3 Anatomical Considerations

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3.1 Introduction

Minimally invasive approaches and surgical techniques are becoming increasingly applied to the treatments of various cervical spine disorders recently. With the aid of high-quality operative view provided from the delicate, miniaturized endoscope optics and video instruments, we have been able to reach the entire cervical spinal segment, with the targeted goal to achieve surgical outcomes comparable to those of previous open surgery.

Although cervical spinal endoscopy has been numerously described as a safe procedure, the surgical process itself could be regarded as either side of sword; an accurate and vigilant placement of the working channel of endoscope is the most important step while still serious complications may occur either during the needle insertion or during the procedure that can entail a fatal vascular, neurological, or visceral injury.

All these complications could be avoided by following a strict procedural protocol acquired through a steeper learning curve based on a thorough knowledge of anatomical locations of vital organs deep inside the neck. The performing surgeon should trace these important structures from the neck surface, be able to locate the endoscopic tools properly without organ manipulation, and be capable to promptly deal with any inadvertent accident. In this chapter, the author has described general anatomical considerations that are to be considered as an important technical aspect before cervical endoscopy for their safe insertion.

3.2 Muscle and Fascia on the Ventral Aspect of Cervical Spine

The anterolateral muscles of the neck include the platysma, sternocleidomastoid, suprahyoid muscles, strap muscles of the larynx, scalenes, longus colli, and longus capitis [1] (Fig. 3.1).

The *platysma* is a thin muscle just beneath the subcutaneous tissues; it spans the deltoid to the upper pectoral fascia, crosses over the clavicle, and passes obliquely, upward and medially to insert onto the mandible.

The *sternocleidomastoid* muscle (SCM) originates from the sternum and the medial clavicle and attaches to the mastoid process and the lateral half of the superior nuchal line of the occipital bone.

Suprahyoid muscles that attach to the hyoid bone include the digastric, stylohyoid, mylohyoid, and geniohyoid muscles.

The strap muscles of the larynx include the sternohyoid, sternothyroid, thyrohyoid, and

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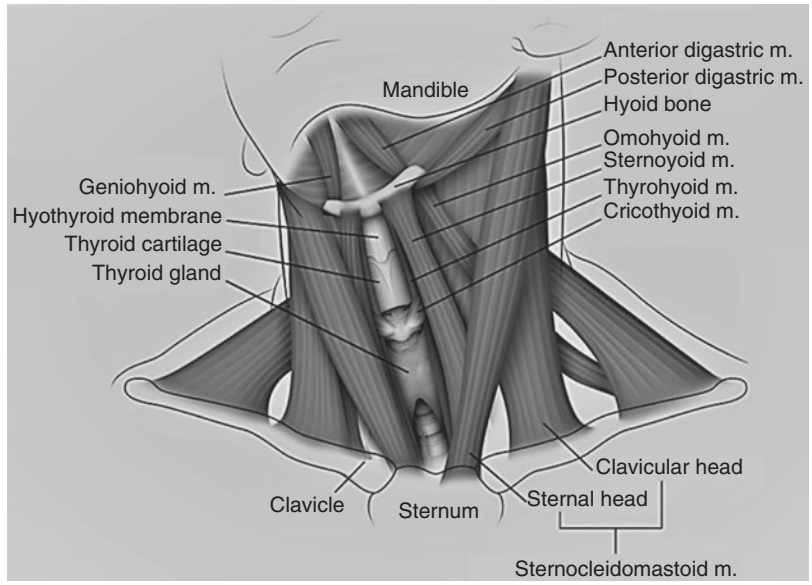

Fig. 3.1 The origin and insertions of the anterolateral muscles of the neck (reproduced from Chang UK et al. 2006)

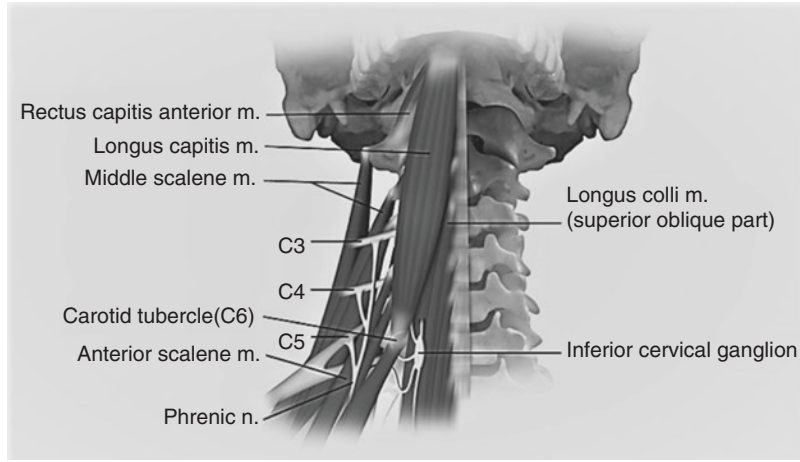

Fig. 3.2 The origin and insertions of the lateral muscles of the neck along with the relative locations of the exiting cervical nerve roots (reproduced from Chang UK et al. 2006)

omohyoid muscles. They cover the larynx, the thyroid gland, and the trachea.

Anterior muscles are the longus colli, longus capitis, rectus capitis anterior, and rectus capitis lateralis muscles [2, 3].

The *longus colli* is a wide muscle with tapered ends that spans from C1 to T3 and extends laterally to attach to the anterior tubercles of the transverse processes of C3–C6 (Fig. 3.2).

The *longus capitis* originates on the anterior tubercles of the transverse processes of C3 to C6 and attaches to the inferior surface of the basilar part of the occipital bone.

Lateral muscles include the scalenes and levator scapulae muscle [1] (Fig. 3.2).

The *scalenus anterior* originates from the anterior tubercles of the transverse processes of C3 to C6 and inserts on the first rib. The *scalenus medius* originates from the posterior tubercles of the transverse processes of C2 to C7 and inserts on the first rib. The subclavian artery and inferior portion of the brachial plexus are located where the anterior and middle scalene muscles fuse at the insertion site. The *scalenus posterior* originates from the posterior tubercles of the transverse processes of C4 to C6 and inserts on the second rib.

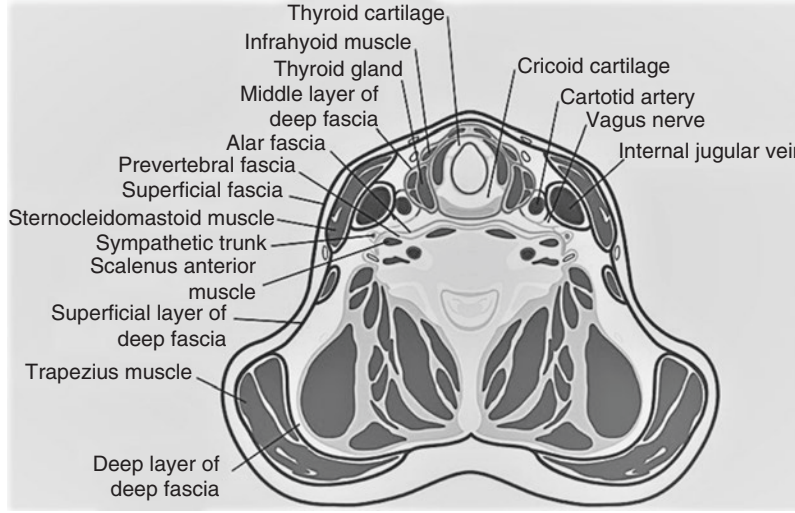

Fig. 3.3 The fascia layers of the anterior neck. The separated compartments formed by these fascia layers contain different muscles and viscera ventral to the cervical spine (reproduced from Chang UK et al. 2006)

The levator scapulae muscle is another component of lateral neck muscles and originates from the lateral mass of the atlas and transverse processes of the subsequent three cervical vertebrae and inserts at the cranial corner of the medial margin of the scapula.

The fascial layers of the anterior neck invest the muscles and viscera of this region to form separate compartments, and generally facilitate the endoscopic surgical procedures (Fig. 3.3).

The fascia of the neck is composed of two large layers: superficial and deep [1].

The superficial cervical fascia is a continuous sheet of fatty subcutaneous tissue extending from the head and neck into the thorax and the shoulder. It invests the platysma muscle, the external jugular vein, and the cutaneous sensory nerve and comprises two layers: supraplatysmal and infraplatysmal.

Deep cervical fascia includes superficial deep layer, middle deep layer, and deepest layer. The superficial layer of the deep cervical fascia is a continuous layer of fibrous tissue arising from the vertebral spinous process and the nuchal ligament and completely encircling the neck. It envelops the trapezius muscle over the posterior triangle, and then splits to enclose the SCM muscle. In the mandibular triangle, it encloses the submaxillary and parotid glands.

The middle layer of the deep cervical fascia encloses the strap muscles and omohyoid, and extends as far laterally as the scapula. A deeper position of the middle layer is the visceral fascia, which surrounds the thyroid gland, larynx, trachea, pharynx, and esophagus. This visceral fascia (or pretracheal) fascia is fused on either side with the deepest layer of the deep cervical fascia (prevertebral fascia), completing a compartment composed of the larynx, trachea, thyroid/parathyroid gland, and pharynx-esophagus. It enables a safe, enough retraction of tracheoesophageal trunk with mere finger retraction during the percutaneous access for cervical spinal endoscopic procedures due to this well-compartment formation.

The deepest layer of the deep cervical fascia is the prevertebral fascia, which covers the scalenus muscles, the longus colli muscles, and the anterior longitudinal ligament. It arises from the cervical spine and nuchal ligament, extends laterally over the muscles of the back of the neck, and crosses the midline to insert on these same structures.

3.3 Neurovascular Structures on the Ventral Aspect of Cervical Spine

Neurovascular structures of the cervical spine include the spinal cord, nerve roots, carotid artery, vertebral artery, laryngeal nerves, sympathetic chain, and epidural vessels [1] (Fig. 3.4).

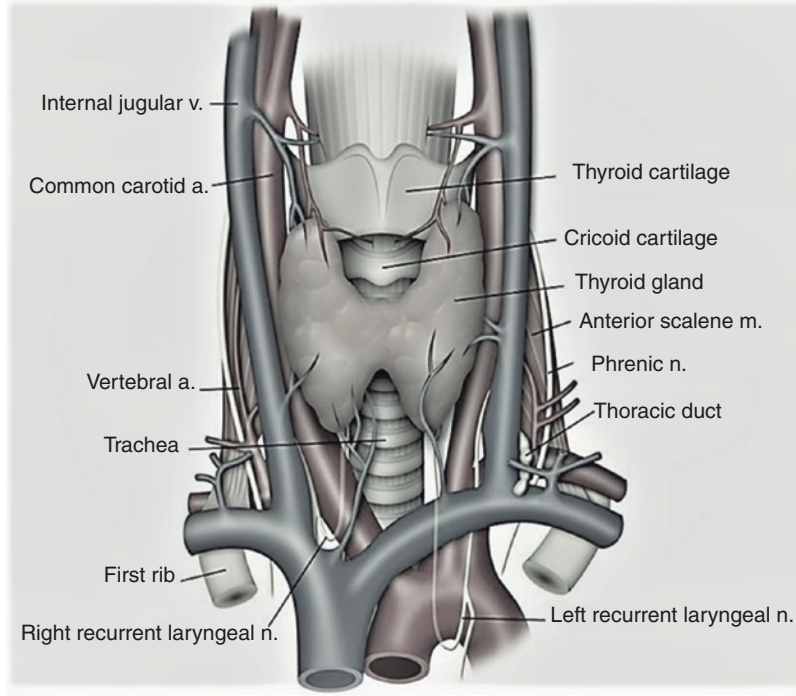

Fig. 3.4 Neurovascular structures of the ventral cervical spine (reproduced from Chang UK et al. 2006)

Cervical nerve roots forming from the ventral and dorsal nerve rootlet complex then extend anterolaterally at a 45-degree angle to the coronal plane and inferiorly at 10 degrees to the axial plane. The nerve roots enter the intervertebral foramen by passing directly in a lateral direction from the spinal canal adjacent to the corresponding cervical level disc and over the top of the corresponding pedicle. The spinal nerve divides into dorsal primary rami and ventral primary rami branches. The gray rami connect the sympathetic cervical ganglion to the ventral primary rami (Fig. 3.5).

The anterior primary rami of C1 to C4 form the cervical plexus and of C5 to T1 form the brachial plexus. The sinuvertebral nerve, which innervates the posterior part of the annulus and the ventral portion of the dura, is connected to the dorsal root ganglion [2, 4].

The vertebral artery is located lateral to the uncinate process and in line with the middle one-third of the vertebral body just anterior to the nerve root. It originates from the subclavian artery and enters the transverse foramen at C6 in most cases.

The carotid artery is placed more medial from the medial edge of the SCM at the C3–C4, more laterally at the C6–C7 level. This allows a rather more enough safety zone for the needle insertion during percutaneous endoscopic procedure on the subaxial cervical spine.

The carotid sheath is an investment of the internal and common carotid arteries, internal jugular vein, and vagus nerve. The ansa cervicalis is on the surface of the carotid sheath and the cervical sympathetic trunk in the dorsomedial aspect.

The thoracic duct runs ventral to subclavian artery, behind the carotid sheath, and terminates at the junction of the left internal jugular vein and subclavian vein. The phrenic nerve lies on the ventral surface of the anterior scalene muscle.

The superior laryngeal nerve (SLN) is a branch of the inferior ganglion of the vagus nerve, and travels along with the superior thyroid artery. As it descends medially toward the thyrohyoid membrane, the SLN lies in the fascia covering the longus colli muscle. A surgeon could come up with this SLN in the actual operative field at the midportion of C3–C4 level as it passes through the

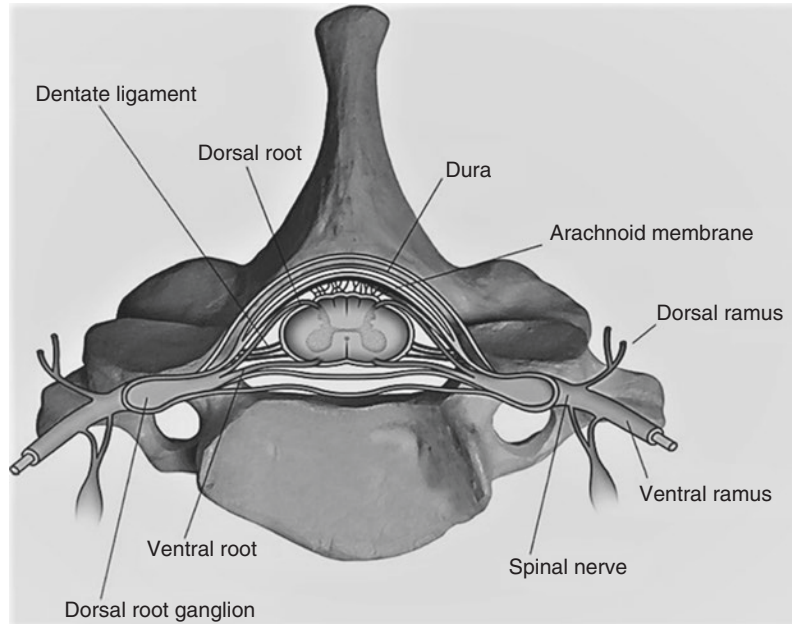

Fig. 3.5 Cervical spinal root from its formation by merged ventral and dorsal root from the spinal cord to its exit and division into dorsal and ventral ramus (reproduced from Chang UK et al. 2006)

pretracheal fascia in the midline. The SLN divides into two branches, external branch (motor) and internal branch (primarily sensory). The former innervates on the cricothyroid muscle, which is responsible for high-pitched-tone creation, while the latter innervates on the interarytenoid muscle, which plays role to prevent aspiration. Usually the laryngeal mucosa receives the dual innervation also from contralateral SLN. It immediately goes deep into the origin of the superior thyroid artery from the external carotid artery.

The inferior laryngeal nerve (ILN) is a recurrent branch of the vagus nerve. On the right side, the recurrent laryngeal nerve (RLN) loops around the subclavian artery, passing dorsomedial to the side of the trachea and esophagus. The best guideline to its location is the inferior thyroidal artery. It is vulnerable as it passes from the subclavian artery to the right tracheoesophageal groove because it is not protected by the groove for much of its course. On the left side, the RLN travels under the arch of the aorta. The left RLN is much less vulnerable than the right RLN because it is protected by the tracheoesophageal groove and its course is lengthy and redundant.

The cervical sympathetic system consists of three ganglia with intervening cords. The sympathetic trunk is located ventral to the transverse process and is embedded in the dorsal aspect of the carotid sheath. The superior cervical ganglion is located on the level of C2–C3, the middle cervical ganglion is at C6–C7, and the inferior ganglion lies between the transverse process of C7 and the neck of the first rib.

3.4 Muscle and Fascia on the Dorsal Aspect of Cervical Spine

The most superficial muscle is the *trapezius*, which originates from the external occipital protuberance, the medial nuchal line, and the spinous processes. The trapezius muscle inserts onto the upper body of scapula, acromion, and lateral aspect of the clavicle.

The intermediate muscles beneath the trapezius include the *splenius capitis* and *splenius cervicis*, which originate from the spinous processes of the lower cervical and upper thoracic spine, and insert on the transverse processes of the upper cervical spine and the mastoid process [5].

In the deep layer are the sacrospinalis muscle group and transversospinalis muscle group. Sacrospinalis (the erector spinae muscles)

consists of a group of muscles running from the lumbosacral spine into the cervical region. These muscles include *iliocostalis* laterally; *longissimus cervicis* and *longissimus capitis* cranially; and the *spinalis cervicis*, *semispinalis capitis*, and *semispinalis cervicis* medially. The other group of deep muscle is the transversospinalis muscle group, which consists of the semispinalis muscle, multifidus muscle, and rotator muscle [5].

The semispinalis muscles are a part of the transverse spinal system of the erector muscles of the spine. They originate from the transverse processes of the lower cervical and upper thoracic spine and insert at the spinous processes of C2–C5, nuchal portion of the occipital squama. Beneath the semispinalis muscles lie the multifidus and rotator muscles. The *multifidus* muscles are also part of the transverse spinal system and originate at transverse processes from C4 downward to the sacrum and insert at all cervical vertebrae up to the spinous process of C2. They cover the laminae of the vertebrae and are covered by the semispinalis muscle. The rotators cross only one segment of the spine and extend from the transverse process to the spinous process of the vertebrae directly above. Most posterior muscles are involved in producing extension of the neck and head, whereas some produce rotation and lateral flexion [3, 6, 7] (Fig. 3.6).

3.5 Superficial Nerves of the Posterior Neck

Cutaneous branches of the posterior primary rami are found adjacent to every spinous process below the C2 spinous process. The largest one is the greater occipital nerve. The lesser occipital nerve is lateral to the greater occipital nerve and is in the retroauricular area.

The dorsal root ganglion is located between the vertebral body and superior articular process. The spinal nerves divide into dorsal ventral primary rami branches (Fig. 3.6).

The posterior primary rami of cervical nerves send motor fibers to the deep muscles and sensory fibers to facet joint, deep muscles, and soft tissue. At the anterior aspect of the facet joint, the dorsal ramus curves dorsolaterally along the superior articular process. Then, the dorsal ramus branches medial and lateral, giving another small branch to the facet joint. The lateral branch crosses the transverse process and reaches to the anterior surface of the longissimus capitis. The medial branch runs dorsomedially through the tunnel between facet capsule and tendon of semispinalis capitis. Then, this medial branch traverses to the lateral edge of the multifidus muscle. After passing the lateral edge of the multifidus muscle, the medial branch divides into superficial and deep branches. The deep branch goes into the space between

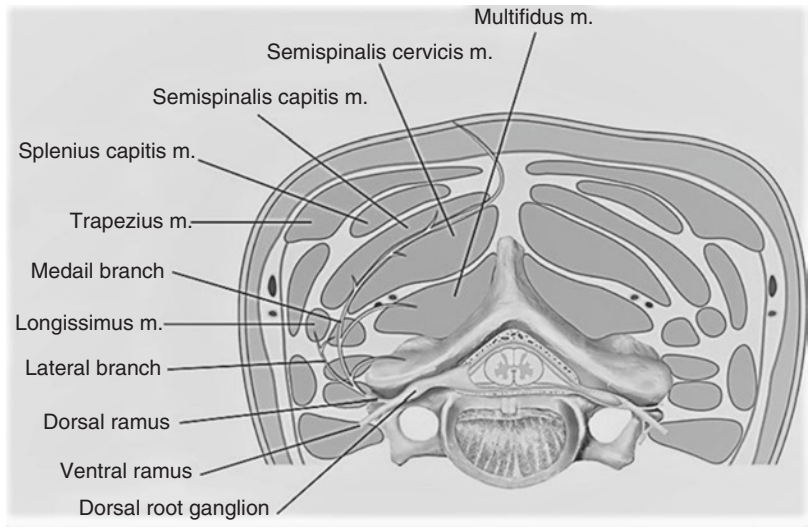

Fig. 3.6 Muscles on the dorsal aspect of the cervical spine and their innervation from the dorsal ramus of the cervical spinal root (reproduced from Chang UK et al. 2006)

the multifidus and semispinalis cervicis muscle. The superficial branch runs between semispinalis capitis and semispinalis cervicis muscles and terminates as cutaneous branches (Fig. 3.6).

As aforementioned, the anterior primary rami of C1–C4 form the cervical plexus while the anterior rami of C5–T1 form the brachial plexus [8].

3.6 Facet Joint

The facet joint is composed of articular processes, facet capsular ligament, and intervening fibrocartilage. Approximately 80–90% of joint surface is covered by cartilage. The coverage surface is wider in the upper cervical spine than in the lower cervical spine. The facet width is 10–12 mm in the upper cervical spine while 16–18 mm in the lower cervical spine. This suggests that the protective action of the facet joint to the segmental anatomy is more predominant in the upper cervical spine.

The orientation of the superior articular facet in relation to the transverse plane changes from posteromedial (C3, C4 level) to posterolateral (C6, C7). The shape of the superior articular facet is circular to oval at C3, C4, and C5 and gradually changes to a transversely elongated surface at C7 and T1 [9, 10].

3.7 Anatomical Considerations Before Anterior Percutaneous Cervical Endoscopy

Lee et al. [11] previously reported about the "safety zone" for the percutaneous cervical approach, which was determined by the sum of two distance calculations: the distances from the operator's fingertip to the digestive tract on the contralateral side (A) and to the carotid artery on the ipsilateral side (B), at each cervical level after obtaining the CT scans of the cervical spine at each level of the intervertebral disc from C3–C4 to C6–C7, by manually pushing the airway in the same position and manner of discography. They also identified the anatomic structure at risk by simulated needle insertion toward the center of the disc through the safety zone (Fig. 3.7).

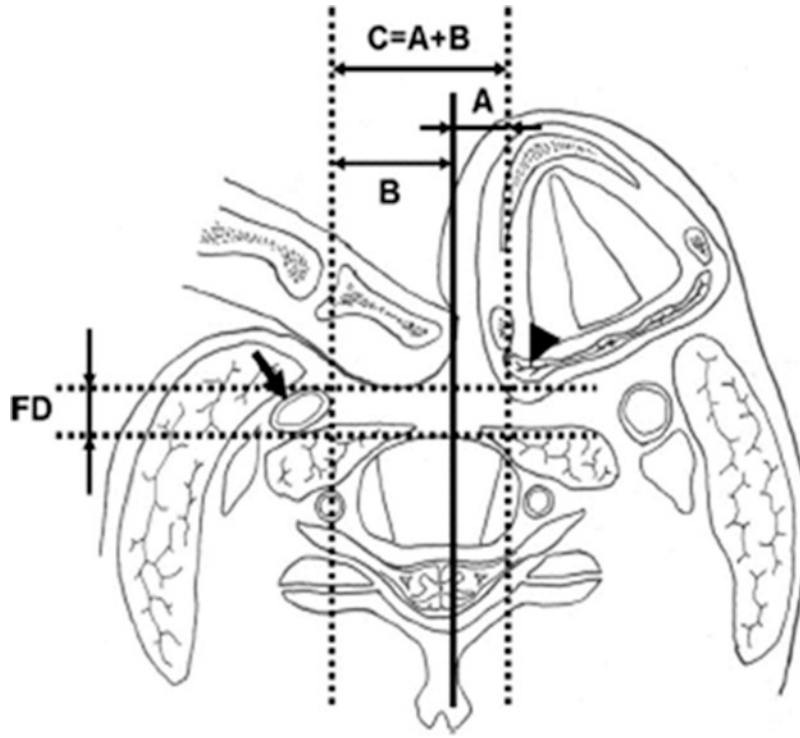

Fig. 3.7 The definition of "safety zone" (C), which is the sum-up value of the distances from the operator's fingertip to the digestive tract on the contralateral side (A) and to the carotid artery on the ipsilateral side (B). Also reducing the finger distance (FD) less than 5 mm from the ventral surface of vertebral body is crucial during percutaneous approach to the cervical spine (reproduced from Lee SH et al. 2007)

Their result was that at C3–C4, the safety zone was measured as 18.9 ± 6.6 mm. The superior thyroidal artery (STA) was located in the safety zone of C3–C4 in 86.7%. At C4–C5, the safety zone was measured as 23.5 ± 6.5 mm. The STA and the right lobe of the thyroid gland (TG) were located in the safety zone in 26.7% and 30%, respectively. At C5–C6, the safety zone was measured as 33.7 ± 6 mm. The TG was located in the safety zone of C5–C6 in 76.7%. At C6–C7, the safety zone was 29.2 ± 4.5 mm. The TG was located on the approach plane in 90%. They concluded that the safety zone was wider at the distal level (C5–C6, C6–C7) than at the proximal level (C3–C4, C4–C5). The safest needle entry point should be between the pushing point of the airway and the pulsating point of the carotid artery. In addition, the needle should be approached toward the center of the disc and reducing the finger distance (FD) less than 5 mm from the ventral surface of vertebral body is crucial to allow a low risk of pharyngoesophageal structure injury during percutaneous approach to the cervical spine.

When performing the cervical disc puncture, one must pay careful attention to the carotid artery, medial to the sternocleidomastoid (SCM) muscle laterally and the tracheoesophageal trunk medially. The pretracheal fascia is fused on either side with the prevertebral fascia, completing a compartment composed of the larynx, trachea, thyroid/parathyroid gland, and pharynx-esophagus. When moved medially, all of these components move together, increasing the safety zone for the initial disc puncture. Laterally the carotid artery has an almost vertical path, overlying the SCM muscle obliquely. The carotid artery is placed more medial from the medial edge of the SCM at the C3–C4 level and more laterally at the C6–C7 level. A more lateral puncture increases the risk of carotid puncture, whereas a more medial puncture increases the risk of injury to the hypopharynx and esophagus. The safest needle entry point is between the airway and the pulsating point of the carotid artery.

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