T₁ and T₂ divides into 2 branches of which the posterior branches unite to become the Ramus posterior inferior, while the 2 anterior branches run independently without uniting. That is, the anterior branch from C₈ unites with the lateral root of the N. medianus while the anterior branches from T₁ and T₂ continue with the Fasciculus medialis, give off the medial root of the N. medianus and continue with the N. ulnaris, but an anastomosing branch also is received from the lateral root of the N. medianus to become the N. ulnaris.

This type was found in 2 cases (3.3%) of my Macacus cyclopsis, but there is no mention of this type elsewhere.
7) Type VII (fig. 5–7)

In this type, there is contribution by C₈–T₁. The formation of the Faciculi lateralis and medialis is the same as in Type I, but the Fasciculus posterior is formed by the Rami posterior superior and medius from the Truncus superior and medius as well as the the posterior branch from C₈ with no contribution by T₁.

This type was noted in 3 cases (5.0%) of my Macacus cyclopsis.

This corresponds to Type XVI of Horiiuchi who has noted just 1
Table 8. Types of the brachial plexus

<table>
<thead>
<tr>
<th>Type</th>
<th>C₄~T₁</th>
<th>C₄~T₂</th>
<th>C₅~T₁</th>
<th>C₅~T₂</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3 (5.0)</td>
<td></td>
<td>36 (60.0)</td>
<td>39 (65.0)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>7 (11.7)</td>
<td>3 (5.0)</td>
<td>5 (8.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>2 (3.3)</td>
<td>3 (5.0)</td>
<td>3 (5.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>3 (5.0)</td>
<td>1 (1.7)</td>
<td>2 (3.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>3 (5.0)</td>
<td>2 (3.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>3 (5.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In only *Macacus cyclops* with no case in *Macacus rhesus*, *fascicularis* or *fuscatus*. However, Chase and De Garis have reported 7 cases (2.33%) in *Macacus rhesus*.

In man, it has been noted in 10 cases (2.2%) of adult Japanese (Hirasawa, Arakawa) and in 17 cases (9.4%) of adult Koreans (Kawasaki) but has not been reported in Japanese fetus.

A general review of the above finding show that in *Macacus cyclops* the Type I classification of the Plexus brachialis is the most frequent (65.0%) and this may be regarded as the so-called typical type (table 8). Findings from other studies on macaques and man also are similar except for the difference in frequency.

**CONCLUSION**

Observation of the Plexus brachialis on each side of the body, a total of 60 limbs of 30 adult *Macacus cyclops* (18 male, 12 female), revealed the following findings.

1) The roots which contribute to the formation of the Plexus brachialis range from C₄ to T₂, and the frequency of the participation of the respective roots shows that the 5 roots from C₅ to T₁ are present in all cases, while T₂ is present in 91.2% and C₄ in 8.3% of the cases.

2) Depending upon the range of roots which participate in the formation of the Plexus brachialis, classification into 4 types is possible of which Type IV (C₅~T₂) is the most frequent (86.7%) indicating that the positions of the contributing roots is more caudal than in man. In other words, it may be said to be of the postfixed form.

3) The respective roots in the Plexus brachialis unite with each
order and form primary divisions, that is the Truncus superior, medius and inferior.

The Truncus superior may be classified into 3 types of which Type A, formed by the union of C₄, C₅ and occasionally C₆, is the most frequent (70.0%).

The Truncus medius in all cases was formed by C₇ alone with no case of participation by other roots such as seen rarely in other monkey and in man.

The Truncus inferior may be classified into 4 types of which most frequent is Group 1 in which the Truncus is formed by the union of C₈, T₁, and T₂ (81.8%). Occasionally, the participation of T₃ may be lacking.

4) Each Truncus further divides and unites to form secondary cords, that is, the Fasciculi lateralis, medialis and posterior.

The Fasciculus lateralis may be separated into 3 types but most frequent is Type 1 in which it is formed by the ventral branches from C₅ and C₆ as well as the Truncus medius from C₇ (75.0%).

The Fasciculus medialis predominantly is of Type 1 in which it is formed by the anterior branch from the Truncus inferior, which mostly is composed by C₈, T₁, and T₂ (85.0%). In a few cases, T₃ was absent.

The Fasciculus posterior in Macacus cyclopsis may be separated into 6 types but most frequently seen is type 1 in which the formation is by the union of the Ramus posterior superior from C₅, C₆ (and occasionally C₅), the Ramus posterior medius from C₇ and the Ramus posterior from C₈, T₁ (and occasionally T₃) (65.0%).

5) The morphological types of the Plexus brachialis, as a whole, may be classified into 7 types and similar to the condition in other primates as well as in man, Type 1 is the most frequent. That is, in Type 1 the Truncus superior is formed by the union of the roots from (C₄), C₅ and C₆, the Truncus inferior by roots from C₇, T₁ and T₂, while the root from C₇ directly become the Truncus medius. Each of these primary nerve cords separates into Ramus anterior and Ramus posterior which unite to form secondary cords of which the Fasciculus lateralis is formed by the union of the Ramus anterior superior and Ramus anterior medius, the Fasciculus medialis just by the Ramus anterior inferior while the Fasciculus posterior is formed by the union of the Ramus posterior superior, Ramus posterior medius and Ramus posterior inferior.

Thus, the typical type of the Plexus brachialis is the same as in man.
ACKNOWLEDGMENT: The author wishes to express appreciation to assist Prof. S. Inokuchi for his advice and assistance.

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