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RESEARCH ARTICLE

Ansa cervicalis — A new classification approach

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ABSTRACT

Normally, the inferior root of Ansa cervicalis passes around the internal jugular vein and runs in an anterior direction to meet the superior root ventral to the common carotid artery. However, anatomical variants of the Ansa cervicalis are as yet not well investigated and understood. To close this gap the present study was undertaken. The Ansa cervicalis was examined in 54 human formalin-fixed cadavers and preparations of the head and neck by conventional dissection. In 66% of the specimens the Ansa cervicalis displayed the typical course that was classified as "internal type" (located medial to the internal jugular vein inside the carotid sheath). The remaining 34% pertained to the "external type" of the Ansa cervicalis (lateral to the internal jugular vein). The distance of the Ansa cervicalis relative to the superior margin of the thyroid cartilage was measured in every specimen. The external type Ansa cervicalis was located significantly lower than the internal type relative to the superior margin of thyroid cartilage. Regarding its location relative to the internal jugular vein four variants of combinations of the external and internal types of Ansa cervicalis on the right and left sides were distinguished. Based on their distance from the superior margin of the thyroid cartilage three types of Ansa cervicalis were defined.

1. Introduction

The Ansa cervicalis is part of the cervical plexus and innervates the infrahyoid muscles of the neck as well as the geniohyoid muscle (Caliot and Dumont, 1983; Chetri and Berge, 1997; Hegazy, 2013; Kikuchi, 1970). It is formed by the ventral branches of spinal nerves C1–C3 (Banneheka, 2008; Poviraev and Chernikov, 1967; Quadros et al., 2015; Vladimirov, 1967; Su et al., 2007; Wang, 1953; Yurian, 1965). For a short distance the fibers of C1 associate with the hypoglossal nerve and follow its course before dissociating from it and forming the superior root of the Ansa cervicalis. Fibers related to C2 and C3 give rise to the inferior root of the Ansa cervicalis (Banneheka, 2008; Sirasanagandla et al., 2013; Tanaca et al., 1988; Vladimirov, 1967). Both the superior root and inferior root parallel each other and run caudally within the carotid sheath. Then, both roots meet each other and form a loop which is known as Ansa cervicalis or Ansa cervicalis profunda. In rare cases the superior root exits the trunk of the vagus instead of the hypoglossal nerve, thus resulting in an aberrant Ansa cervicalis (Jelev, 2013; Manjunath, 2000).

The infrahyoid muscles directly or indirectly act on the larynx by supporting the laryngeal cartilages during phonation. Therefore, any injury to these muscles or their nerve supply can cause a disturbance in phonation. After recurrent laryngeal nerve palsy due to a thyroid gland operation, the Ansa cervicalis is often used as a surrogate structure to re-innervate the larynx (Smith and Houtz, 2016). This may improve laryngeal function considerably. Sometimes, almost normal conditions are achieved in terms of the general ability to speak and other primary laryngeal functions. Remarkably, onetime severance of the Ansa cervicalis does not result in functionally relevant pathologies. This, together with the close proximity of the Ansa cervicalis to the larynx, lends itself to nerve reconstruction procedures of the neck (Crumley, 1991; Hegazy, 2013; Palamarchuk, 2013; Quadros et al., 2015; Su et al., 2007; Zheng et al., 1996).

According to descriptions in atlases and textbooks of human anatomy the loop of the Ansa cervicalis is usually situated on the external (lateral) surface of the internal jugular vein (for example, Sobotta 24th ed.). However, some authors (Caliot and Dumont, 1983; Crumley, 1991) also noted the possibility of the Ansa cervicalis being located internal (medial) to the internal jugular vein.

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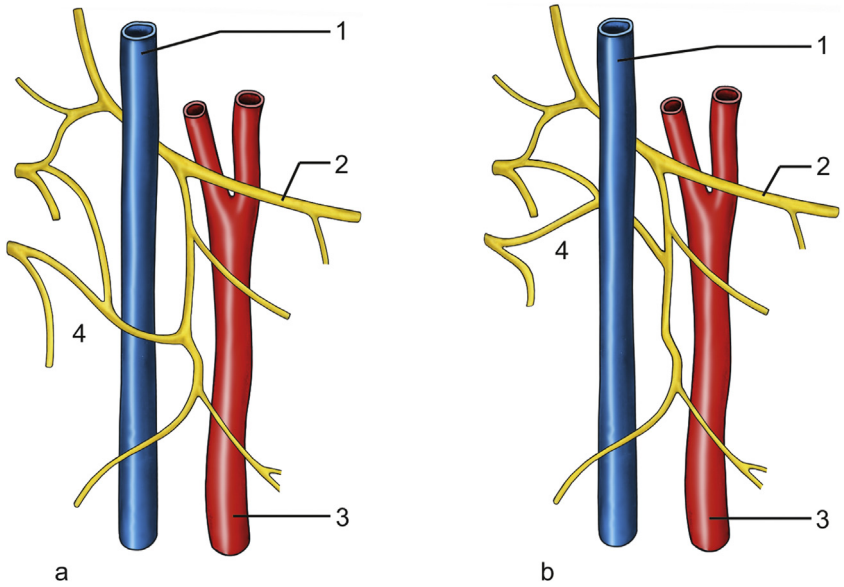

Fig. 1. Schematic drawing of an **a** external (lateral) and **b** an internal (medial) type of Ansa cervicalis. 1 – internal jugular vein; 2 – hypoglossal nerve [XII]; 3 – common carotid artery; 4 – ansa cervicalis.

The internal (medial) type was reported to occur more frequently than the external (lateral) type — at least in the Japanese population (Kikuchi, 1970; Tanaca et al., 1988). Banneheka (2008), however, distinguished three types of Ansa cervicalis: lateral, medial and mixed. Clinically, the anatomical variations of the Ansa cervicalis may be of importance for surgical interventions in the neck/throat region, including laryngeal re-innervation procedures. This is emphasized by the close proximity of the Ansa cervicalis to the great blood vessels within the carotid sheath, which have to remain intact during surgery (Hegazy, 2013; Kikuchi, 1970; Loukas et al., 2007). Mwachaka et al. (2010) demonstrated a location of the Ansa cervicalis lateral to the internal jugular vein in 81.5% of their samples. They described the location of the superior and inferior roots of the Ansa cervicalis relative to the posterior belly of the digastric muscle and the superior belly of the omohyoid muscle.

The aim of the present study was to obtain further insight into the variability of the Ansa cervicalis. To the authors' knowledge the thyroid cartilage has as yet not been used as a reference point to describe the exact topographic position and configuration of the Ansa cervicalis loop. Therefore, the present study was designed to fill this gap by meticulous dissection of human body donors and accurate description of the topography of the Ansa cervicalis relative to the internal jugular vein and the superior margin of the thyroid cartilage.

2. Materials and methods

All of the examined cadavers were obtained from the Department of Human Anatomy of Moscow Medical Sechenov University, Russia. All heads and necks of the investigated donor cadavers were free of recent trauma, head or neck infections, and any other disease affecting head and neck function. In total, 54 formalin-fixed cadavers (conventional fixation with 4% paraformaldehyde, 70% alcohol, glycerin and water) were used. Of these, 26 cadavers were female (age range 42–76 years); 28 cadavers were male (age range 42–62 years). In 22 cadavers preparation was performed on both sides of the body (resulting in 44 Ansae cervicales). In 32 cadavers preparation was performed on one side only: in 18 out of 32 cadavers on the right side and in 14 out of 32 cadavers on the left side (resulting in 32 additional Ansae cervicales). Unilateral analysis of the Ansa cervicalis was always due to the contralateral side having already been destroyed by anatomy students in routine anatomy dissection courses. Thus, in total, 76 Ansae cervicales were analyzed, with 40 being situated on the right side and 36 on the left side. When the inferior root was located external (lateral) to the internal jugular vein to form the Ansa cervicalis loop, it was classified as "external (lateral) type" (Figs. 1 a, 2 a). Accordingly, if the Ansa cervicalis was located internal (medial) to the internal jugular vein, it was classified as "internal (medial) type". (Figs. 1 b, 2 b)

Table 1
Different bilateral variants of the Ansa cervicalis regarding its position relative to the internal jugular vein.

Variant of combination	Position of Ansa cervicalis relative to the internal jugular vein	
	Left	Right
Variant 1	External	External
Variant 2	Internal	Internal
Variant 3	Internal	External
Variant 4	External	Internal

For a more accurate investigation of different variants of the Ansa cervicalis we used the thyroid cartilage as a reference point to describe the exact topographic position and configuration of the Ansa cervicalis loop. For this the highest point (Fig. 3) of the thyroid plate on the respective side was projected horizontally onto the carotid artery. Subsequently, the distance was measured between this point and the loop of the Ansa cervicalis (Fig. 3).

3. Results

In 65.8% of the 76 Ansae cervicales investigated, an external/lateral type was found (Fig. 2a). This was the case in 65.0% and 66.7% on the right side and the left side, respectively. All other specimens (34.2%) exhibited an internal/medial type (Fig. 2b).

In the 22 specimens that had been subjected to bilateral examination, four different side-related combinations of external and internal Ansa cervicalis types were found relative to the internal jugular vein (Table 1).

Variant 1 represents the external type of Ansa cervicalis on both sides of the body. *Variant 1* was detected in 36.4% of the bilaterally dissected specimens (n = 22 cadavers/44 Ansae cervicales) and was

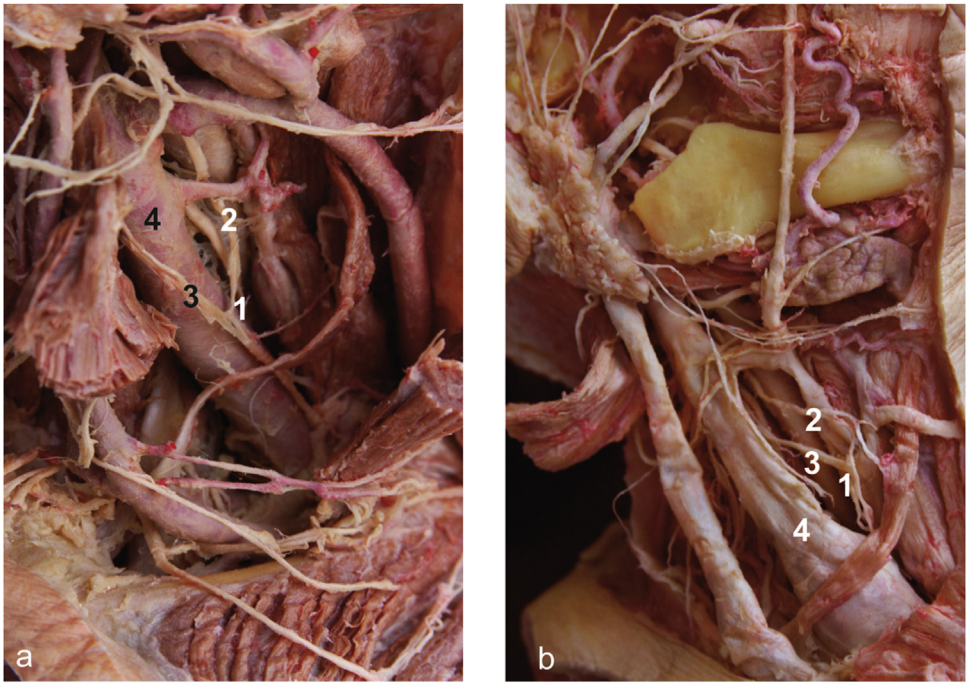

Fig. 2. Examples of dissected specimens **a** demonstrating an external type of ansa cervicalis and **b** demonstrating an internal type of ansa cervicalis. 1 – ansa cervicalis; 2 – superior root; 3 – inferior root; 4 – internal jugular vein.

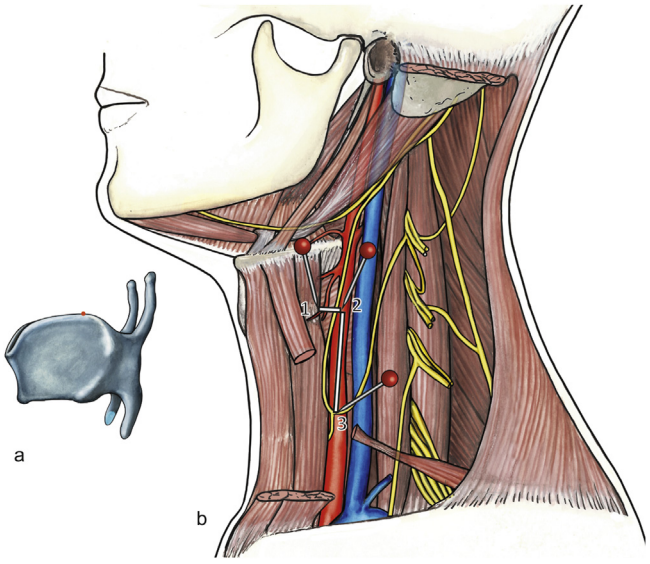

Fig. 3. Illustration of how the measurement of Ansa cervicalis was performed. The highest point of the thyroid plate (red point in **a**, and red needle marked with 1 in **b**) on the respective side was projected horizontally onto the carotid artery (red needle marked with 2 in b) and the distance measured between this point (red needle marked with 2 in **a**) and the loop of the Ansa cervicalis (red needle marked with 3 in **b**). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

classified as *external/external*. *Variant 2* was defined as the internal type on both sides and was therefore classified as *internal/internal* with an occurrence rate of 22.7% of the bilaterally dissected specimens (n = 22 cadavers/44 Ansae cervicales). *Variant 3* presented itself as external type on the right and internal type on the left. It was therefore classified as *external/internal* with an occurrence rate of 36.4% (n = 22 cadavers/44 Ansae cervicales). *Variant 4* was defined as internal type on the right and external type on the left and therefore classified as *internal/external* with an occurrence rate of 4.5% of the bilaterally dissected specimens (n = 22 cadavers/44 Ansae cervicales).

Table 2
Bilateral distribution of variants of Ansa cervicalis concerning their distance from the superior margin of the thyroid cartilage (n = 76).

Distance of the Ansa cervicalis from the superior margin of the thyroid cartilage in mm	Share of preparations (%)	
	Right side (n = 40)	Left side (n = 36)
A (≤ to 15 mm)	35.0	30.6
B (16–30 mm)	32.5	36.1
C (>30 mm)	32.5	33.3

In the majority of cases (81,6%) the caudal end of the Ansa cervicalis was located inferior to the superior margin of the thyroid cartilage. In the remaining cases (18.4%) the caudal end of the Ansa cervicalis was found on the same level or above the superior margin of the thyroid cartilage (up to 5 mm). The most inferior position of the caudal end of the Ansa cervicalis was 46 mm inferior to the superior margin of the thyroid cartilage (right side).

Determination of the position of the caudal end of the Ansa cervicalis relative to the highest point of the respective plate of the thyroid cartilage (Fig. 2) allowed for a division of the samples into three groups. Group A was comprised of specimens with a position of the caudal end of the Ansa cervicalis 15 mm or less below the superior margin of the thyroid cartilage. In group B the caudal end of the Ansa cervicalis was found 16–30 mm below the superior margin of the thyroid cartilage. In group C this value was more than 30 mm below the superior margin of the thyroid cartilage. Thus, the variability of the distances between the caudal end of the Ansa cervicalis and the superior margin of the thyroid cartilage was described with 15 mm intervals.

As shown in Table 2, the dissected specimens were distributed almost evenly across groups A–C. On the right side (n = 40) 35.0% were assigned to group A, whereas group B and C were each com-

Table 3
Combination of two different classification criteria for Ansa cervicalis variants (external or internal to internal jugular vein and distance from the superior margin of the thyroid cartilage; n = 76).

Distance of the Ansa cervicalis from the superior margin of the thyroid cartilage in mm	Share of preparations showing the external type (%)		Share of preparations showing the internal type (%)	
	Right side (n = 26)	Left side (n = 24)	Right side (n = 14)	Left side (n = 12)
A (below up to 15 mm)	3.7	0	100.0	91.7
B (16–30 mm)	48.15	50.0	0	8.3
C (more than 30 mm)	48.15	50.0	0	0

prised of 32.5%. On left side (n = 36) 30.6% constituted group A, 36.1% were assigned to group B, and 33.3% to group C.

Through combination of the two different criteria of classification (criterion 1: external/internal type relative to the internal jugular vein; criterion 2: distance between caudal end of Ansa cervicalis and the superior margin of the thyroid cartilage) an interesting finding was obtained (Table 3): 98% of the external types (right and left side combined [n = 50]) were found in groups B and C and thus displayed a position of the caudal end of the Ansa cervicalis at 16 mm or more below the superior margin of the thyroid cartilage (96.3% on the right side [n = 26; of these 48.15% belonged to type B and 48.15% belonged to type C]; 100% on the left side [n = 24; of these 50% belonged to type B and 50% belonged to type C]. 96.15% of the internal type Ansae cervicales [right and left side combined; n = 26]) were found in group A and thus correlated with a position of the caudal end of the Ansa cervicalis at 15 mm or less below the superior margin of the thyroid cartilage (100% on the right side [n = 14]; 91.7% on the left side [n = 12]). Thus, variants exhibiting a low position of the Ansa cervicalis in relation to the superior margin of the thyroid cartilage are normally located external/lateral to the internal jugular vein. Conversely, Ansa cervicalis with a higher position relative to the superior margin of the thyroid cartilage are usually located internal/medial to the internal jugular vein.

In two cases the Ansa cervicalis formed two loops on one side with one loop showing a more superior position than the other (Fig. 4).

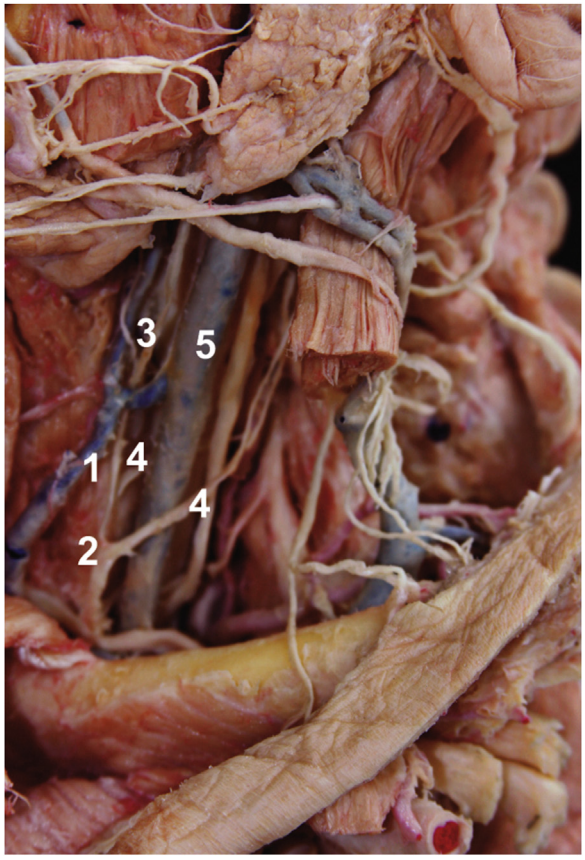

Fig. 4. Example of a dissected specimendemonstratinga case with two loops of Ansa cervicalis formed on the left side: 1 – superior Ansa cervicalis (internal type); 2 – inferior Ansa cervicalis (external type); 3 – superior root; 4 – inferior root; 5 – internal jugular vein.

4. Discussion

The Ansa cervicalis (profunda) can be considered as a secondary ansa of the cervical plexus, because it develops from the arcuate ansae (connections) between the anterior roots of the upper four spinal nerves (C1–C4).

Our data indicate that the Ansa cervicalis (its inferior root) is more often situated external (lateral) to the internal jugular vein rather than internal (medial) to it. This corroborates previous reports by Poviraev and Chernikov (1967) as well as Mwachaka et al. (2010) who obtained very similar data. As opposed to this, Banneheka (2008) found the Ansa cervicalis internal (medial) to the jugular vein (internal type) more frequently. The author suggested that such differences may be the result of marked differences between Europeans and Japanese in terms of the special anatomy of the Ansa cervicalis. However, Bannehaka refrained from providing more details concerning this issue.

The present study does not constitute a mere examination of the position of the Ansa cervicalis relative to the internal jugular vein, as conducted previously by many authors. Instead, we also analyzed the cranio-caudal position of the inferior end of the Ansa cervicalis with the superior margin of the thyroid cartilage as a reference point. To the best of the authors' knowledge this has not been done before. We furthermore identified peculiar features in the location of the Ansa cervicalis of internal (medial) and external (lateral) types relative to the superior margin of the thyroid cartilage (Table 2) and combined these findings with the position in relation to the internal jugular vein (Table 3). This combination revealed that the Ansa cervicalis usually lies external (lateral) to the internal jugular vein, if its inferior end displays a comparatively low position (with the superior margin of the thyroid cartilage as a reference point). As opposed to this, variants with a higher position of the caudal end of the Ansa cervicalis usually also lie internal (medial) to the internal jugular vein.

Until today the mechanisms of the embryological development of different Ansa cervicalis positions relative to the internal jugular vein are not understood completely (Mwachaka et al., 2010; O'Ramilly and Müller, 1984; Palamarchuk, 2013; Poviraev and Chernikov, 1967; Quadros et al., 2015).

Moreover, the mechanism of how exactly nerve branches of the cervical plexus enter the hypoglossal nerve and, in rare cases, the vagus nerve are as yet unclear as well (Jelev, 2013; Manjunath, 2000). The present study does not address embryological aspects

of Ansa cervicalis formation. The mechanisms by which the developing axons seek and find the correct path to their target cells are also not presented. There is as yet no literature on the time point of superior root entry into the hypoglossal nerve or, in rare cases, into the trunk of the vagus nerve. In our opinion the hypoglossal nerve may act as a conducting structure for the superior root of the Ansa cervicalis. A similar example of such a conducting structure can be found among the cranial nerves. The Chorda tympani, for example, a branch of the facial nerve, uses the lingual nerve (a branch of the mandibular nerve) as a conducting structure. Together with the lingual nerve the fibers of the Chorda tympani reach their target structures: the sublingual and submandibular glands (parasympathetic/secretory fibers) and the taste buds of the anterior two-thirds of the tongue (sensory fibers).

A division of the Ansa cervicalis variants into an external (lateral) and an internal (medial) type, relative to the internal jugular vein, was first proposed by Kikuchi (1970). In addition to the internal (medial) and external (lateral) types, Banneheka (2008) also defined the mixed type of Ansa cervicalis. Here, the inferior root formed one branch passing the internal jugular vein laterally and a second branch passing it medially. In the present study, however, we neglected the possibility of a mixed type of Ansa cervicalis.

Our data suggest that the external (lateral) type of Ansa cervicalis is found more frequently (in 66% of cases), than the internal (medial) type. According to authors from Japan (Banneheka, 2008; Kikuchi, 1970; Tanaca, 1967) the internal (medial) type of Ansa cervicalis is more common. This conspicuous difference between Russian (Poviraev and Chernikov, 1967; Yurian, 1965) and Japanese (Banneheka, 2008; Kikuchi, 1970; Tanaca, 1967) studies may be partially accounted for by anatomical differences between Europeans and Japanese in the formation of the large blood vessels of the neck (internal jugular vein, common carotid artery), the vagus nerve and the neck muscles (especially, the infrahyoid group). Banneheka (2008) asserts that the medial type of Ansa cervicalis is characteristic of the Japanese population.

To the best of the authors' knowledge, the present study represents the first investigation of the position of the Ansa cervicalis relative to the superior margin of the thyroid cartilage. According to the findings presented here, the external (lateral) type was located significantly lower than the internal (medial) type relative to the superior margin of the thyroid cartilage. Up to now, there were no descriptions of the position of the Ansa cervicalis with the superior margin of the thyroid cartilage as a reference point to be found in the literature.

The factors and mechanisms leading to the formation of the Ansa cervicalis and its two different positions relative to the internal jugular vein are also still unknown. Hypothetically, the developing internal jugular vein itself may determine the position of the Ansa cervicalis. Alternatively, the two types may also be a result of the pattern of superior and inferior root nerve fiber ingrowth. Inductive influences between nerve fibers may also play a pivotal role in this context. The inductive processes between the rootlets defines the direction of their growth and their position relative to the internal jugular vein (O'Ramilly and Müller, 1984).

Perhaps, even the developing infrahyoidal muscles also contribute to the induction and direction of nerve fibers. So, the complex chemical communication processes between the developing infrahyoidal muscles and the developing nerve roots and/or between the nerve roots themselves may be causative for the formation of the Ansa cervicalis.

The position of the Ansa cervicalis in relation to the superior margin of the thyroid cartilage may also be associated with differences in the content of nerve fibers which participate in the formation of the inferior root of Ansa cervicalis (Poviraev and Chernikov, 1967; O'Ramilly and Müller, 1984). If the inferior root solely consists of nerve fibers which arise from the ventral branch of the second cervical spinal nerve (C2), the Ansa cervicalis will assume a higher position. An inferior root consisting of fibers derived from the ventral root of the third cervical spinal nerve (C3) will shift the Ansa cervicalis to a lower position. However, due to a lack of functional data this is speculative and constitutes a limitation of this study.

Based on the results presented in the present study and on previous findings by other authors (Banneheka, 2008; Kikuchi, 1970; Poviraev and Chernikov, 1967) we suggest the following classification system for the description of Ansa cervicalis variants:

1) Number of loops:
   (A) one loop;
   (B) two loops;
   (C) three loops;
2) Relation to the internal jugular vein:
   (A) external type;
   (B) internal type;
3) Location relative to the superior margin of the thyroid cartilage:
   (A) high location (≤15 mm below superior margin of thyroid cartilage);
   (B) middle location (16–30 mm below superior margin of thyroid cartilage);
   (C) low location (>30 mm below superior margin of thyroid cartilage);
4) Spinal segments contributing to superior root:
   (A) C_1;
   (B) C_1–C_2;
5) Spinal segments contributing to inferior root:
   (A) C_2;
   (B) C_2–C_3;
   (C) C_3;
6) Origin of superior root:
   (A) hypoglossal nerve;
   (B) vagus nerve (Jelev, 2013).

Topographical peculiarities of the Ansa cervicalis are highly relevant for reconstructive surgery, surgical operations on the thyroid gland or larynx and after trauma of the blood vessels of the neck region. Here, we offered a new approach for the classification of Ansa cervicalis variants by defining their location with a combination of their topographical relation to the internal jugular vein and to the superior margin of the thyroid cartilage.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.aanat.2018.10.010.

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