Histology of the Human Carotid Sheath Revisited

By

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Summary: Using semiserial sections, we histologically observed the carotid sheath and adjacent structures in 8 sides of 5 cadavers. For description, we classified the carotid sheath into 2 parts or laminae: 1) a laminar “adventitia” enclosing each of the cervical great vessels; and 2) a “common sheath” outside the adventitia. Arterial and venous adventitial structures sometimes fused and provided a definite septum between the artery and vein. Contrasting with previous descriptions, the common sheath did not fuse with superficial or pretracheal lamina of the cervical fasciae, but often fused with visceral fascia to provide a thick plate. The common sheath as well as the prevertebral lamina of the cervical fasciae sometimes became interrupted or unclear, but the adventitia was consistently complete circular. The alar fascia was usually considered as one layer of the multilaminar structure behind the cervical viscera, but it was difficult to identify as a single proper lamina. The carotid sheath was thus not a dissection artifact, but a definite histological structure. However, interindividual and/or site-dependent variations were evident in thicknesses of the adventitia and common sheath. Consequently, the author proposed a model of the fascial arrangement around cervical great vessels that unexpectedly differs from most descriptions in textbooks.

According to textbooks of human anatomy (Spitzka, 1913; Schaffer, 1953; Hollinshead, 1982; Ouchi, 1982; Clemente, 1985; Williams et al., 1995; Standring, 2005), the carotid sheath, as a distinct condensation of the deep cervical fasciae, completely encloses the common carotid artery, internal jugular vein and vagus nerve. Parts of the sheath are composed of the superficial and pretracheal laminae of the cervical fasciae, whereas the sheath is believed to be separated from the prevertebral lamina of the cervical fasciae according to most authors.

However, Grodinsky and Holyoke (1938) noted that some groups have reported an incomplete medial part and that, surprisingly, 2 or 3 research groups have even denied the existence of a real sheath. As a result, “strong or weak”, “thick or thin” and “tight or loose” cases of the carotid sheath may exist. In other words, whether the sheath appears complete or incomplete may depend on interindividual variations. Moreover, a histological study by Parsons (1910) concluded that the carotid sheath is an artifact produced by surgical or anatomical dissection. Range and Woodburne (1964) also reported a fascial structure as a dissection artifact. In this context, we believe that histological observations are required to evaluate the continuation of fascial structures, as gross dissections easily reconstruct or produce a sheath-like structure along vessels and nerves (Kato et al., 2002; Tamakawa et al., 2003; Kinugasa et al., 2006). Nevertheless, little histological information is available on the carotid sheath (Parsons, 1910).

Furthermore, questions have been raised regarding suggested site-dependent differences in carotid sheath arrangement (Hollinshead, 1982; Clemente, 1985). Do the superficial and pretracheal laminae of the cervical fasciae contribute to formation of the carotid sheath depending on site or supero-inferior level? However, few descriptions detail differences along the supero-inferior axis with the exception of a report by Grodinsky and Holyoke (1938). Moreover, they described upper and mediastinal continuations of the carotid sheath on macroscopic observations, such as the carotid sheath passing deep to the stylohyoideus and pos-
terior belly of the digastricus in the upper part of the neck, fusing with the anteroinferior surface of a covering fascia of these muscles. However, interindividual variations seemed to present in a site-dependent manner.

The aim of this study was thus to histologically examine: 1) interindividual differences, i.e., complete or incomplete, thick or thin, tight or loose, and which structures the sheath fuses with or attaches to; and 2) site-dependent differences among 5 levels: a) level of the body of the hyoid bone; b) level of the oropharynx; c) level of the laryngopharynx and thyroid gland (or, more strictly, level of the glottis); d) level of the cricoid cartilage and uppermost trachea; and e) level of the subclavian artery.

Materials and Methods

Cervical great vessels with adjacent structures intact were obtained from 7 sides of 5 cadavers (2 male, 3 female) without macroscopic tumors (mean age, 85 years; range, 76–95 years). These cadavers had been donated to Tokyo Medical University for education and research and had been treated postmortem. The upper and lower ends of the materials correspond to the base of the mandible and origin of the subclavian artery, respectively. To preserve the prevertebral lamina of the cervical fasciae in histology, close attention was paid to including the scalenus anterior and longus colli muscles into the materials. After decalcification of the laryngeal cartilages and hyoid bone using 5% nitric acid solution, materials were horizontally subdivided into 5–6 pieces along the supero-inferior axis and the medial and lateral margins were trimmed. After routine procedures for paraffin embedded histology, transverse or horizontal semiserial sections (interval, 5 mm) were prepared (thickness, 10–20 μm). Hematoxylin and eosin staining was performed.

Protocols for the present research project did not include any specific issues that needed approval from the Ethics Committee of the institutions. The present work conformed to the provisions of the Declaration of Helsinki in 1995 (as revised in Edinburgh in 2000).

Results

The carotid sheath, which encloses the cervical great vessels, was divided into 2 laminar structures: 1) fibrous connective tissue around each of the common carotid artery and internal jugular vein; and 2) a common sheath enclosing both the artery and vein. The present study will apply the familiar term “adventitia” to the former and the term “common sheath” to the latter (Fig. 1). In the wider meanings, this adventitia seems to be included in a concept of the carotid sheath because, in gross observations, separation from the common sheath is difficult. The adventitia was consistently multilaminar and often >1 mm thick, but the common sheath was thin and often identified as a single lamina despite being composed of bundles of fibrous tissues at higher magnification (Fig. 1B). The vagus nerve was consistently located outside of the adventitia (in detail, see below), but the nerve was usually enclosed in a common sheath.

Most of the present figures show 2–3 levels of...
abundant semiserial slices of the long cervical region, i.e., level of the hyoid bone body or the upper level; level of the larynx and thyroid gland or the middle level; and level of the subclavian artery or the lower level. The upper level included the origin of the external carotid artery in the deep side of the submandibular gland, while the lower level displayed both cut surfaces of the common carotid and subclavian arteries (Figs. 1–5).

The high origin of the external carotid artery was seen in the left side of specimen 58 (Figs. 2, 3). Notably, a left/right difference in topographical relationships was seen between the artery and vein. At the level of the larynx in 2 of 5 cadavers, the vein was located on the ventral side of the left-side artery (specimens 56 and 57; Fig. 4). Due to this dorsoventral arrangement of the artery and vein, the vagus nerve was also shifted ventrally and did not face the prevertebral lamina of the cervical fasciae. Although the prevertebral lamina was usually thick and clear (Figs. 1 and 2), a slight left/right difference was identified in the fascia, such as unclear prevertebral lamina near the internal and external carotid arteries in the right upper level of specimen 58 (Fig. 3) and in the left middle level of specimen 56 (Fig. 4). Other site-dependent differences in fascial arrangement are described below.

**Level of the hyoid bone body or upper level**

A common sheath enclosing arteries and veins usually became thin and/or interrupted in the upper level, particularly along venous surfaces. The arterial adventitia enclosed the external and internal carotid arteries together, but tended to become thinner than the middle level (specimen 58 right in Fig. 3). Arterial branches and venous tributaries carried a proper adventitia, but this was looser than that of the great vessels. The hypoglossal and accessory nerves as well branches of the external carotid artery interrupted and disturbed the basic fascial arrangement, but the common sheath for the internal carotid artery and internal jugular vein still remained its circular arrangement (Fig. 5A). The vagus nerve (inside of the common sheath) and ansa cervicalis (outside of the sheath) displayed the same topographical relationship as in the larynx level. A common sheath of the great vessels did not fuse with a fascia covering the submandibular and parotid glands (specimen 56 right in Figs. 4 and 5). The lateral aspect of the common sheath tended to become closer to a fascia covering the sternocleidomastoideus and thus sometimes appeared to fuse mutually (specimen 57 right, Fig. 1A). A septum between the artery and vein, provided by both adventitial tissues, became thin or interrupted. In contrast, another connective tissue plate was seen between the external and internal carotid arteries (specimen 56 left in Fig. 4A).

The prevertebral lamina of the cervical fasciae became thinner than that in the middle level in specimen 58 right (Fig. 3), but became thicker in specimen 56 left (Fig. 4). A multilaminar fascial structure was seen in the dorsal side of the oropharynx, and one appeared to correspond to the
Fig. 2. Poorly developed carotid sheath and superior and inferior continuations (left side).
Specimen 58 left. This specimen carries a thin arterial adventitia (Fig. 3). Panel A displays the upper level including the hyoid bone (HB), but the common carotid artery (CC) is still seen due to the high origin of the external carotid artery. Panel B, the middle level, includes absence of the ventrolateral part of the carotid sheath (asterisks). Panel C exhibits the lower level including the subclavian artery (SC). Fascia is evident (triangles) between the subclavian and common carotid arteries. Magnifications for these 3 panels are the same, corresponding to Figs. 3A–C on the right side. Arrows indicate the prevertebral lamina of the cervical fasciae. RN, recurrent laryngeal nerve; TA, transverse cervical artery; VA, vertebral artery. Panels D and E represent higher magnifications of a square with D and E in panel B, respectively. Note in panel D the unclear common sheath of the carotid sheath (open stars) in contrast to the thick prevertebral lamina of the cervical fasciae (arrows). Panel E, the up-down orientation is rotated at a right angle, displaying a retrovisceral multilaminar structure.
alar fascia connecting bilateral common sheathes. This structure sometimes fused with the visceral fascia (specimen 57 right in Fig. 1A). Fascia separating jugulodigastric nodes from the great vessels was often thin or absent (specimen 58 right in Fig. 3A; specimen 56 right in Fig. 5A). The stylohyoideus and posterior belly of the digastricus were located closely to but separated from the common sheath (Fig. 5A). The sympathetic nerve trunk and its associated ganglion sometimes attached to the arterial adventitia and they were likely to exist in the superficial side of the prevertebral lamina in the upper level (Fig. 4A).

Level of the subclavian artery or lower level

The common carotid and subclavian arteries independently carried a proper adventitia. The adventitia of the subclavian artery attached to the prevertebral lamina of the cervical fasciae. The sympathetic nerve trunk and ganglion often attached to the arterial adventitia and were located on the superficial side of the prevertebral lamina (Fig. 2C). A septum between the artery and vein became unclear when the artery and vein were separated by concomitant nerves and lymph nodes. Instead, a definite fascia was sometimes seen between the common carotid and subclavian arteries (Fig. 2C). The vagus nerve attached to the adventitia of the common carotid artery, but it was separated from that of the subclavian artery. Notably, the visceral fascia became thin and interrupted (Fig. 3C). Thus, the space in the carotid sheath tended to communicate with the retrovisceral space. Instead, a multilaminar structure including the alar fascia became unclear on the dorsal side of the cervical esophagus. The subclavian artery appeared to interrupt the prevertebral lamina of the cervical fasciae.

Discussion

Descriptions on cervical fascial arrangement vary depending on the authors (Fig. 6). Grodinsky and Holyoke (1938) and Ouchi (1982) described in diagrams an independent pretracheal layer or fascia for the infrahyoid muscles, including the omohyoi-deus. However, the carotid sheath was separated from the pretracheal layer in the former, whereas the pretracheal layer provided a lateral part of the carotid sheath in the latter. In contrast, in each of the diagrams by Spitzka (1913), Hollinshead (1982) and Clemente (1985), the pretracheal layer joined the superficial fascial layer containing the sternocleidomastoideus. These authors thus regarded a fascia covering the medial or inner side of the sternocleidomastoideus as a lateral part of the carotid sheath. Moreover, Spitzka (1913) and Clemente (1985) described fusion between the carotid sheath and visceral fascia covering the thyroid gland and laryngopharynx. Arrangement of the prevertebral fascial also differs between authors. In Hollinshead (1982), the alar fascia was not regarded as a connecting part of the bilateral carotid sheaths, but it originated from the prevertebral fascia. Ouchi (1982) did not pay attention to the alar fascia. In Spitzka (1913), the dorsal part of the carotid sheath comprised the prevertebral fascia (Fig. 6A). Overall, Grodinsky and Holyoke (1938) regarded the carotid sheath and alar fascia as independent fascial structures, whereas other authors have tended to emphasize that other cervical fasciae more or less contribute to parts of the carotid sheath. In addition, in Grodinsky and Holyoke (1938), Ouchi (1982) and Clemente (1985), the sympathetic trunk was not covered by the prevertebral fascia, but instead lay outside the carotid sheath. Grodinsky and Holyoke (1938; in their Fig. 9) described an independent sheath containing the sympathetic trunk and attaching to the carotid sheath although the topography was different between their original figures.

The present study demonstrated several basic rules differing from previous descriptions of the carotid sheath: 1) the common sheath is separated from both a fascia covering the sternocleidomastoideus and the prevertebral fascia; 2) the common sheath often fuses with the visceral fascia to provide...
a thick connective tissue plate on the medial side of the great vessels; and 3) a fascia or some fasciae seem to communicate between bilateral common sheaths, although a single alar fascia (see below) was difficult to identify in a retropharyngeal multilaminar structure. These results are summarized in Figure 6F, which was basically similar to Grodinsky and Holyoke (1938) despite abundant interindividual and site-dependent differences.

Grodinsky and Holyoke (1938) emphasized that bilateral carotid sheathes are connected by the “alar fascia” on the immediately dorsal side of the pharynx and cervical esophagus, which are lined with another, visceral fascia. Thus, according to their observations, the alar fascia is located between the visceral fascia and prevertebral lamina of the cervical fasciae and extends across the midline. However, the alar fascia concept displays gradual changes depending on the researchers. Honma et al. (2000), in a study demonstrating that injectates of C6 stellate ganglion block travel through the prevertebral interlaminar space or danger space between the alar fascia and prevertebral lamina of the cervical fasciae, described a meso-like fascia connecting the carotid sheath and alar fascia. Thus, as seen in Hollinshead (1982; Fig. 6C), Honma et al. (2000) considered the alar fascia as part of the prevertebral laminae rather than an “ala” (i.e., wing) of the carotid sheath. A concept that the alar fascia connects the bilateral sheathes might be based on a frequent adhesion between the visceral fascia and common sheath (see above) because the retropharyngeal fascia (a part of the visceral fascia) and alar fascia have often been confused in literatures (reviewed in Honma et al., 2000).

Grodinsky and Holyoke (1938) designated “space 3A” for the potential space within the carotid sheath. Injected materials were usually limited in the space according to injection studies into the space, but sometimes extended through the sheath or wall of the space to cause leakage into the postcervical and/or visceral spaces. Notably, injectates did not extend higher than the level of the hyoid bone due to adherence between the sheath and adjacent structures such as the stylopharyngeus and posterior belly of the digastric muscles. However, the present study did not reveal such tight adherence. Clemente (1985) introduced a theory that the carotid sheath extends superiorly as far as the skull base. However, at the upper and lower levels examined in the present study, the common sheath tended to be thinner than the middle level. Observations of each part of the carotid sheath, i.e., the adventitia and common sheath, were useful for understanding interindividual differences because thickness of the common sheath tended to vary between individuals, contrasting with the relatively stable adventitia. In previous diagrams (Fig. 6), only Hollinshead (1982) described structures similar to the present adventitia, but they seemed to be subdivisions of the common sheath. Nevertheless, the number of cadaver sides examined seemed too small to allow discussion of interindividual differences separate from site-dependent differences.

Fusion between the common sheath and visceral fascia was often evident in the middle level. Is this a result of inflammation of the thyroid gland? However, deep cervical nodes, in which inflammation should occur frequently during life, did not adhere to fascia, but tended to scatter in a loose connective tissue. No previous reports appear to have described pathological changes of the cervical fascia other than studies on deep cervical infection into the retrovisceral space (Nguyen et al., 1992; Nicklalus and Kelly, 1996). Likewise, pathological neck masses are frequently reported in elderly patients (Maisel, 1980), and may emphasize or disturb the fascial arrangement. Skeletal muscle degeneration with aging, as reported for the external urethral sphincter (Strasser et al., 1999), is also likely to change the fascial arrangement, especially along the pretracheal lamina and infrahyoid muscles, although specimens have not been able to be retrieved from younger subjects to confirm this hypothesis.

Fig. 4. Carotid sheath and left/right differences in vascular topographical relation (left side).

Specimen 56 left. Panel A shows the upper level crossing the hyoid bone (HB), while panel B corresponds to the middle level including the larynx (LX). Arrows indicate the prevertebral lamina of the cervical fasciae. In panel A, a fascia (triangles) covering the submandibular gland (SM) is 2 mm away from the great veins. In panel B, the internal jugular vein (IJ) is located on the ventral side of the common carotid artery (CC). The prevertebral lamina of the cervical fasciae is unclear (open stars). A thick visceral fascia is evident (white triangles). Part of a covering fascia for the sternocleidomastoideus (SM) is adjacent to the common sheath near the great vein (asterisks for both fasciae). Magnifications for these 2 panels are the same and correspond to Figure 5 in the right side.
Fig. 5. Carotid sheath and a left/right difference in vascular topographical relation (right side). Specimen 56 right. Panels A and B correspond to almost the same levels as shown in those of Figures 4A and 4B, respectively. Arrows indicate the prevertebral lamina of the cervical fasciae. In panel A, note unclear fasciae (asterisks) between the parotid gland (PG) and great vessels. The common sheath attaches to the prevertebral lamina. The digastricus (DG) and stylohyoideus (SyH) are separated from the common sheath. AN, accessory nerve; HN, hypoglossal nerve; LA, lingual artery. In panel B, a covering fascia of the sternocleidomastoideus (SM) is separated from a common sheath of the great vessels (asterisks for both fasciae). The prevertebral lamina of the cervical fasciae is interrupted on the dorsomedial side of the artery (open stars). The ventromedial part of the common sheath and a septum between the artery and vein are thick. Magnifications for these 2 panels are the same (bar in panel A, 10 mm) as in Figure 4.
Fig. 6. Schematic diagrams of carotid sheath found in textbooks and the present results. Panels A, B, C, D and E are drawn according to my understandings of Spitzka (1913), Grodinsky and Holyoke (1938), Hollinshead (1982), Ouchi (1982) and Clemente (1985), respectively. In these previous descriptions, Grodinsky and Holyoke (1938) regarded the carotid sheath and alar fascia as an independent fascial structure. Other authors have emphasized that other cervical fasciae such as the superficial, pretracheal, prevertebral and visceral fasciae contribute more or less to parts of the carotid sheath. Panel F is a schematic diagram summarizing the present observations, basically similar to the findings of Grodinsky and Holyoke (1938) despite the suggestion of abundant interindividual and site-dependent differences.
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