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Ansa Cervicalis Nerve: Review of the Topographic Anatomy and Morphology

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In recent years, there has been a proliferation of techniques utilizing the ansa cervicalis nerve to reinnervate the paralyzed larynx. The anatomic course and morphology of the ansa cervicalis are complicated by the variable course and location along the great vessels of the neck, as well as the significant differences observed in the arrangement of its contributing roots and regional branching patterns. Herein, we review the surgical anatomic course of ansa cervicalis and its innervation of the muscles of the neck, and develop specific recommendations with respect to the use of this nerve in laryngeal reinnervation.

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INTRODUCTION

In the past few decades, laryngology has witnessed a dramatic proliferation of surgical procedures designed for the treatment of dysphonia secondary to unilateral paralysis of the vocal cord. They include medialization procedures such as Teflon (DuPont, Wilmington, DE) injection,[1] thyroplasty,[2] and arytenoid adduction,[3] and reinnervation procedures such as nerve-muscle pedicle implantation[4] and nerve-nerve anastomosis using ansa cervicalis nerve transfer to the recurrent laryngeal nerve.[5] Reinnervation procedures are purported to work by preventing vocal cord atrophy and maintaining symmetric vocal cord mass and tension.[5]

The ansa cervicalis nerve has become a prime choice for use in laryngeal reinnervation because of its proximity to the larynx and because it is quite active during phonation. *Ansa* is a Latin term meaning "handle of a cup" or "haft."[6] The ansa cervicalis nerve is formed by the junction of two main nerve roots derived entirely from ventral cervical rami. A loop (summit) is formed at the point of their anastomosis. For decades the superior root was called the *descendens hypoglossi* because it branches off from the hypoglossal nerve. In the past the ansa cervicalis was called the *ansa hypoglossi*. The branches of the ansa cervicalis innervate the infrahyoid (strap) muscles of the neck.

Recently, there has been an interesting debate as to which branch of the ansa cervicalis used for laryngeal reinnervation would result in the best vocal quality. Frazier and Mosser[7] were the first to report the anastomosis of the ansa cervicalis nerve to the recurrent laryngeal nerve in humans. They utilized the superior root of the ansa cervicalis and achieved an "improved" surgical outcome in five of 10 patients. Crumley et al.[8] have recommended the ansa cervicalis branch to the sternothyroid. They reason that the branch to the sternothyroid is located very near the recurrent laryngeal nerve, and although the pattern of sternothyroid activation is predominantly inspiratory, it discharges throughout the respiratory cycle and would provide a certain degree of continuous tone to the vocalis muscle after reinnervation. It is also thought that the subsequent paralysis of the sternothyroid muscle relaxes tension on the thyroid cartilage and further medializes the paralyzed cord. Some investigators, however, have argued against the use of the sternothyroid branch because the pattern of activation from this nerve may result in cord adduction during inspiration rather than phonation.[9] The thyrohyoid is the most active strap muscle during phonation, with peak activity during expiration. Crumley,[8,10] however, has advised against using the nerve branch to this muscle because it would require a cable graft to reach the recurrent la-

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ryngeal nerve stump and the resulting paralysis of the thyrohyoid would eliminate the adductor properties of this muscle on the vocal fold.

The ansa cervicalis nerve formation is relatively complex, as its course and location along the great vessels of the neck vary. Yet there is a remarkable paucity of information on this nerve in the current otolaryngology literature. Therefore we have undertaken a literature review on the anatomic course, morphologic variation, and regional branching patterns of this nerve. We report our findings below and provide some recommendations on the use of this nerve in laryngeal reinnervation.

METHODS

The MEDLINE database was searched from 1966 to 1996 for all publications with the keywords "ansa cervicalis." All relevant articles from search results were reviewed. In addition, many major anatomical textbooks published in the 20th century were consulted for classical descriptions of the ansa cervicalis nerve. Any references in the textbooks were further pursued. This information formed the core for the following review.

RESULTS

Hypoglossal Nerve

The hypoglossal nerve emerges from the skull base through the hypoglossal canal medial to the internal jugular vein and posteromedial to the internal carotid artery. It then passes laterally and downward to lie against the posterior surface of the vagus nerve, where it exchanges branches of communication with this nerve and with the sympathetic trunks. It continues downward between the jugular vein and the internal carotid artery. Close to its exit from the skull it is usually joined by branches of communication from the first cervical nerve; it is these fibers which leave the hypoglossal nerve as the superior root of the ansa cervicalis, the nerve to the thyrohyoid, and the nerve to the geniohyoid. The fibers within the hypoglossal nerve itself supply only muscles of the tongue.[11]

At the level of the origin of the occipital artery from the external carotid artery, the hypoglossal nerve forms an arc away from its vertical course to become horizontal (Fig. 1). It passes forward, across the lateral surfaces of both the internal and the external carotid arteries, medial to the posterior belly of the digastric, and gives off the superior root of the ansa cervicalis.[12] In a series of 20 adult dissections reported by Kuniak and Klacansky,[12] the average width of the hypoglossal nerve was 2.2 mm before the superior root of the ansa cervicalis branched off and 2.05 mm afterward.

Nerve to the Thyrohyoid

The nerve to the thyrohyoid muscle branches from the hypoglossal before the latter nerve dips beneath the stylohyoid muscle in close proximity to the posterior border of the hyoglossus muscle (Fig. 1). Af-

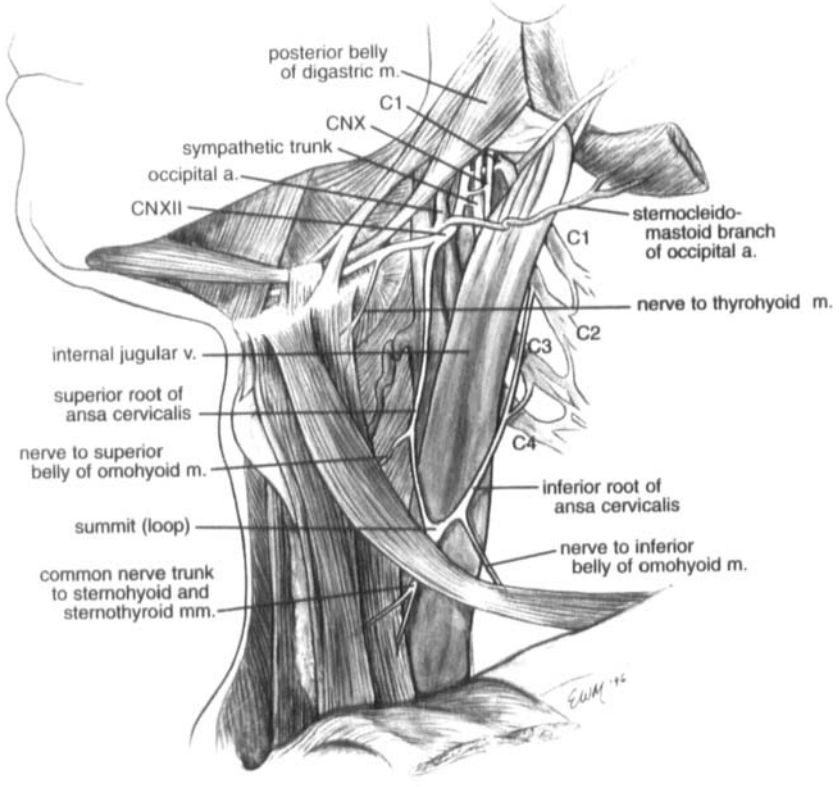

Fig. 1. Regional anatomy of the ansa cervicalis nerve. The nerve and its branches are illustrated in their most frequent morphologic and topographic form. The nerve to the thyrohyoid branches from the hypoglossal nerve and runs obliquely across the hyoid bone to innervate the thyrohyoid. The nerve to the superior belly of the omohyoid branches from the superior root and enters the muscle at a level between the thyroid notch and a horizontal plane 2 cm inferior to the notch. The nerves to the sternohyoid and sternothyroid share a common trunk, which branches from the loop. The nerve to the inferior belly of the omohyoid also branches from the loop. The loop is most frequently located just deep to the site where the superior belly (or tendon) of the omohyoid muscle crosses the internal jugular vein.

ter arising from the hypoglossal nerve, it runs obliquely across the greater cornu of the hyoid bone to innervate the thyrohyoid muscle. Its fibers are derived from the communication of the hypoglossal nerve with the first cervical nerve.[13] The hypoglossal nerve continues forward under cover of the submandibular gland, passing above the hyoid bone on its way to innervate the tongue.[11,13,14] In its course, the hypoglossal nerve passes within 4 to 5 mm of the intermediate tendon of the digastric muscle.[15]

Superior Root

Origin and course. The superior root of the ansa cervicalis is classically described as a long slender branch that emerges from the superior portion of the arc of the hypoglossal nerve as that nerve makes the turn around the occipital artery to assume a horizontal course toward the tongue.[11,14,16,17] At its origin, the superior root is medial to the posterior belly of the digastric muscle and lateral to the internal and external carotid arteries.[12] It descends obliquely downward and slightly medially on the internal carotid artery and then the common carotid, either in front of or within the carotid sheath, and is joined at a variable level in the neck by the inferior root of the ansa cervicalis, forming a loop.[14] Occasionally the superior root seems to be derived either entirely or in part from the vagus, but in these instances the fibers can be traced back to their true origin from the cervical plexus.[14]

The level of origin of the superior root from the hypoglossal nerve trunk can vary. In a series of 80 comparative dissections in 40 adults, Caliot and Dumont[15] observed its origin at the level of the intermediate tendon of the digastric muscle in 25% of the cases. In the remaining 75% the origin was above this tendon, usually only several millimeters above, but frequently very high, even at the very exit of the hypoglossal nerve from the anterior condylar canal.

The descent of the superior root of the ansa cervicalis can be followed down the neck along its intimate relationship to the great vessels. Caliot and Dumont[15] observed its vertical descent on the external carotid in 60% of the cases, and on the internal carotid in 40%. Further down and closer toward its anastomosis with the inferior root, the superior root is found in direct relation to the internal jugular vein and is most frequently observed passing laterally to the anterolateral side of the internal jugular vein.[12] As the nerve descends, it gets progressively narrower. Kuniak and Klacansky[12] measured the average diameter of the superior root at the point of separation from the hypoglossal nerve at 1.03 mm. At the point of anastomosis to form the loop, the nerve width had decreased to 0.79 mm. Total length of the superior root on average was 7.1 cm.

Innervation to the superior belly of the omohyoid. Classically, the branch to the superior belly of the omohyoid was almost invariably reported to originate directly from the superior root of the ansa cervicalis (Fig. 1).[11,13,17] This was confirmed by Liguoro et al.[18] in a study of 35 adult dissections. In contrast, in a dissection of 20 specimens by Caliot and Dumont,[15] the nerve to the superior omohyoid belly was found in 10 (50%) of the preparations. Among these, six (60%) originated from the superior root of the ansa cervicalis and four (40%) originated from the summit of the ansa (Fig. 2).

The nerve to the superior belly of the omohyoid may contact the muscle at different levels. In a series of 221 observations, this nerve passed behind the posterior edge of the omohyoid muscle anywhere from 2.5 cm superior to the superior thyroid notch to 5 cm inferior to the notch.[19] However, in 91% of the cases the nerve crossed between the level of the notch and a horizontal plane 2 cm inferiorly. In only one case (0.5%) was the nerve found at a level superior to the horizontal plane of the notch. In the re-

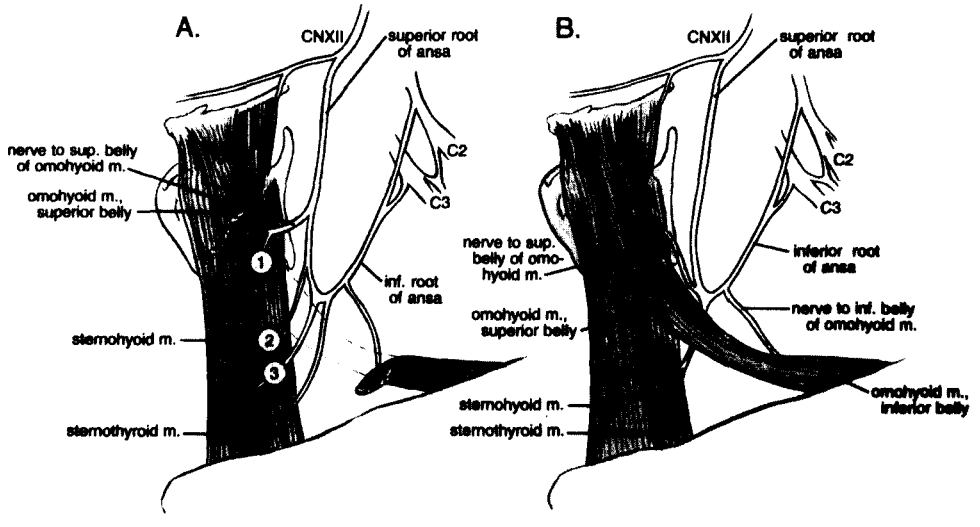

Fig. 2. **A.** Variations to the innervation of the sternohyoid and sternothyroid. The nerve to the sternohyoid can arise from *1.* a common trunk with the nerve to the superior belly of the omohyoid, *2.* the superior root, or *3.* the loop of the ansa cervicalis. The nerve to the sternothyroid muscle always arises from the loop in the variant cases. **B.** Variations to the innervation of the omohyoid. In one study, in 40% of cases the nerve to the superior belly of the omohyoid branched from the loop. The nerve to the inferior belly of the omohyoid always arises from the loop and runs in a loop of cervical fascia below the central tendon.

maining 8.5%, the nerve was found at a level between 2.5 and 5 cm inferior to the notch.

Other nerve branches. On rare occasions, other nerve branches have been noted to arise from the superior root of the ansa cervicalis. A nerve filament from this root sometimes passes into the thorax, where it joins the vagus or sympathetic nerve; in these cases the aberrant branch is itself probably derived originally from either the sympathetic or the vagus.[14] Turner[20] also reported a case of the phrenic nerve receiving a root of origin from the superior root. This branch arose in the lower part of the left neck from the superior root, entered the thorax, passed anterior to the innominate vein and the transverse part of the arch of the aorta, and joined the ipsilateral phrenic nerve in front of the root of the left lung. In this person, the main trunk of the phrenic received cervical roots of origin from C4 and C5, but not from C3. Turner hypothesizes that the C3 root of the phrenic nerve had accompanied the C3 contribution to the inferior root of the ansa cervicalis and with it had reached the superior root, with which it ran for about 5 cm before being given off to join the phrenic nerve within the thorax. The superior root may also send a branch to the sternocleidomastoid muscle[14,21] and to the upper portions of the sternohyoid and sternothyroid muscles.[11]

Inferior Root

The inferior root of the ansa cervicalis usually arises from the junction of two primary ventral cervical rami, most commonly C2 and C3. In a study of 160 preparations of stillborn infant cadavers by Poviraev and Chernikov,[22] the inferior root of the ansa cervicalis was derived from the primary ventral rami of C2 and C3 in 74% of the cases, from C2, C3, and C4 in 14%, from C3 alone in 5%, from C2 alone in 4%, and from C1, C2, and C3 in 2%. In the series of Caliot and Dumont,[15] C3 was the most frequent contributor to the inferior root, with 64 cases (80%), and C2 contributed in 29 cases (36%). The variable location and manner in which these primary ventral rami combine to form the inferior root contribute to the morphologic variation of the ansa cervicalis (*see* section below).

As a general rule these contributing branches emerging from the cervical ventral rami combine before the summit of the ansa cervicalis to form the inferior root. This can occur anywhere from 1.7 cm to 4.4 cm from the summit.[23] Sometimes the contributing branches travel separately all the way to the level of the summit and the formation of the inferior root is completed over the internal jugular vein. This has been reported to occur at a frequency of 15%.[12]

The descending course of the inferior root has two main patterns and both relate to the internal jugular vein.[13] The root may pass at first posterior and then lateral to the internal jugular vein and then cross in front of this vein a little below the middle of the neck to anastomose with the superior root across the front of the vein. In the other pattern, the root may pass medial to the internal jugular vein, passing between this vein and the common carotid artery. Both these patterns occur frequently. In a study of 118 dissections the nerve was found to pass on the lateral side of the internal jugular vein in 57% of the cases, and the medial side of the internal jugular vein in 43% of the cases.[24] Caliot and Dumont[15] observed the lateral position in 65 cases (81%) and the medial position in 12 cases (15%). Therefore, the superior and inferior roots of the ansa cervicalis most frequently meet over the lateral wall of the internal jugular vein, medial to the superior belly of the omohyoid muscle. The inferior root, including the connecting part of the ansa cervicalis has an average length of 5.5 cm and an average width of 0.83 mm.[12]

The Loop

Formation and location. The superior and inferior roots of the ansa cervicalis form a loop, or summit, at the point of their anastomosis. Poviraev and Chernikov[22] classified the structure of the loop as a "concentrated" type, characterized by thick nerve trunks in the form of a solitary arch from which one or two branches for the infrahyoid muscles emerge, and a "diffuse" type, characterized by finer nerve trunks in the form of a plexus. The former type was seen in 43% of their 160 preparations and the latter in 15%. From the loop, a majority of the infrahyoid muscles receive innervation. The length of the inferior root and its relationship to the internal jugular vein determine the location of the loop.

The superior belly of the omohyoid muscle serves as a helpful landmark for locating the loop. The roots of the ansa cervicalis may be either long or short, and therefore the union between the two roots may be situated low (long ansa) or high (short ansa) in the neck.[11] A long or short ansa is defined according to the position of the summit of the ansa cervicalis in relation to the omohyoid muscle.[15] The summit may be placed at any level from immediately inferior to the occipital artery to approximately 4 cm superior to the sternum.[17] The most frequent position of the summit, however, is just deep to the site where the superior belly (or tendon) of the omohyoid muscle crosses the great vessels (Fig. 1). Caliot and Dumont[15] reported this position in 51 (64%) of 80 dissections. In 17 cases (21%) the loop was superior to the omohyoid muscle (short ansa) and in 12 cases (15%) the loop was found inferior (long ansa) (Fig. 3).

Innervation to the sternohyoid and sternothyroid muscles. Kuniak and Klacansky[12] report an inconstant count of two to four filiform branches,

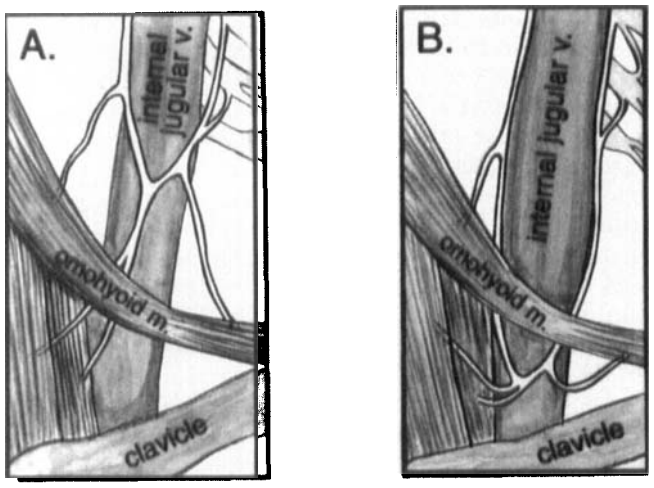

Fig. 3. Variations of the loop location. The loop may also be located superior to the omohyoid muscle (short ansa) **(A)** or inferior to the omohyoid muscle (long ansa) **(B)**. These variations have been reported to occur at a frequency of 21% and 15%, respectively.

approximately 3 cm long and 0.47 mm wide, arising out of the ansa and feeding the infrahyoid muscles.[12] One branch was wider (average, 0.9 mm), longer (average, 4.3 cm), and more constant. Beneath the omohyoid it branched further, and its two terminal branches dove into the sternohyoid and sternothyroid muscles approximately 2 cm above the clavicle. The entire ansa cervicalis was approximately 12.6 cm long. Caliot and Dumont[15] report similar findings: the nerves to the sternohyoid and sternothyroid muscles shared a common trunk that arose at the summit of the ansa cervicalis in 17 of 20 cases (85%) (Fig. 1). In the remaining cases, the nerve to the sternohyoid was derived from the common trunk with the nerve to the superior belly of the omohyoid (one case), from the summit (one case), or from the superior root (one case) (Fig. 2). The nerve to the sternothyroid was derived from the summit of the ansa cervicalis in all three cases.

Whereas the lower portions of the sternohyoid and sternothyroid muscles are invariably innervated by prominent ansa cervicalis nerve branches derived from the loop, the innervation to the upper portions is less well defined. The upper portions of the sternothyroid and sternohyoid muscles are possibly innervated by branches from the superior root,[11] branches derived from the hypoglossal nerve, or a fine network of nerve filaments overlying the oblique line of the thyroid cartilage.[25] These nerve branches have not been well studied.

Innervation to the inferior belly of the omohyoid. The nerve to the inferior belly of the omohyoid always arises from the summit of the ansa cervicalis and its trajectory is always along the intermediate tendon of the muscle (Figs. 1 and 2B). It runs in a loop of cervical fascia below the central tendon of the muscle.[15,17]

Morphological Variations of the Ansa Cervicalis

Three main components contribute to the morphological variations of the ansa cervicalis formation. The first is the morphology of the inferior root. The inferior root varies greatly compared with the superior root owing to the various cervical root combinations possible in its formation. The five combinations observed by Poviraev and Chernikov[22] were described earlier. Caliot and Dumont[15] describe four combinations: the inferior root derived from a single cervical root in 23 cases (29%), from two cervical roots in 47 (59%), from three cervical roots in seven (9%), and from four cervical roots in one case (1%). They found the inferior root absent in two cases (3%). Additionally, Maruyama[26] reports three main combinations with three subtypes within each combination (for a total of nine combinations). All reports agree, however, that C2 and C3 contribute most frequently to the inferior root, whereas C1 and C4 contribute less commonly.

The second component is the length of the loop in relation to the omohyoid muscle (Fig. 3). Caliot and Dumont[15,23] combine these two components and describe seven morphological variations of the ansa cervicalis (Fig. 4). The final component is the numerous patterns of innervation to the strap muscles described herein.

The ansa cervicalis is also frequently asymmetric. Caliot and Dumont[15] found the superior root symmetric on both sides of the neck most of the time, but the inferior root was symmetric in only 10 (25%) of 40 subjects. The entire ansa cervicalis was symmetric in only six subjects (12%). In a dramatic example of asymmetry, Kuniak and Klacansky[12] observed a case in which two narrow branches derived from the C2 and C3 primary ventral rami on the right side of the neck projected *dorsally* on the internal jugular vein and joined with the superior root anterior to the vein, approximately 1 to 2 cm under the common facial branch of the vein. Therefore, on the right the ansa cervicalis was substantially shorter (6.8 cm) and the descending branches from the loop to the infrahyoid muscles longer (4.8 to 7.8 cm). On the left, the inferior root contributions from C2 and C3 joined distally over the posterolateral side of the internal jugular vein before the anastomosis with the superior root, approximately 4 to 5 cm inferior to the omohyoid muscle. Consequently, the ansa cervicalis was substantially longer (20.2 cm) and the main nerve trunk from the loop innervating the sternohyoid and sternothyroid muscles was substantially shorter (2.2 cm long and 0.43 mm wide).

Phrenic Nerve and Other Connections

The phrenic nerve usually arises from the third, fourth, and fifth cervical nerves, such that it

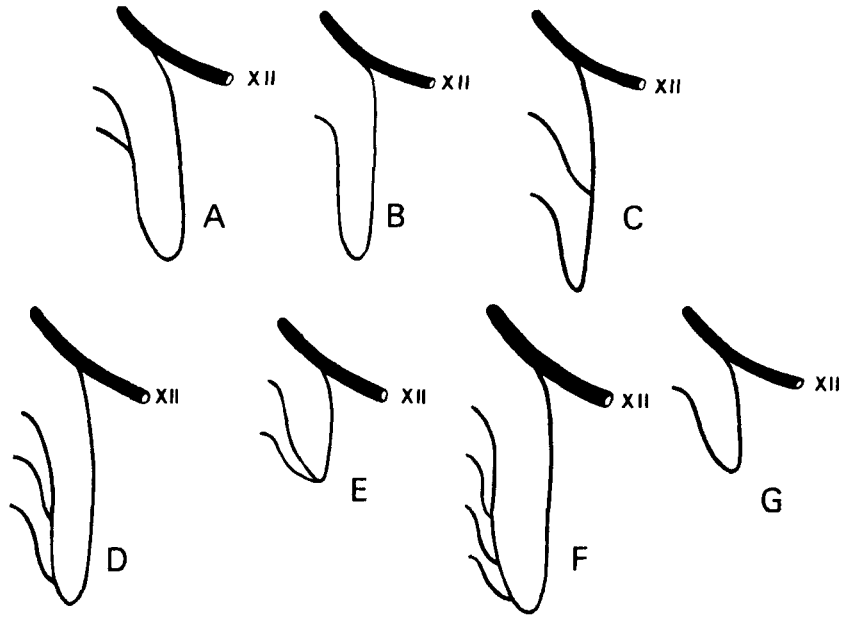

Fig. 4. Seven morphologic forms of the ansa cervicalis nerve formation described by Caliot and Dumont from 80 observations (*see* text). **A.** Double classic form (40%). **B.** Simple classic form (27%). **C.** Double form with two separate roots (11%). **D.** Triple form (9%). **E.** Double short form (8%). **F.** Quadruple form (1%). **G.** Single short form (1%).

is derived from segments that contribute to both cervical and brachial plexuses. A contribution to the phrenic nerve from the ventral ramus of C5, derived as a branch from the nerve to the subclavius muscle, and referred to as the *accessory phrenic nerve* is well known. However, accessory phrenic nerves are also frequently reported to arise from the ansa cervicalis.

Classically, twigs from the loop itself or from the nerves that supply the sternohyoid and sternothyroid are occasionally reported to descend in front of or behind the internal jugular vein into the thorax and join the cardiac and phrenic nerves.[13,16,17] A phrenic branch arising from the superior root of the ansa cervicalis reported by Turner[20] was mentioned earlier. Among the 160 observations by Poviraev and Chernikov[22], in five cases the ansa participated in the innervation of the heart, in four the nerve twigs reached the cardiac plexus as part of the superior branches, and in one case they were included with the superior cardiac nerve. Furthermore, the ansa communicated with the trunk of the vagus in eight cases and with the phrenic nerve in one case. In 14 cases the ansa participated in the innervation of the pericardium.

DISCUSSION

The ansa cervicalis nerve is located in the vicinity of major nerve structures. Because sacrificing this nerve causes no serious functional or cosmetic sequelae, it is an ideal candidate for use in nerve reconstruction in the neck. Its use is not limited to laryngeal reinnervation. Kukwa et al.[27] describe the use of this nerve in preventing the morbidity associated with tongue hemiatrophy after facial-hypoglossal anastomosis. Despite the multitude of topographic and morphologic variations of the ansa cervicalis nerve formation reported in the literature, the structures of surgical interest in laryngeal reinnervation (main nerve roots and branches) are found in relatively predictable locations. *1.* The superior root descends along the anterolateral aspect of the internal jugular vein, frequently embedded within the carotid sheath. *2.* The inferior root assumes a position posterolateral to the internal jugular vein. *3.* The nerves to the sternothyroid and sternohyoid are terminal branches of a common nerve trunk that arises from the loop structure. *4.* Upon posterior retraction of the sternocleidomastoid muscle and anterior retraction of the superior belly of the omohyoid, the ansa loop can be located overlying the carotid sheath where the superior belly (or tendon) of the omohyoid muscle crossed over the internal jugular vein.

The nerve branches can first be identified on the ansa cervicalis and then followed distally to their muscular insertion, or vice versa. Several pertinent variations of the ansa formation need to be highlighted. The loop can be short or long. The nerve branch to the superior belly of the omohyoid muscle often arises from the loop itself. Additionally, the inferior root frequently courses medial to the internal jugular vein. In these cases, the formation of the ansa loop occurs between the internal jugular vein and the common carotid artery, and some dissection of the carotid sheath is necessary to find it. However, the dangers of an inadvertent injury to the great vessels are significant and it would be prudent to initially locate the individual nerve branches or to use a nerve stimulator to find the ansa over the carotid sheath.

The physiologic excursion of the larynx during deglutition and phonation requires a tension-free

neurorrhaphy in any laryngeal reinnervation procedure. Furthermore, the use of nerves that are similar in diameter is essential, because a disparity in the diameter of the two nerves can lead to axonal escape and failure to achieve optimal results.[28] The recurrent laryngeal nerve is approximately 1 mm in diameter.[29] Based on these criteria, either the superior root of the ansa cervicalis (width, 0.79 mm to 1.03 mm) or the common nerve trunk to the sternohyoid and the sternothyroid (width, 0.9 mm) would be appropriate for anastomosis with the recurrent laryngeal nerve. The nerve to the superior belly of the omohyoid is also located in close proximity of the larynx. This was the nerve of choice for nerve-muscle pedicle reinnervation of the larynx.[4]

A few important anatomic details of the ansa cervicalis nerve formation remain to be studied. First, the sternohyoid and sternothyroid muscles are frequently cut in exposing the thyroid gland, and efforts are sometimes made to avoid injuring their nerve supply. Although some reports have suggested that the upper portions of the sternohyoid and sternothyroid are innervated by ansa cervicalis nerve branches that enter the muscles at the level of the thyroid cartilage, these branches have not been precisely studied or consistently reported.[11,24] On the other hand, the nerve branches to the lower portions of sternohyoid and sternothyroid almost invariably emerge from the loop and enter the muscles in their lower third, usually approximately 2 cm above the jugular notch. Therefore, the innervation of these muscles would best be maintained by sectioning them approximately halfway between the thyroid cartilage and the jugular notch. Second, quantitative data on the recurrent (if any) motor fibers within the ansa cervicalis nerve loop structure are lacking. This information would determine whether the proximal or the distal stump of the ansa root should be utilized for nerve anastomosis. Finally, it is assumed that the ansa cervicalis is mostly an efferent motor nerve. However, the infrahyoid muscles play a role in laryngeal steadiness and excursion during phonation and deglutition and the composition of nerve fibers (afferent vs. efferent) within this nerve are unknown.

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