A Morphological Study on the Human Obturator Externus Muscle with Reference to Anomalous Muscle and Anomalous Fasciculus Originating from the Obturator Externus Muscle

By

Motoki YATSUNAMI, Tetsuo TAI, Yutaka IRIE, Koichi OGAWA and Ryosuke MIYAUCHI

Department of Anatomy, Fukuoka University School of Medicine, 7-45-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, Japan

– Received for Publication, October 23, 2003 –

Key Words: Obturator externus, Anomalous muscle, Anomalous fasciculus, Innervation, Gross anatomy

Summary: To elucidate the essential nature of the human obturator externus muscle (OE), the gross anatomy of the anomalous muscle and anomalous fasciculus originating from this muscle as well as the posterior division of the obturator nerve (P) were examined in 73 thighs of 45 Japanese adult cadavers. The investigation of anomalous muscle and anomalous fasciculus was effected by observation of the supernumerary muscular branch and supernumerary muscular twig from the P.

The anomalous muscle occurring between the adductor brevis muscle (AB) and adductor minimus muscle (AMI) (37/73 thighs; 50.7%) and the anomalous fasciculus fused to the posterior surface of the AMI (18/73 thighs; 24.7%) were detected. It was demonstrated by the course of the P and the suppling nerve, that the OE was divided into its superior fasciculus (or fasciculi) (SF) and main belly by the P, moreover the anomalous muscle originated from the former and the anomalous fasciculus from the latter.

Presumably, in the process of ontogeny, the SF of the original OE retained its original morphology (23/73 thighs; 31.5%), a part of the SF was converted to anomalous muscle (27/73 thighs; 37.0%), the entire SF was converted to anomalous muscle (10/73 thighs; 13.7%), and the entire SF underwent retrogression and disappeared (13/73 thighs; 17.8%). The presence (50/73 thighs; 68.5%) or absence (23/73 thighs; 31.5%) of piercing of the OE by the P seemed to depend upon the circumstances surrounding the morphological change in the SF. The original OE was considered to occur as an OE pierced by the P not possessing any supernumerary muscular branch or twig. Actually, the original OE was confirmed to occur with a low frequency (15/73 thighs; 20.5%). It was inferred that the original OE readily underwent variation in the process of ontogeny due to the influence of the obturator nerve. The segmental composition of the obturator nerve was considered not to be involved in the morphological change in the OE.

The obturator externus muscle (OE) is considered to show very little variation in respect to its origin, insertion and relation to the adjacent muscles. Some textbooks even described that the OE rarely showed any variation (Anson, 1966; Töndury, 1968; Hollinshead, 1974; Bergman et al., 1988). Accordingly, literature on the OE includes only a case report of the OE split into several fasciculi by the nerves and blood vessels (Vrijman, 1924–1925) and a study on the anomalous muscle originating from this muscle (Nakamura et al., 1992; Miura et al., 1994).

Nonetheless, if we look at the OE in the light of the topographical relationship between this muscle and the obturator nerve, we cannot help but be interested in this muscle. In some textbooks (Elze, 1954; Töndury, 1968), the OE is frequently described as being pierced by the posterior division of the obturator nerve (P). There also are a number of reports on the incidence of piercing of the OE by the P (Ouchi, 1951; Tozinbara, 1960; Nakamura et al., 1992, etc.). Are variations in the topographical relationship between the obturator nerve and the OE produced only by the morphological change in the former, or by some circumstances in the formation of morphology of the latter? To our knowl-
edge, there is no report of a study planned for resolution of these questions. We consider, if the essential nature of the OE is elucidated, the above questions will be clearly answered.

The present study was conducted to elucidate the essential nature of the OE by investigating anomalous muscle originating from the OE, and to analyze the topographical relationship between the OE and the obturator nerve.

**Materials and Methods**

Japanese adult cadavers (28 males, 46 thighs: 17 females, 27 thighs) randomly selected from the cadavers preserved in the Fukuoka University School of Medicine were used in the study. After a laparotomy had been performed and the abdominal and pelvic viscera removed, the trunk was cut horizontally at a level between the 12th thoracic and 1st lumbar vertebrae, and the pelvis was cut sagittally in the midline. All the muscles of the thigh except the adductor group were removed. The adductor group and obturator nerve were examined by the ordinary anatomical method. In some of the specimens for study, the superior ramus of the pubis was removed in order to observe more accurately the ramification pattern of the obturator nerve and the nerve supply to the OE. The adductor brevis muscle (AB) dually innervated by the anterior division of the obturator nerve (A) and P and the adductor minimus muscle (AMI) receiving the P on both the anterior and posterior aspects, which occurred in the present examination, were dissected out in the form of a nerve-muscle specimen. The intramuscular distribution of the supplying nerve was observed under a stereomicroscope in these specimens.

**Results**

To study the morphology of the OE, the anatomy of the anomalous muscles arising from this muscle and the obturator nerve was carefully recorded.

1. The morphology and incidence of the anomalous muscular branch arising from the P (Table 1)

   It is said that muscles develop in a number of ways in the process of ontogeny, such as division, displacement, and fusion with adjacent muscles. However, it is generally recognized that the relationship between the muscle and the supplying nerve is maintained without change throughout this process (Eisler, 1912; Hollinshead, 1974). We therefore considered it possible to investigate the anomalous muscle more accurately by observing the nerve.

   The P ordinarily runs over or pierces the OE after its passage through the obturator canal, to emerge on the anterior aspect of the thigh, and courses distally between the AB and the AMi and the adductor magnus muscle (AMa). In coursing through this region, the P generally supplies branches to the OE from the anterior and posterior aspects, and to the AMi and AMa from the anterior aspect (Bühler, 1904; Frohse & Fränkel, 1913; Elze, 1954; Moghaddam, 1963). Accordingly, muscular branches except the ordinary ones arising from the P, such as muscular branches distributed in the OE and those supplying the AMi and AMa from the anterior aspect, can be regarded as anomalous muscular branches. The following two types of anomalous muscular branches, that is, the supernumerary muscular branch and the supernumerary muscular twig, were observed.

   1) The supernumerary muscular branch distributed in the anomalous muscle and in the AB

      (1) The supernumerary muscular branch distributed in the anomalous muscle: An anomalous muscle sometimes occurred between the AB and AMi (17/73 thighs, 23.3%). The anomalous muscle arose from the inferior ramus of the pubis, and ran obliquely downwards and laterally, to be inserted into the pectineal line by means of the aponeurosis,
the posterior aspect of the base of the lesser trochanter, or the anterior aspect of the insertion aponeurosis of the AMi. The supernumerary muscular branch from the P was distributed in the anomalous muscle at the posterior aspect (Figs. 1 and 2).

(2) The supernumerary muscular branch distributed in the AB: It is said that the AB is located dorsal to the A, and invariably receives branches from that at the anterior aspect. In the present study, it was sometimes observed that the AB received not only the A at the anterior aspect, but the supernumerary muscular branch from the P at the posterior aspect (20/73 thighs, 27.4%) (Figs. 3 and 4).

Stereomicroscopic findings on the intramuscular distributions of the branches from the A and the supernumerary muscular branch in the AB: As in the study by Miura et al. (1994), the intramuscular distributions of the supernumerary muscular branch from the P and the branches from the A were examined under a stereomicroscope. The branches from the A were distributed all over the AB. On the other hand, the supernumerary muscular branch was distributed in the dorsal layer of a part of the fasciculi of the AB. Though the range of distribution of the branches from the A overlapped that of the supernumerary muscular branch, intramuscular communication between these two branches was rarely detected. The fasciculus where the supernumerary muscular branch was distributed could be relatively clearly distinguished from the pure AB. The fasciculus supplied by the supernumerary muscular branch was considered homologous to the aforesaid anomalous muscle, from the view points of the pattern of nerve supply, topographic relationship between this fasciculus and the P and that between this fasciculus and the adjacent muscles. Accordingly, the supernumerary muscular branch distributed in this fasciculus from the posterior aspect was homologous to that distributed in the anomalous muscle. Since the intramuscular distribution of the nerve in the present study was identical with that found by Miura et al. (1994), the figure is omitted.

In the present paper, the supernumerary muscular branch distributed in the AB from the posterior aspect is described as the supernumerary muscular branch distributed in the anomalous muscle that occurred between the AB and AMi. Thus, the supernumerary muscular branch distributed in the anomalous muscle was observed in 37 of 73 thighs (50.7%) (Table 1).

2) The supernumerary muscular twig distributed at the posterior aspect of the AMi

It is said that the AMi is supplied by the P at the anterior aspect. However, the AMi was found to be supplied by, besides the ordinary nerve, a supernumerary muscular twig from the P at the posterior aspect in 18 of 73 thighs (24.7%) (Figs. 5 and 6). In 8 of the 73 thighs (8/73 thighs: 11.0%), the supernumerary muscular twig distributed at the posterior aspect of the AMi and the supernumerary muscular branch to the anomalous muscle were both observed in the same thigh (Fig. 3-b) (Table 1).

Stereomicroscopic findings on the intramuscular nerve distribution in the AMi: Several ordinary branches that entered the AMi from its anterior aspect were thicker than the supernumerary muscular twig. The supernumerary muscular twig was single. The ordinary branches were distributed over the entire AMi. On the other hand, the supernumerary muscular twig was distributed at the fasciculus of the dorsal layer of the proximal portion of the AMi. Though the range of distribution of the ordinary branches overlapped that of the supernumerary muscular twig, they could be clearly distinguished from each other (Fig. 7).

2. Relationship between the course of the obturator nerve and the incidences of the supernumerary muscular branch and twig (Table 1)

The P pierced the OE in 50 of 73 thighs (68.5%), while it ran over the upper border of this muscle to emerge in the thigh in 23 thighs (31.5%).

Of 50 thighs that had the P piercing the OE, 19 thighs showed a supernumerary muscular branch to the anomalous muscle, 8 thighs showed both a supernumerary muscular branch to the anomalous muscle and a supernumerary muscular twig to the AMi (Fig. 3-b), and 8 thighs showed a supernumerary muscular twig to the AMi. In 23 thighs with the P running over the OE, the supernumerary muscular branch to the anomalous muscle was observed in 10 thighs, and the supernumerary muscular twig to the AMi in 2 thighs.

3. Relationship between the segmental composition of the obturator nerve and the incidences of the supernumerary muscular branch and twig (Table 2)

The obturator nerve was composed of L234 (65/73 thighs: 89.0%), L34 (4/73 thighs: 5.5%) and L345 (4/73 thighs: 5.5%).

Discussion

1. Incidence of the anomalous muscle between the AB and AMi

The incidence of an anomalous muscle has been described by Shiina (1931, 4/10 thighs: 40.0%), Kazama et al. (1958, 19/240 thighs: 7.2%) and Abe (1964, 11/98 thighs: 11.2%), but none of them paid
any attention to the AB dually innervated by the A and P, that is, the anomalous muscle fused to the dorsal aspect of the AB. Meanwhile, the incidence of the anomalous muscle fused to the dorsal aspect of the AB was described by Hasue (1958, 2/35 thighs; 5.7%) and Tozinbara (1960, 14/32 thighs; 43.8%), but neither of them paid any attention to the anomalous muscle that occurred independently between the AB and AMi. The incidences of the anomalous muscle occurring independently between the AB and AMi and that fused to the dorsal aspect of the AB were respectively reported only by Bardeen (1907, 7/85 thighs; 8.2%) and Nakamura et al. (1992, 56/100 thighs; 56.0%). No significant difference was detected between the results of investigation by us (37/70 thighs: 50.7%) and those by Nakamura et al. (1992). Accordingly, the anomalous muscle may be considered to occur with a considerably high frequency (50% or more). It is not clear what accounted for the remarkably low incidence of the anomalous muscle reported by Bardeen.

2. True nature of the anomalous muscle between the AB and AMi

The anomalous muscles found in the present study (37 cases) could be classified into the following two types by the course of the P.

1) Anomalous muscle that occurred in the thigh with the OE pierced by the P (27 cases) (Figs. 1 and

### Abbreviations

- **A**: anterior division of the obturator nerve
- **AB**: adductor brevis muscle
- **AL**: adductor longus muscle
- **AMa**: adductor magnus muscle
- **AMi**: adductor minimus muscle
- **G**: gracilis muscle
- **GT**: greater trochanter
- **HJ**: hip joint
- **LT**: lesser trochanter
- **OE**: obturator externus muscle
- **P**: posterior division of the obturator nerve
- **Pe**: pectineus muscle
- **PT**: pubic tubercle
- **QF**: quadratus femoris muscle
- **SF**: superior fasciculus (or fasciculi)

Fig. 1. Anterior view. The black asterisk indicates the anomalous muscle. The P pierces the OE. The AB, G and Pe are reflected. The A is displaced upwards. b: The anomalous muscle (black asterisk) is reflected. The supernumerary muscular branch (black arrowhead) originating from the P is distributed in the anomalous muscle at the posterior aspect.

Fig. 2. Anterior view. The black asterisk indicates the anomalous muscle. The P runs over the OE. The AB, AL, G and Pe are reflected. The A is displaced upwards and laterally. b: The anomalous muscle (black asterisk) is reflected. The supernumerary muscular branch (black arrowhead) originating from the P is distributed in the anomalous muscle at the posterior aspect.
3): As Bardeen (1907) and Frose & Fränkel (1913) described, the OE is divided into the superior fasciculus (or fasciculi) (SF) and the main belly by the P. The SF is situated ventral to the P and receives branches from that at its dorsal aspect. Like the SF, the anomalous muscle also is located ventral to the P and receives the branch from that at its dorsal aspect (Fig. 3-b). The anomalous muscle was considered homologous to the SF from the points of view of the topographical relationship between the nerve and muscle and the pattern of nerve supply. That is, the anomalous muscle is composed of a part of the SF of the OE. The mechanism of formation of the anomalous muscle was considered as follows: in the process of ontogeny, a muscle that separated from the SF of the OE to become independent was not inserted into the trochanter fossa, but into the pectineal line, posterior aspect of the lesser trochanter or insertion aponeurosis of the AMi.

2) Anomalous muscle that occurred in the thigh with the OE not pierced by the P (10 cases) (Fig. 2): The anomalous muscle was considered homologous to that described in the preceding section, in the light of the topographical relationship between the nerve and muscle and the pattern of nerve supply. However, unlike the aforesaid anomalous muscle formed by a part of the SF of the OE, this anomalous muscle was considered to be the SF itself. That is, the SF was not inserted into the trochanter fossa, but into the pectineal line, posterior aspect of the lesser trochanter or insertion aponeurosis of AMi.

The OE is divided into the SF and main belly by being pierced by the P. A part (27 cases) or all (10 cases) of the SF was inferred to have formed the anomalous muscle (Table 1).

3. Topographical relationship between the P and the OE (Table 1)

The P is described as piercing the OE, or runs over the upper border of this muscle, to emerge in the thigh (Frose & Fränkel, 1913; Elze, 1954; Hollinshead, 1974). The incidence of the OE pierced by the P was reported only by Ouchi (1951, 27/39 thighs; 69.2%), Hokanishi (1957, 40/40 thighs; 100%), Hasue (1958, 35/35 thighs; 100%), Tozinbara (1960, 12/32 thighs; 37.5%) and Nakamura et al. (1992, 70/100 thighs; 70%). Data obtained by Hokanishi, Hasue and Tozinbara differ considerably from ours (50/73 thighs; 68.5%). It is unknown what caused this difference. However, the data obtained in the present study approximated those reported by Ouchi and Nakamura et al., so that at least some corroboration exists between our data and those of others.

In the present study, the P did not pierce the OE in 23 thighs. The mechanism of formation of the obturator externus not pierced by the P will be discussed. The anomalous muscle occurred in 10 of 23 thighs, and did not occur in 13 thighs.

1) OE in thighs with the anomalous muscle (10 thighs): As described under 2) in the previous section, the anomalous muscle is the SF of the OE itself. Accordingly, the original OE in these thighs should be regarded as having been pierced by the P.

2) OE in thighs without the anomalous muscle (13 thighs): According to Uhlmann (1968), the OE is pierced by the P and is divided into the SF and main belly in prosimians, simians, and anthropoid apes. From the point of view of phylogeny or comparative anatomy, therefore, it is inferred that the original human OE is pierced by the P and divided into the SF and main belly. It is said that a muscle can develop in various manners during the process of ontogeny, such as differentiation, displacement and retrogression/disappearance. It has also been reported that a muscle or a part of the muscle can retrogress or disappear in the process of ontogeny. Moreover, this phenomenon has been verified in the light of nerve supply (Eisler, 1901 and 1912; Kasai and Chiba, 1977; Miyauchi, 1983; Miyauchi et al., 1986; Koizumi, 1989). If it is permitted to make a daring inference from these descriptions, the mechanism of formation of the OE not pierced by the P may be as follows: the SF of the original OE, that is, the aforesaid anomalous muscle and the supernumerary muscular branch retrogressed/

Fig. 3. Anterior view. The P pierces the OE. The AL, G and Pe are reflected. The A is displaced upwards. a: The AB receives the branches from the A (red threads) at the anterior aspect. b: The AB, AMi and SF are reflected. The AB receives the supernumerary muscular branch (black arrowhead) originating from the P at the posterior aspect. The black asterisk indicates the anomalous muscle. The supernumerary muscular twig (white arrowhead) distributed in the AMi is also observed in this thigh. The white asterisk indicates the anomalous fasciculus.

Fig. 4. Anterior View. The P runs over the OE. The AL and Pe are reflected. The A is displaced laterally. a: The AB receives the branches from the A (red threads) at the anterior aspect. b: The AB is reflected. The AB receives the supernumerary muscular branch (black arrowhead) originating from the P at the posterior aspect. The black asterisk indicates the anomalous muscle.
disappeared in the process of ontogeny. This resulted in the occurrence of the OE not pierced by the P.

The morphological change in the SF of the original OE in the process of ontogeny can be inferred to occur as follows: the original OE was divided by the P into the SF and main belly. We considered that the SF either retrogressed/disappeared (13/73 thighs; 17.8%), was displaced (10/73 thighs; 13.7%), or a part of the SF was displaced (27/73 thighs; 37.0%). Presumably, the SF was morphologically unstable, and underwent changes with a high frequency (50/73 thighs; 68.6%).

4. The true nature of the AMi supplied by the supernumerary muscular twig and the incidence of this twig

The supernumerary muscular twig originated from the nerve distributed in the superficial layer of the main belly of the OE (Fig. 5-b). The fasciculus supplied by the supernumerary muscular twig could be relatively clearly distinguished from the pure AMi under a stereomicroscope (Figs. 7). Accordingly, in the light of nerve supply, this fasciculus was considered homologous to the superficial layer of the main belly. It can be inferred that the anomalous fasciculus separated from the main belly to become independent was secondarily fused to the dorsal aspect of the AMi during the process of ontogeny.

To our knowledge, the only report on this supernumerary muscular twig was one by Nakamura et al. (1992). The incidence of this twig obtained by us (18/73 thighs; 24.7%) was clearly higher than that by Nakamura et al. (4/100 thighs; 4.0%). Nakamura et al. described the anatomy of the obturator nerve as well as the AMi and AMa only from the anterior aspect, and did not observe the posterior aspect of these structures. It may be that Nakamura et al. missed the majority of the supernumerary muscular twigs. However, since the objective of the present study differs from that by Nakamura et al., criticism of their work is not justified.

5. Relationship of the segmental composition of the obturator nerve to the incidences of the supernumerary muscular branch and twig (Tables 2 and 3)

The incidence of three types of obturator nerve observed in the present study was similar to those reported by Ishii (1936), Matsuyama (1950), Zaluska (1971) and Miura et al. (1994). Accordingly, the incidence of these nerves as obtained by us appears to be common.

The P did not pierce the OE in 23 thighs. As described under section 3, the SF of the OE in these thighs seemed to have been displaced or retrogressed/disappeared. Therefore, Table 2 can be changed into Table 3.

The obturator nerve which is composed either of L234, L34, and L345 had the supernumerary muscular branch and/or twig in 80% (52/65 thighs), 75% (3/4 thighs) and 75% (3/4 thighs), respectively (Table 3). Accordingly, the segmental compositions of the obturator nerve may not be related to the incidences of the supernumerary muscular branch and/or twig.

6. Original OE and the influence of the obturator nerve on this muscle

Various morphological changes in the original OE were discussed above. To conclude, the original OE occurred as an OE pierced by the P without any supernumerary muscular branch or twig (Fig. 8). In the present study, the original OE was observed in 15 of 73 thighs (20.5%) (Tables 1 and 3). The original OE showed variation with a markedly high frequency (79.5%). The morphology of the original OE seems to have been confused by its being pierced by the P.

Conclusion

The original OE is divided into the SF and main belly by the P that pierces it. The original OE becomes an unstable muscle when it is pierced by the P in the process of ontogeny. As a result, the
anomalous muscle and anomalous fasciculus originate respectively from the SF and the main belly with a high frequency. The anomalous muscle originating from the SF undergoes various morphological changes, and the OE pierced or not pierced by the P occurs according to the circumstances associated with these morphological changes. The anomalous fasciculus originating from the main belly is secondarily fused to the posterior aspect of the AMi.

References


Table 3. Relationship between the segmental composition of the obturator nerve and the incidences of the supernumerary muscular branch and twig from our discussion

<table>
<thead>
<tr>
<th></th>
<th>L234 65 cases</th>
<th>L34 4 cases</th>
<th>L345 4 cases</th>
<th>Total 73 cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obturator nerve with the supernumerary muscular branch</td>
<td>18 + (8) + [(9)]</td>
<td>1 + (1) + [(11)]</td>
<td>0 + (1) + [(11)]</td>
<td>40</td>
</tr>
<tr>
<td>Obturator nerve with the supernumerary muscular branch and supernumerary muscular twig</td>
<td>7 + (0)</td>
<td>0 + (0)</td>
<td>1 + (0)</td>
<td>8</td>
</tr>
<tr>
<td>Obturator nerve with the supernumerary muscular twig</td>
<td>8 + (2)</td>
<td>0 + (0)</td>
<td>0 + (0)</td>
<td>10</td>
</tr>
<tr>
<td>Obturator nerve without the supernumerary muscular branch or supernumerary muscular twig</td>
<td>13</td>
<td>1</td>
<td>1</td>
<td>15</td>
</tr>
</tbody>
</table>

[ ]: supernumerary muscular branch inferred to have retrogressed/disappeared.