Introduction

The cervical plexus block (CPB) provides effective anesthesia and analgesia for the head and neck region [1–7]; the most common clinical use for CPBs has been carotid endarterectomy (CEA) [8–12]. Traditionally, CPBs were classified as deep or superficial [13], but in 2004, Telford and Stoneham [14] suggested the intermediate CPB involving a sub-investing fascial injection in addition to the superficial and deep CPBs on the basis of the cadaveric study by Pandit et al. [15]. In 2010, Choquet et al. [16] attempted to refine the concept of intermediate CPBs using ultrasound technique. Nevertheless, “superficial,” “intermediate,” and “deep” are poorly defined anatomical terms that simply indicate the topographic relationship of the tissue with respect to the skin; therefore, there has been some confusion in the nomenclature and definition of CPBs, particularly the intermediate CPB.

Since the role of ultrasound in the head and neck region has expanded, CPBs can be performed more safely and accurately under ultrasound guidance. In this review, the authors will describe the methods, including ultrasound-guided techniques, and clinical applications of conventional deep and superficial CPBs; in addition, the authors will discuss the controversial issues regarding intermediate CPBs, including nomenclature and associated potential adverse effects that may often be neglected, focusing on the anatomy of the cervical fascial layers and cervical plexus. Finally, the authors will attempt to refine the classification of CPB methods based on the target compartments, which can be easily identified under ultrasound guidance, with consideration of the effects of each method of CPB.

Keywords: Airway obstruction; Cervical fascia; Cervical plexus; Cervical plexus block; Phrenic nerve palsy; Ultrasonography.

Cervical plexus blocks (CPBs) have been used in various head and neck surgeries to provide adequate anesthesia and/or analgesia; however, the block is performed in a narrow space in the region of the neck that contains many sensitive structures, multiple fascial layers, and complicated innervation. Since the intermediate CPB was introduced in addition to superficial and deep CPBs in 2004, there has been some confusion regarding the nomenclature and definition of CPBs, particularly the intermediate CPB. Additionally, as the role of ultrasound in the head and neck region has expanded, CPBs can be performed more safely and accurately under ultrasound guidance. In this review, the authors will describe the methods, including ultrasound-guided techniques, and clinical applications of conventional deep and superficial CPBs; in addition, the authors will discuss the controversial issues regarding intermediate CPBs, including nomenclature and associated potential adverse effects that may often be neglected, focusing on the anatomy of the cervical fascial layers and cervical plexus. Finally, the authors will attempt to refine the classification of CPB methods based on the target compartments, which can be easily identified under ultrasound guidance, with consideration of the effects of each method of CPB.

Keywords: Airway obstruction; Cervical fascia; Cervical plexus; Cervical plexus block; Phrenic nerve palsy; Ultrasonography.
is essential to a successful CPB because certain cervical fasciae are known to have a substantial role in the diffusion of local anesthetic solution [15,18–20]. Nonetheless, the structural characteristics of the cervical fasciae have not been fully investigated from the perspective of regional anesthesia. Furthermore, there has been a disagreement with regard to accurate identification of the deep cervical fascia, especially in the lateral cervical region [21–24], and anatomical variations also exist [20,25]. Accordingly, this review first describes the anatomy of the cervical fascial layers and cervical plexus, then the methods for performing CPBs including ultrasound techniques, and then the effects of conventional deep and superficial CPBs and the relatively new but controversial intermediate CPB. Moreover, this review will discuss potential adverse effects related to CPBs that may often be neglected, and finally, attempt to refine the classification of CPB methods based on the target compartments that can be easily identified under ultrasound guidance, with consideration for the effects and potential adverse effects of each method of CPB.

Anatomy

Cervical fascia

The study of cervical fascial layers is clinically important in predicting the spread of disease [26–28], optimizing surgical management [29], and performing regional anesthesia in the neck area [15,18–20], and cervical fascial alteration may play a significant role in the pathogenesis of chronic neck pain [30,31]. However, descriptions of fascial arrangements and definitions of fascial spaces in the neck area are inconsistent and unclear, and the terminology is variable. According to the 41th edition of Gray’s Anatomy [32], the fascia is described as “sheaths, sheets or other masses of connective tissue large enough to be visible to the unaided eye,” and the Fascia Nomenclature Committee of Fascia Research Congress describes it as “a sheath, a sheet, or any other dissectible aggregations of connective tissue that forms beneath the skin to attach, enclose, and separate muscles and other internal organs” [33]. Nonetheless, the structural classification of cervical fasciae has been the subject of controversy despite the use of more recent techniques and materials for preserving and studying fascial structure. As Grodinsky and Holyoke [34] described in their pioneering study based on cadaver dissection in 1938, the inherent difficulties in dissecting cervical fascial spaces and the obvious artificiality of grouping them may produce confusion in the description of cervical fasciae and discrepancies among different authors. According to recent work by Guidera et al. [35], the cervical fasciae can be classified as superficial and deep, although, instead of using the term “superficial cervical fascia,” the more specific term “subcutaneous tissue” has been suggested to reduce confusion with the superficial layer of the deep cervical fascia [36]. The deep cervical fascia can be divided into three layers [35]: (a) the superficial layer, which was also called the investing fascia but is now referred to as the masticator fascia, submandibular fascia, or sternocleidomastoid (SCM)-trapezius fascia, although it has been argued that the SCM-trapezius fascia is incomplete between the SCM and trapezius muscles [21,22]; (b) the middle layer, which is suggested as to be named as strap muscle fascia or visceral fascia; and (c) the deep layer, which is suggested to be named as the perivertebral fascia instead of the prevertebral fascia because the term “prevertebral fascia” should be used for the anterior part only. The carotid space, containing major vessels, the deep cervical lymph nodes, and nerves, is a very important structure that can be affected during a CPB, and this space is usually referred to as the “carotid sheath and its contents” [36]. According to the literature [37,38], the carotid sheath is a definite histological structure that is distinct from other fascial layers, and the common carotid sheath shows inter-individual and/or site-dependent variations in thickness. However, there is disagreement about whether the carotid sheath is formed by all three layers of deep cervical fascia, only the deep or superficial layer of the deep cervical fascia, or has no demonstrable layer of fascia [36]. Palliyalil et al. [39] described that the carotid sheath is a strong fibroelastic tissue barrier that shields its contents from saliva and local infection after neck surgery, but local anesthetics seem to infiltrate the carotid sheath [40]. Fig. 1 shows a schematic drawing of the cervical fasciae as Guidera et al. [35] suggested.

Cervical plexus

The cervical plexus is situated in a groove between the longus capitis and the middle scalene muscles, underneath the prevertebral fascia but not in the interscalene groove, as the anterior scalene muscle is almost absent cranially proximal to the C4 or C3 levels [42]. Two nerve loops, which are formed by the union of the adjacent anterior spinal nerves from C2 to C4, give off four superficial sensory branches, listed in cranio-caudal order as follows: lesser occipital (C2, C3), great auricular (C2, C3), transverse cervical (C2, C3), and supraclavicular nerves (C3, C4); these initially run posteriorly and soon pierce the prevertebral fascia. Afterwards, they pass through the interfascial space between the SCM and the prevertebral muscles before reaching the skin and superficial structures of the neck via the nerve point of the SCM muscle [43,44]. Thus, superficial branches of the cervical plexus travel a relatively long distance from the paravertebral space to their respective superficial endpoints including the skin and subcutaneous tissues of neck and the posterior aspect of the head and shoulders [45,46]. In contrast, the fibers emanating anteromedially from the superior (C1–C2) and inferior (C2–C3)
roots unite at the level of the omohyoid central tendon to form a loop, the ansa cervicalis [47]. The ansa cervicalis is known to supply motor branches to the infrahyoid and SCM muscles [48] with a great degree of variation in its origin and distribution [49]; however, ansa cervicalis has been suspected to have an afferent neuronal composite [50]. The anterior rami of C3 and C4 form a loop and the branches of this loop join C5 to give rise to the phrenic nerve. The cervical plexus is known to anastomose with the spinal accessory nerve, hypoglossal nerve, facial nerve, vagus nerve, glossopharyngeal nerve, and sympathetic trunk [43,49,51]. Fig. 2 shows a schematic drawing of the deep and superficial cervical plexuses.

### Cervical plexus block methods

CPBs can be performed at the deep, superficial, or intermediate level, although these terms are poorly defined.

### Deep cervical plexus block

The deep CPB is described as a paravertebral block targeting the C2–C4 spinal nerves [13,53], which can be achieved either by a single injection or by three separate injections [13,53,54]. The deep CPB performed at the paravertebral space can not only block superficial branches but also deep branches of cervi-
cal plexus, resulting in the relaxation of neck muscles, although this has not been shown to be important clinically [10,14,55]. Furthermore, if ansa cervicalis also has an afferent neuronal composite [50], the deep CPB would have more clinical significance in treating postoperative pain after neck surgeries involving the infrahyoid and/or SCM muscles, or pain originating in the neck. Wan et al. [56] and Goldberg et al. [57] reported that deep CPBs at the C2 or C3 transverse process could treat cervicogenic headaches effectively. The deep CPB has also been applied during thyroid or parathyroid surgery [58,59], oral and maxillofacial surgery [3], and CEA [60–64] to obtain adequate anesthesia and/or analgesia. Deep CPBs can produce major complications such as intravascular injection, epidural or sub-arachnoid injection, and phrenic nerve palsy, due to its deep endpoint [12,65]; however, with the introduction of ultrasound, the deep CPB has become a relatively safe and simple procedure [3,42,66,67]. For the ultrasound-guided (USG) deep CPB, Perisanidis et al. [3] and Saranteas et al. [67] simply injected local anesthetics into the space between the prevertebral fascia and the cervical transverse process under ultrasound guidance, but Wan et al. [56] and Sandeman et al. [66] injected local anesthetics after the needle touched the target cervical transverse process under ultrasound guidance.

**Superficial cervical plexus block**

The superficial CPB is conventionally described as a subcutaneous injection technique performed at the mid-portion of the posterior border of the SCM muscle targeting superficial branches of the cervical plexus [12,13]. This conventional subcutaneous infiltration technique for the superficial CPB can be performed using an ultrasound guided technique [68], and, depending on the types of surgery in the head and neck region, it is also possible to block one or more superficial branches of the cervical plexus selectively by using landmarks [1,4,69,70] or an ultrasound technique [71–74]. The superficial CPB, unlike the

![Fig. 3. Landmark-based superficial cervical plexus blocks have been performed for ear, neck, and upper chest wall surgeries to obtain adequate anesthesia and/or analgesia in Ajou University Hospital. (A) Great auricular and lesser occipital nerve blocks were performed in a 77-year-old male patient undergoing excision of ear hemangioma. (B) Selective supraclavicular nerve block was performed in a 4-year-old female patient undergoing excision of a congenital melanocytic nevus on the right upper chest wall. (C) Great auricular and transverse cervical nerve blocks were performed in a 94-year-old female patient undergoing excision of a squamous cell carcinoma on the right neck area. (D) Selective supraclavicular nerve block was performed in a 52-year-old male patient undergoing incision and drainage of an abscess on the right upper chest wall. To avoid deep injection, the needle was bent slightly.](image-url)
deep CPB, is known to carry a low risk of complications and is easy to master [12,59,75]. Nonetheless, during a superficial CPB, it is important to make sure that the needle tip is positioned in the subcutaneous tissue to avoid adverse effects of deep block [76,77]. Unilateral or bilateral superficial CPBs can be used as postoperative analgesia after a variety of head and neck surgeries such as thyroidectomy [1,78,79], minimally invasive parathyroidectomy [59], tymanomastoid surgery [4], anterior cervical discectomy and fusion [5], and infratentorial and occipital craniotomy [80]. It can also be used as a sole anesthetic modality for external ear surgery [74]. Superficial CPBs can also be used as an adjuvant block for shoulder, clavicle, breast and upper chest wall surgeries, particularly by blocking the supraclavicular branches. In Ajou University Hospital, we have been applying landmark-based superficial CPBs to various superficial head, neck, and upper chest wall surgeries both in pediatric and adult patients to obtain anesthesia and/or analgesia (Fig. 3).

Intermediate cervical plexus block

History

In 2002, Zhang and Lee [21] reported that the investing layer of the deep fascia does not exist in the space between the SCM and trapezius muscles, an area called the posterior cervical triangle [81]. They conducted a sectional anatomic investigation with the use of epoxy sheet plastination in cadavers, but their results are still controversial [24,35,36]. Interestingly, in the 41st edition of Gray’s Anatomy [82], it is described that the investing fascia between the SCM and trapezius muscles is formed of areolar tissue that is indistinguishable from that in the superficial cervical fascia. Nonetheless, in 2003, Pandit et al. [15] introduced a new concept of a sub-investing fascial injection technique (superficial to the prevertebral fascia but underneath the investing fascia) as one method for performing superficial CPB. In this study, Pandit et al. [15] hypothesized that there is communication between the superficial and deep spaces through the prevertebral fascia, which may explain why the efficacy of the superficial CPB is comparable to that of the deep CPB and combined deep and superficial CPB during CEA [10,62]. In 2004, Telford and Stoneham [14] expected that this intermediate CPB might also produce the same effects as the deep CPB while avoiding some practical difficulties of deep CPB; however, this would be possible with the contingency that a communication through the prevertebral fascia actually exists. In 2007, Pandit et al. [12] stated clearly that an intermediate block is one where the injecting needle pierces the investing fascia of the neck, deep to the subcutaneous layer, but superficial to the prevertebral fascia. In this context, the permeable nature of the prevertebral fascia must be an important issue because it can eventually determine the characteristics of the intermediate CPB; however, several articles [7,9,83–85] have already been published on the basis of Pandit’s hypothesis [15] that the injectate of intermediate CPB can spread to deep tissues through the prevertebral fascia, and thus intermediate CPB can have similar effects to a deep CPB, although there has been no clinical study verifying the permeable nature of the prevertebral fascia.

Technique and nomenclature

Studies by Barone et al. [85], Ramachandran et al. [8], and Merdad et al. [83] used a blind approach for the intermediate CPB targeting the space between investing fascia and prevertebral fascia by using landmarks and loss of resistance or pop technique, although Merdad et al. [83] used the term “superficial” CPB instead of “intermediate” CPB. Nonetheless, it was probably not easy even for very experienced practitioners to place the needle tip precisely at the desired space without the aid of ultrasonography. Since Kefalianakis et al. [86] published the first report of USG CPB targeting the space between SCM and anterior scalene muscles for CEA in 2005, USG CPB has become more popular because it can be performed safely and accurately in the target space [87]. In 2010, Choquet et al. [16] advocated that the intermediate CPB should target the posterior cervical space (PCS) at the C4 level. The PCS described by Choquet et al. [16] is the interfascial space between the SCM and prevertebral muscles, which can be seen on cross-sectional imaging. They used the ultrasound technique and contended that the PCS corresponds to the sub-investing fascial space described by Pandit et al. [15]. The superficial branches of cervical plexus arising from deep tissues pass through this space after piercing the prevertebral fascia, exiting to the skin and superficial tissues via the posterior border of the SCM muscle [16].

Since Choquet et al. [16] introduced the intermediate CPB using ultrasound technique, many studies have been published under the name of USG intermediate CPB [3,9,11,63,84,85,88–95]. In those studies, authors performed either the posterior or anterior approach for the intermediate CPB to obtain anesthesia and/or analgesia for CEA [63,84,92–95], surgeries involving SCM muscle [90,91], and cervical esophagus diverticulectomy [88] under ultrasound guidance. For the USG posterior approach for intermediate CPBs, after the target cervical level is identified by increment from the C7 vertebra with ultrasound scanning, the SCM and middle scalene muscles are positioned in the middle of the screen. At this point, the needle is advanced into the PCS (interfascial space between the SCM and prevertebral muscles) in a lateral to medial direction (in-plane technique) using the anterior border of the middle scalene muscle as the landmark for placing the needle tip. Afterwards, local anesthetic is injected slowly and carefully while observing the spread of local anesthetic in the PCS [90,91]. The anterior approach for USG intermediate CPBs may provide similar results to other re-
Effects of the intermediate cervical plexus block

Importantly, intermediate CPBs can provide different anesthetic and analgesic effects compared with the superficial CPB. The cervical plexus (C2–C4) is known to afford sensory innervation to the SCM muscle, including proprioception, with variable anastomosis with the spinal accessory nerve [43,100–104]. Therefore, the SCM muscle seems to have a complex innervation, but cervical branches of the nerve that supply the SCM muscle, after piercing the prevertebral fascia, are known to anastomose with the spinal accessory nerve at the posterior surface or inside of the SCM muscle [100,101,105]. While the spinal accessory nerve itself is also known to have a sensory function [52,106,107], the cervical plexus (ansa cervicalis) is believed to constitute another source of motor innervation for the SCM muscle in addition to the spinal accessory nerve [48,52,100–104].

Therefore, it is possible that the USG intermediate CPB, which is performed accurately in the PCS at a specific cervical vertebral level, can block all four cutaneous branches of cervical plexus and sensory/motor branches of the cervical plexus supplying the SCM muscle simultaneously so that it provides adequate anesthesia and analgesia for neck surgeries that involve manipulation or resection of the SCM muscle [90] or resection of the SCM muscle [91]. Similarly, Yerzingat-sian [111] suggested depositing local anesthetic directly into the SCM muscle in order to block the sensory branches of the cervical plexus, which innervate the SCM muscle during local anesthesia for thyroidectomy. According to Senapathi et al. [99], an USG intermediate CPB is more effective than the multi-directional subcutaneous injection technique of the superficial CPB for reducing pain after thyroidectomy, although authors used the term “USG superficial CPB” instead of USG intermediate CPB. Additionally, the pain associated with the SCM muscle, as in SCM syndrome [112], or the pain associated with trigger points in the SCM muscle [113–115] can be theoretically treated by this technique. In Ajou University Hospital, the posterior approach of USG intermediate CPB targeting the PCS at the C4–C5 level has been performed in pediatric and adult patients regularly, if required (Fig. 4). In contrast, the classical superficial CPB performed subcutaneously would not have these intermediate block effects. In this respect, although it is not currently clear whether the investing fascia (SCM-trapezius fascia) exists or not in the posterior cervical triangle, it would be reasonable to define the superficial CPB as the technique that involves a multi-directional or single subcutaneous injection targeting one or more superficial branches of the cervical plexus, regardless of the use of ultrasound technique. In addition, although both superficial and intermediate CPBs are essentially targeting same superficial branches of cervical plexus, intermediate CPBs may produce some adverse events that superficial CPBs do not produce.

![Fig. 4. Ultrasound image of the posterior approach for an intermediate cervical plexus block at C4–5 level in a 3-year-old torticollis patient undergoing unipolar sternocleidomastoidectomy (SCM) release with myectomy. Hydrosclerotomy of the posterior cervical space between the SCM muscle and prevertebral fascia by local anesthetic is seen, and local anesthetic spreads to the area near the carotid sheath. CA: carotid artery, JJV: internal jugular vein, LA: local anesthetic. White arrow points: prevertebral fascia.](image-url)
Cervical plexus block and carotid endarterectomy

The most common clinical use for CPBs has been CEA. CEA is a validated intervention for stroke prevention associated with symptomatic carotid stenosis [116,117], which involves incisions in the skin, platysma muscle, carotid sheath, and carotid artery. Since the first report of CPBs for CEA [118] in 1988, various techniques for CPBs have been evaluated in CEA, although the ideal anesthetic technique for CEA remains a matter of debate [54,119–121]. Stoneham et al. [10] in 1998 and Pandit et al. [62] in 2000 reported that the superficial CPB is as effective as deep or combined deep and superficial CPB for CEA. However, during CEA under CPB, supplementation of local anesthetic to subcutaneous or deep tissues by the surgeon is often performed regardless of the type of CPB method [74,94,122], probably because within the structures of the neck, including the carotid sheath, there are some areas innervated by cranial nerves, where even deep CPBs cannot reach [8,51,94,123–125], or incisional pain near the midline, which is presumably mediated by contralateral fibers, may occur [8,74,123,126]. Seidel et al. [19] demonstrated a constant anastomosis between the cervical branch of facial nerve and the transverse cervical nerve of the cervical plexus. The pain associated with the incision of the carotid sheath during CEA was completely relieved by lidocaine spray [124], and cranial nerves (glossopharyngeal and vagus nerves) and the sympathetic trunk were suggested to be involved in providing sensory innervations to the carotid artery and sheath [51,94,124]; therefore, delivery of local anesthetic close to the carotid sheath during CEA may be reasonable. Recently, single USG intermediate CPBs [62,84,89,92,95] or USG intermediate CPBs combined with USG infiltration of local anesthetic to the perivascular area of the carotid artery [9,11,93,94] has become a new option to reduce the amount of intraoperative local anesthetic supplementation by surgeon during CEA, while the use of deep CPB for CEA has been decreased. However, direct infiltration of local anesthetic to the perivascular area of the carotid artery can produce some adverse effects due to cranial nerve palsy [9,11,93,94,127,128].

Safety issues related to cervical plexus blocks

Phrenic nerve palsy

The phrenic nerve is formed from the ventral rami of C3 to C5, and runs from lateral to medial in a downward oblique direction on the surface of the anterior scalene muscle, beneath the prevertebral fascia. According to Castresana et al. [129], combined deep and superficial CPBs produce acute abnormalities of diaphragmatic motion in 61% of patients. Notably, there seems to be no possibility that conventional superficial CPBs affect the phrenic nerve [53], as long as the injection is performed accurately in the subcutaneous tissue [77]. One of the reasons why all patients receiving deep CPB do not develop a diaphragmatic motion abnormality might be the anatomical variations including the predominance of the 5th cervical nerve and presence or absence of an accessory phrenic nerve [129]. Furthermore, the SCM muscle is the accessory muscle of respiration, which is essential when the diaphragm is weak [130–132]. The deep CPB is known to be largely associated with diaphragmatic paralysis [129], which, combined with the relaxation of the SCM muscle can lead to worse effects on respiratory function than we have previously known, particularly in patients with clinically significant lung disease or suspected diaphragmatic motion abnormalities [133].

The prevertebral fascia (deep layer of the deep cervical fascia) forms a tubular sheath for the vertebral column and the muscles associated with it, such as the longus colli and longus capitis anteriorly, the scalenes laterally, and the deep cervical muscles posteriorly [13,43]. According to the literature, this prevertebral fascia seems to play a role as a barrier to the spread of local anesthetics [134] or even abscesses [26,135] by forming a watertight space [134], suggesting that a suppuration in the prevertebral space does not extend rapidly in any direction due to compactness of this compartment [26]. There are also evidences that local anesthetic can distend the prevertebral fascia during stellate ganglion blocks [136], and that local anesthetic is entrapped in the PCS during intermediate CPBs [3]. Recently, using fresh cadavers, Seidel et al. [19] investigated the dissemination of injected dye solution that was injected into the PCS using the ultrasonographic technique; consequently, the dye remained in the PCS implicating that the prevertebral fascia is impermeable, contrary to Pandit’s hypothesis [15]. Nonetheless, Seidel et al. [19] suggested that a clinical study is needed to investigate whether phrenic nerve blocks are preventable with the intermediate CPB.

Unlike deep CPBs [42,64] and interscalene brachial plexus block [137], both of which inevitably require puncturing the prevertebral fascia and injecting local anesthetic near the cervical spinal roots, the possibility that an USG intermediate CPB affects the phrenic nerve might seem to be low, probably due to the aforementioned protective nature of the prevertebral fascia [26,134,135], which is also shown in the cadaveric study by Seidel et al. [19], and the location and course of the phrenic nerve [77]. Martusevicius et al. [9] performed an USG regional anesthesia technique similar to an USG intermediate CPB in 60 patients, which did not lead to arm weakness or difficulty breathing, and in the study by Tran et al. [97], despite the deposition of local anesthetic into the PCS between the SCM and scalene muscles under ultrasound guidance, no instances
of unintentional brachial plexus, Horner’s syndrome, or dyspnea was observed. In agreement with these findings, two studies performed by Kim et al. [90,91] also showed no signs of brachial plexus block, Horner’s syndrome, or dyspnea after a single USG intermediate CPB in adult patients undergoing robotic thyroidectomy and in pediatric torticollis patients undergoing unipolar release of the SCM muscle with myectomy. In addition, Calderon et al. [89] described that although the diffusion of the local anesthetic in the PCS was observed during USG intermediate CPBs, the spread of local anesthetic beyond the prevertebral fascia was not detected, which may also be significant evidence supporting the concept that the prevertebral fascia has a protective quality. Nevertheless, at present, evidence is insufficient to authenticate the true nature of the prevertebral fascia, which must be investigated in clinical trials.

### Airway obstruction

Mechanical airway obstruction due to tissue edema or hematoma is a well-recognized surgical complication after various neck surgeries including thyroidectomy [138] and CEA [139,140]. Particularly during CEA, surgical procedures including dissection, traction, and retraction can injure the facial nerve, hypoglossal nerve, the vagus nerve including its branches (recurrent and superior laryngeal nerves), or glossopharyngeal nerve within the operative field [141–144]. Among them, bilateral injury of vagus nerve, recurrent laryngeal nerve, or hypoglossal nerve can result in fatal upper airway obstruction [141,145]. Although data regarding cranial nerve blockades associated with single deep CPBs are scarce [59,61,127], it is plausible that deep CPBs can paralyze the glossopharyngeal, vagus, hypoglossal, and accessory nerves, particularly when cephalad spread of local anesthetic occurs, because extensive neural anastomoses exist between the lower cranial nerves and the upper cervical nerves, although this is highly variable between individuals [51,53]. Accordingly, it is important to remember that bilateral deep CPBs can cause not only bilateral phrenic nerve palsy but also fatal airway obstruction by paralyzing the vagus or hypoglossal nerve. More importantly, in patients with preexisting contralateral vagus (or recurrent laryngeal) or hypoglossal nerve injury, even unilateral deep CPBs can lead to total airway obstruction; therefore, although, pre-existing unilateral vocal cord paralysis is usually clinically asymptomatic [127,146] and unilateral hypoglossal nerve palsy shows minimal disability [145], preoperative routine history taking and physical examination of the tongue and vocal cords would be necessary in patients receiving deep CPB [59] as well as in patients undergoing CEA [147] regardless of anesthetic techniques.

As described earlier, direct infiltration of local anesthetic into the paracarotid area during CEA either by a surgeon or an anesthesiologist may be effective for blocking the incisional pain of the carotid sheath or artery [124,148], but it can also produce adverse effects related to the blockade of cranial nerves [9,11,93,94,127,128], besides impairment of baroreceptor reflex [94]. Recently, USG techniques that involve infiltration of the local anesthetic in the paracarotid area have been introduced in combination with subcutaneous infiltration or intermediate CPB in order to decrease intraoperative supplementation of local anesthetic during CEA [9,11,93,94]. According to Casutt et al. [148], an USG carotid sheath block performed by injecting a mixture of local anesthetic and contrast media to the ventral side of carotid artery leads to extensive spread of the local anesthetic, which is confirmed by post-block CT image. Martusevicius et al. [9] reported that temporary hoarseness, facial palsy, and dysphagia occurred in 72%, 13%, and 12% of patients who had received combined USG intermediate CPB and USG paracarotid infiltration of local anesthetics, respectively. Accordingly, bilateral infiltration of local anesthetic to the paracarotid area may cause fatal airway obstruction.

Regarding the intermediate CPB, the spread pattern of the local anesthetic in the PCS may be important. During the interfascial plane block, many factors may influence the spread of local anesthetic and quality of the block, while precise needle placement, and deep understanding of fascial tissue anatomy and structure are required [149]. Zhang and Lee [21] contended that the PCS is actually an extension of subcutaneous tissue and the carotid sheath becomes attached to the subcutaneous fatty tissue without any clear demarcation by a fascia. In the clinical setting, we have often seen that local anesthetics spread easily toward the carotid sheath even when the tip of the injecting needle is placed between the anterior scalene muscle or longus capitus muscle and middle scalene muscle during posterior approach of the USG intermediate CPB (Fig. 4). Tran et al. [97] compared USG and landmark-based superficial CPBs in patients undergoing surgery of the shoulder and clavicle; however, the USG CPB technique they used was actually an USG intermediate CPB, with injection of 10 ml of local anesthetics into the PCS, as described here, rather than an USG superficial CPB, while their landmark-based superficial CPB was virtually a subcutaneous CPB. They reported that dyspnea, desaturation, and brachial plexus block were absent, but that hoarseness or difficulty in swallowing occurred in 10% of patients in the ultrasound group. Leblanc et al. [92] reported that dysphonia occurred in 12%, Horner’s syndrome occurred in 4%, and swallowing disorder occurred in 2% of patients after a single USG intermediate CPB using 10 ml of local anesthetic for CEA, but they purposely advanced the needle tip close to the carotid sheath for injection. In contrast, Alilet et al. [95] did not advance the needle tip close to the carotid sheath during the single USG intermediate CPB using 10 ml of local anesthetic for CEA, and they reported a very
low incidence of hoarseness (2.4%) and palsy of the hypoglossal nerve (2.4%). Therefore, it can be postulated that the incidence of hoarseness and dysphagia after a single USG intermediate CPB may depend on the block techniques as well as the injected volume of local anesthetic. In contrast, when the intermediate CPB was combined with paracarotid infiltration of local anesthetics, a much higher incidence of hoarseness and dysphagia was observed [9,93,94].

Hoarseness (dysphonia), which is likely to be associated with blockades of vagus nerve or its branches (recurrent and superior laryngeal nerves), difficulty in swallowing (dysphagia), which is likely to be associated with vagus, glossopharyngeal, or hypoglossal nerve blockade, and facial nerve blockade may be the result of medial and upward spread of the local anesthetic during the USG intermediate CPB. Temporary dysphonia due to ipsilateral blockade of the vagus, recurrent laryngeal, or superior laryngeal nerve after an USG intermediate CPB usually is not clinically significant. However, bilateral blockade of the vagus nerve, recurrent laryngeal nerve, or hypoglossal nerve can induce fatal airway obstruction. Therefore, bilateral intermediate CPBs might be dangerous, and even unilateral CPBs can lead to airway obstruction in patients with preexisting contralateral vagus or hypoglossal nerve injury, which may require routine preoperative examination. During the USG intermediate CPB, in order to avoid inadvertent cranial nerve blockades, it would be advocated to place the needle tip in the PCS well outside of the carotid sheath, use a small volume of local anesthetic, and inject the local anesthetic slowly while observing the spread of local anesthetic, thereby restricting the medial spread of the local anesthetic toward the carotid sheath [90,91], unless carotid sheath block is required.

Other adverse effects

Horner’s syndrome does not have any clinical consequence in itself, but it is an unpleasant side effect, although it may not be described as a complication [150]. The occurrence of the Horner’s syndrome after intermediate CPB may be debatable because the location of the cervical sympathetic chains in relation to the prevertebral fascia, the permeable nature of the prevertebral fascia, and the extent of the spread of local anesthetic in the PCS toward the carotid sheath during intermediate CPB may have some influence. Usui et al. [42] and Civelek et al. [151] described that the cervical sympathetic chains are situated immediately underneath the prevertebral fascia covering the longus muscles; on the contrary, in the 41st edition of Gray’s anatomy [152], it is stated that the cervical sympathetic trunk lies on the prevertebral fascia behind the carotid sheath. Nonetheless, the occurrence of Horner’s syndrome has been reported after superficial CPBs [59], combined superficial and deep CPBs [59,63], a single USG intermediate CPB [92,98], and combined USG intermediate CPB and paracarotid infiltration of local anesthetic [9,11,94]. However, according to Lyons and Mills [25], among 12 cadaveric neck dissections, the cervical sympathetic chain was found within the carotid sheath in 2 cadavers. This anatomic variation may not only cause damage to the sympathetic chain during neck dissection or simple catheterization of the internal jugular vein [153], but also influences the occurrence of Horner’s syndrome during a CPB with/without paracarotid infiltration of local anesthetic.

The most common cause of spinal accessory nerve palsy is iatrogenic insult during neck surgery, especially surgeries located in the posterior cervical triangle [106,154]. Anatomically, the spinal accessory nerve enters the posterior cervical triangle 2 cm above Erb’s point and then courses obliquely across the posterior cervical triangle to end in the anterior surface of the superior part of the trapezius muscle with many variations [155]. In the posterior cervical triangle, the accessory nerve lies superficial to the prevertebral fascia [156]; thus, it can be affected during superficial CPB [53], but the intermediate CPB targeting the PCS underneath the SCM muscle is not likely to affect the spinal accessory nerve [157].

Fig. 5. Three different target areas of cervical plexus blocks (CPBs) in the cervical fascial spaces are depicted schematically (C4 transverse section). (A) The target area for superficial CPB is subcutaneous tissue around the mid portion of posterior border of the sternocleidomastoid (SCM) muscle. (B) The target area for intermediate CPB is the space between the SCM muscle and the prevertebral fascia. (C) The target area for deep CPB is the space between the prevertebral fascia and the target transverse process.
Refining the classification of cervical plexus block

For systematized nomenclature of CPB techniques, we can suggest three practical classifications of CPBs (Fig. 5), based on the anatomical studies regarding cervical fasciae, nerve innervation, and the relevant clinical reports as described in this review. The first technique is the superficial CPB, which involves a multi-directional or single subcutaneous injection around the posterior margin of the SCM muscle, targeting the superficial branches of the cervical plexus, regardless of the use of ultrasound technique. This superficial CPB can also be performed to block selectively one or more superficial branches of the cervical plexus by landmark or ultrasound technique. The superficial CPB is very useful, safe, and easy to learn, which every regional anesthesiologist should master. The second technique is the intermediate CPB, which involves the placement of the injecting needle into the PCS (between the SCM muscle and prevertebral fascia) at the C4 level, targeting both the superficial branches of cervical plexus and presumably sensory/motor branches of the cervical plexus supplying the SCM muscle. The USG intermediate CPB is simple to learn and reproduce, but the potential for adverse effects should not be overlooked. Lastly, the deep CPB involves the placement of a needle between the prevertebral fascia and the cervical nerve roots at the C2–C4 level, targeting both superficial and deep branches of cervical plexus simultaneously. In spite of some advantages, deep CPBs may require analysis of risks and benefits before application. For safe and successful intermediate CPB and deep CPB, ultrasound technique is strongly recommended.

Summary

CPBs are performed in the neck area, which has high complexity with multiple fascial layers in a narrow space. Recently, a new and more specific terminology of the cervical fasciae has been suggested, but there is still controversy over the accurate identification and description of the cervical fasciae, including the investing and prevertebral fascia, and the carotid sheath. Furthermore, anatomical variations in the cervical fascial layers can have a significant influence on the effects of each method of CPB. Therefore, currently, it is difficult to describe the true effects of each CPB approach, although most of the CPB methods are now being performed accurately and safely under ultrasound guidance. In this review, we discussed the intermediate CPB in detail, which is a relatively new technique, but has some controversial issues. Although block effects and potential adverse effects of the intermediate CPB mandate further investigations, we simply classified CPBs into three general approaches, superficial, intermediate, and deep, based on the target compartment of each approach that can be identified easily on ultrasound.

ORCID

Jin-Soo Kim, https://orcid.org/0000-0003-4121-2475
Justin Sangwook Ko, https://orcid.org/0000-0003-3155-0550
Seunguk Bang, https://orcid.org/0000-0001-6609-7691
Hyungtae Kim, https://orcid.org/0000-0003-2488-9986
Sook Young Lee, https://orcid.org/0000-0002-4688-2155

References

1. Kesisoglou I, Papavramidis T, Michalopoulos N, Ioannidis K, Trikoupi A, Sapalidis K, et al. Superficial selective cervical plexus block following total thyroidectomy: a randomized trial. Head Neck 2010; 32: 984-8.
2. Tobias JD. Cervical plexus block in adolescents. J Clin Anesth 1999; 11: 606-8.
3. Perisanidis C, Saranteas T, Kostopanagiotou G. Ultrasound-guided combined intermediate and deep cervical plexus nerve block for regional anaesthesia in oral and maxillofacial surgery. Dentomaxillofac Radiol 2013; 42: 29945724.
4. Suresh S, Barcelona SL, Young NM, Seligman I, Heffner CL, Coté CJ. Postoperative pain relief in children undergoing tympanomastoid surgery: is a regional block better than opioids? Anesth Analg 2002; 94: 859-62.
5. Mariappan R, Mehta J, Massicotte E, Nagappa M, Manninen P, Venkatraghavan L. Effect of superficial cervical plexus block on postoperative quality of recovery after anterior cervical discectomy and fusion: a randomized controlled trial. Can J Anaesth 2015; 62: 883-90.
6. Hardy D. Relief of pain in acute herpes zoster by nerve blocks and possible prevention of post-herpetic neuralgia. Can J Anaesth 2005; 52: 186-90.
7. Shin HY, Kim DS, Kim SS. Superficial cervical plexus block for management of herpes zoster neuralgia in the C3 dermatome: a case report. J Med Case Rep 2014; 8: 59.
8. Ramachandran SK, Picton P, Shanks A, Dorje P, Pandit JJ. Comparison of intermediate vs subcutaneous cervical plexus block for carotid endarterectomy. Br J Anaesth 2011; 107: 157-63.
9. Martusevicius R, Swiatek F, Joergensen LG, Nielsen HB. Ultrasound-guided locoregional anaesthesia for carotid endarterectomy: a
prospective observational study. Eur J Vasc Endovasc Surg 2012; 44: 27-30.
10. Stoneham MD, Doyle AR, Knighton JD, Dorje P, Stanley JC. Prospective, randomized comparison of deep or superficial cervical plexus block for carotid endarterectomy surgery. Anesthesiology 1998; 89: 907-12.
11. Rössel T, Kersting S, Heller AR, Koch T. Combination of high-resolution ultrasound-guided perivascular regional anesthesia of the internal carotid artery and intermediate cervical plexus block for carotid surgery. Ultrasound Med Biol 2013; 39: 981-6.
12. Pandit JJ, Satya-Krishna R, Gratton P. Superficial or deep cervical plexus block for carotid endarterectomy: a systematic review of complications. Br J Anaesth 2007; 99: 159-69.
13. Winnie AP, Ramamurthy S, Durrani Z, Radonjic R. Interscalene cervical plexus block: a single-injection technic. Anesth Analg 1975; 54: 370-5.
14. Telford RJ, Stoneham MD. Correct nomenclature of superficial cervical plexus blocks. Br J Anaesth 2004; 92: 775.
15. Pandit JJ, Dutta D, Morris JF. Spread of injectate with superficial cervical plexus block in humans: an anatomical study. Br J Anaesth 2003; 91: 733-5.
16. Choquet O, Dadure C, Capdevila X. Ultrasound-guided deep or intermediate cervical plexus block: the target should be the posterior cervical space. Anesth Analg 2010; 111: 1563-4.
17. Saranteas T, Paraskeuopoulos T, Anagnostopoulos S, Kanellopoulos I, Mastoris M, Kostopanagiotou G. Ultrasound anatomy of the cervical paravertebral space: a preliminary study. Surg Radiol Anat 2010; 32: 617-22.
18. Guay J, Grabs D. A cadaver study to determine the minimum volume of methylene blue or black naphthol required to completely color the nerves relevant for anesthesia during breast surgery. Clin An 2011; 24: 202-8.
19. Seidel R, Schulze M, Zukowski K, Wree A. Ultrasound-guided intermediate cervical plexus block. Anatomical study. Anaesthesist 2015; 64: 446-50.
20. Shakespeare TJ, Tsui BC. Intermittent hoarseness with continuous interscalene brachial plexus catheter infusion due to deficient carotid sheath. Acta Anaesthesiol Scand 2013; 57: 1085-6.
21. Zhang M, Lee AS. The investing layer of the deep cervical fascia does not exist between the sternocleidomastoid and trapezius muscles. Otolaryngol Head Neck Surg 2002; 127: 452-4.
22. Zhang MN, HD, Nash, L. Investing layer of the cervical fascia of the neck may not exist. Anesthesiology 2006; 104: 1344-5.
23. Pandit JJ, Dorje P, Satya-Krishna R. Investing layer of the cervical fascia of the neck may not exist. Anesthesiology 2006; 104: 1344.
24. Natale G, Condino S, Stecco A, Soldani P, Belmonte MM, Gesi M. Is the cervical fascia an anatomical proteus? Surg Radiol Anat 2015; 37: 1119-27.
25. Lyons AJ, Mills CC. Anatomical variants of the cervical sympathetic chain to be considered during neck dissection. Br J Oral Maxillofac Surg 1998; 36: 180-2.
26. Levitt GW. Cervical fascia and deep neck infections. Laryngoscope 1970; 80: 409-35.
27. Gidley PW, Ghorayeb BY, Sternberg CM. Contemporary management of deep neck space infections. Otolaryngol Head Neck Surg 1997; 116: 16-22.
28. Granite EL. Anatomic considerations in infections of the face and neck: review of the literature. J Otolaryngol Surg 1976; 34: 34-44.
29. Moncada R, Warpeha R, Pickelman J, Spak M, Cardoso M, Berkow A, et al. Mediastinitis from odontogenic and deep cervical infection. Anatomic pathways of propagation. Chest 1978; 73: 497-500.
30. Stecco A, Meneghini A, Stern R, Stecco C, Imamura M. Ultrasonography in myofascial neck pain: randomized clinical trial for diagnosis and follow-up. Surg Radiol Anat 2014; 36: 243-53.
31. Tischopp KP, Gysin C. Local injection therapy in 107 patients with myofascial pain syndrome of the head and neck. ORL J Otorhinolaryngol Relat Spec 1996; 58: 306-10.
32. Standring S. Gray’s Anatomy. 41th ed. London, Churchill Livingstone Elsevier. 2016, p 41.
33. Adstrum S, Hedley G, Schleip R, Stecco C, Yucesoy CA. Defining the fascial system. J Bodyw Mov Ther 2017; 21: 173-7.
34. Grodinsky M, Holyoke EA. The fasciae and fascial spaces of the head, neck and adjacent regions. Am J Anat 1938; 63: 367-408.
35. Guidera AK, Dawes PJ, Fong A, Stringer MD. Head and neck fascia and compartments: no space for spaces. Head Neck 2014; 36: 1058-68.
36. Guidera AK, Dawes PJ, Stringer MD. Cervical fascia: a terminological pain in the neck. ANZ J Surg 2012; 82: 786-91.
37. Hayashi S. Histology of the human carotid sheath revisited. Okajimas Folia Anat Jpn 2007; 84: 49-60.
38. Piffer CR. Mesoscopic and microscopic study of the carotid sheath. Acta Anat (Basel) 1980; 106: 393-9.
39. Pandit JJ, Satya-Krishna R, Gration P. Superficial or deep cervical plexus block for carotid endarterectomy surgery. Anesthesiology 1998; 89: 907-12.
40. Kimura T, Nishiwaki K, Yokota S, Komatsu T, Shimada Y, Oya S, et al. Severe hypertension after stellate ganglion block. Br J Anaesth 1998; 81: 116-20.
41. Winnie AP, Ramamurthy S, Durrani Z, Radonjic R. Interscalene cervical plexus block: a single-injection technic. Anesth Analg 1975; 54: 370-5.
42. Moore K, Dalley AF, Agur AM. Clinically Oriented Anatomy, 7th ed. Baltimore, Lippincott Williams & Wilkins, 2014, p 988.
43. Moore K, Dalley AF, Agur AM. Clinically Oriented Anatomy, 7th ed. Baltimore, Lippincott Williams & Wilkins, 2014, p 988.
intermediate and lateral branches of supraclavicular nerves. Surg Radiol Anat 2007; 29: 605-10.
45. de Arruda JV, Sartini Filho R, Neder AC, Ranali J. Intraoral anesthesia of the cervical plexus responsible for the sensory innervation of the platymys muscle or skin of the neck. Rev Bras Odontol 1974; 31: 229-31.
46. Standing S. Gray's Anatomy: 41th ed. London, Churchill Livingstone Elsevier, 2016, pp 463-4.
47. Paraskevas GK, Natisis K, Nitsa Z, Mavrodi A, Kitsoulis P. Unusual morphological pattern and distribution of the ansa cervicalis: a case report. Rom J Morph Embryol 2014; 55: 993-9.
48. Brennan PA, Alam P, Ammar M, Tsiroyannis C, Zagkou E, Standing S. Sternocephalomastoid innervation from an aberrant nerve arising from the hypoglossal nerve: a prospective study of 160 neck dissections. Surg Radiol Anat 2017; 39: 205-9.
49. Jelev L. Some unusual types of formation of the ansa cervicalis in humans and proposal of a new morphological classification. Clin Anat 2013; 26: 961-5.
50. Khaki AA, Shokouhi G, Shoja MM, Farahani RM, Zarrintant S, Khaki A, et al. Ansa cervicalis as a variant of spinal accessory nerve plexus: a case report. Clin Anat 2006; 19: 540-3.
51. Shoja MM, Oyesiku NM, Shokouhi G, Griessenauer CJ, Chern JJ, Rizk EB, et al. A comprehensive review with potential significance during skull base and neck operations, Part II: glossopharyngeal, vagus, accessory, and hypoglossal nerves and cervical spinal nerves 1-4. Clin Anat 2014; 27: 131-44.
52. Restrepo CE, Tubbs RS, Spinner RJ. Expanding what is known of the anatomy of the spinal accessory nerve. Clin Anat 2015; 28: 467-71.
53. Masters RD, Castresana EJ, Castresana MR. Superficial and deep cervical plexus block: technical considerations. AANA J 1995; 63: 235-43.
54. Merle JC, Mazoit JX, Desgranges P, Abhay K, Rezaigia S, Dhonneur G, et al. A comparison of two techniques for cervical plexus blockade: evaluation of efficacy and systemic toxicity. Anesth Analg 1999; 89: 1366-70.
55. Stoneham MD, Stamou D, Mason J. Regional anaesthesia for carotid endarterectomy. Br J Anaesth 2015; 114: 372-83.
56. Wan Q, Yang H, Li X, Lin C, Ke S, Wu S, et al. Ultrasound-guided versus fluoroscopy-guided deep cervical plexus block for the treatment of cervicogenic headache. Biomed Res Int 2017; 2017: 4654803.
57. Goldberg ME, Schwartzman RJ, Domsky R, Sabia M, Torjman MC. Deep cervical plexus block for the treatment of cervicogenic headache. Pain Physician 2008; 11: 849-54.
58. Aunac S, Carlier M, Singelyn F, De Kock M. The analgesic efficacy of bilateral combined superficial and deep cervical plexus block administered before thyroid surgery under general anesthesia. Anesth Analg 2002; 95: 746-50.
59. Pintaric TS, Hocevar M, Jereb S, Casati A, Novak Jankovic V. A prospective, randomized comparison between combined (deep and superficial) and superficial cervical plexus block with levobupivacaine for minimally invasive parathyroidectomy. Anesth Analg 2007; 105: 1160-3.
60. Davies MJ, Silbert BS, Scott DA, Cook RJ, Mooney PH, Blyth C. Superficial and deep cervical plexus block for carotid artery surgery: a prospective study of 1000 blocks. Reg Anesth 1997; 22: 442-6.
61. Ivanec Z, Mazul-Sunkol B, Lovricević I, Sonicki Z, Gvozdenović A, Klincan K, et al. Superficial versus combined (deep and superficial) cervical plexus block for carotid endarterectomy. Acta Clin Croat 2008; 47: 81-6.
62. Pandit JJ, Bree S, Dillon P, Elcock D, McLaren ID, Crider B. A comparison of superficial versus combined (superficial and deep) cervical plexus block for carotid endarterectomy: a prospective, randomized study. Anesth Analg 2000; 91: 781-6.
63. Sait Kavaklı A, Kavrut Öztürk N, Umut Ayoğlu R, Sağdıç K, İnanoğlu K, et al. Comparison of combined (deep and superficial) and intermediate cervical plexus block by use of ultrasound guidance for carotid endarterectomy. J Cardiothorac Vasc Anesth 2016; 30: 317-22.
64. Dhonneur G, Saidi NE, Merle JC, Asfazadourian H, Ndoko SK, Blyth C. Demonstration of the spread of injectate with deep cervical plexus block: a case series. Reg Anesth Pain Med 2007; 32: 116-9.
65. Carling A, Simmonds M. Complications from regional anaesthesia for carotid endarterectomy. Br J Anaesth 2000; 84: 797-800.
66. Sandeman DJ, Griffiths MJ, Lennox AF. Ultrasound guided deep cervical plexus block. Anaesth Intensive Care 2006; 34: 240-4.
67. Saranteas T, Kostopanagiotou GG, Anagnostopoulou S, Mourouzis K, Sidiropoulou T. A simple method for blocking the deep cervical plexus using an ultrasound-guided technique. Biomed Res Int 2011; 39: 971-2.
68. Shin HJ, Yu HN, Yoon SZ. Ultrasound-guided subcutaneous cervical plexus block for carotid endarterectomy in a patient with chronic obstructive pulmonary disease. J Anesth 2014; 28: 304-5.
69. Herbland A, Cantini O, Reynier P, Malvoisin P, Jougou J, Arimone Y, et al. The bilateral superficial cervical plexus block with 0.75% ropivacaine administered before or after surgery does not prevent postoperative pain after total thyroidectomy. Reg Anesth Pain Med 2006; 31: 34-9.
70. Wyburn-Mason R. The nature of tic douloureux; treatment by alcohol block or section of the great auricular nerve. Br Med J 1953; 2: 119-22.
71. Thallaj A. Ultrasound guidance of uncommon nerve blocks. Saudi J Anaesth 2011; 5: 392-4.
72. Maybin J, Townsley P, Bedforth N, Allan A. Ultrasound guided supraclavicular nerve blockade: first technical description and the relevance for shoulder surgery under regional anaesthesia. Anaesthesia 2011; 66: 1053-5.
anesthetic for ear surgery. Clin Pract 2016; 6: 856.

75. Guay J. Regional anesthesia for carotid surgery. Curr Opin Anaesthesiol 2008; 21: 638-44.

76. Broderick AJ, Mannion S. Brachial plexus blockade as a result of aberrant anatomy after superficial cervical plexus block. Reg Anesth Pain Med 2010; 35: 476-7.

77. Cornish PB. Applied anatomy of cervical plexus blockade. Anesthesiology 1999; 90: 1790-1.

78. Mayhew D, Sahgal N, Khirwadkar R, Hunter JM, Banerjee A. Analgesic efficacy of bilateral superficial cervical plexus block for thyroid surgery: meta-analysis and systematic review. Br J Anaesth 2018; 120: 241-51.

79. Kannan S, Surhonne NS, R CK, B K, D DR, R S RR. Effects of bilateral superficial cervical plexus block on sevoflurane consumption during thyroid surgery under entropy-guided general anesthesia: a prospective randomized study. Korean J Anesthesiol 2018; 71: 141-8.

80. Girard F, Quentin C, Charbonneaux S, Ayoub C, Boudreault D, Chouinard P, et al. Superficial cervical plexus block for transitional analgesia in infratentorial and occipital craniotomy: a randomized trial. Can J Anaesth 2010; 57: 1065-70.

81. Tubb RS, Loukas M, Shoa MM, Salter EG, Oakes WJ, Blount JP. Approach to the cervical portion of the vagus nerve via the posterior cervical triangle: a cadaveric feasibility study with potential use in vagus nerve stimulation procedures. J Neurosurg Spine 2006; 5: 540-2.

82. Standing S. Gray’s Anatomy, 41th ed. London, Churchill Livingstone Elsevier. 2016, p 445.

83. Merdad M, Crawford M, Gordon K, Papsin B. Unexplained fever after bilateral superficial cervical block in children undergoing cochlear implantation: an observational study. Can J Anaesth 2012; 59: 28-33.

84. Kokófer A, Nawratil J, Felder TK, Stundner O, Mader N, Gerner P. Ropivacaine 0.375% vs. 0.75% with prilocaine for intermediate cervical plexus block for carotid endarterectomy: a randomised trial. Eur J Anaesthesiol 2015; 32: 781-9.

85. Barone M, Diemunsch P, Baldassarre E, Oben WE, Ciarlo M, Wolter J, et al. Carotid endarterectomy with intermediate cervical plexus block. Tex Heart Inst J 2010; 37: 297-300.

86. Kefalianakis F, Koeppel T, Geldner G, Gahlen J. Carotid-surgery in ultrasound-guided anesthesia of the regio colli lateralis. Anaesthesiol Intensivmed Notfallmed Schmerzther 2005; 40: 576-81.

87. Ciccozzi A, Angeletti C, Guetti C, Pergolizzi J, Angeletti PM, Mariani R, et al. Regional anaesthesia techniques for carotid surgery: the state of art. J ultrasound 2014; 17: 175-83.

88. Barone M, Brigand C, Sonnek T, Ramlugun D, Calon B, Rottenberg D, et al. Intermediate cervical plexus block for cervical esophagus diverticulectomy. Acta Anaesthesiol Belg 2015; 66: 59-61.

89. Calderon AL, Zeloaou P, Benatir F, Davidsson J, Desebbe O, Rahali N, et al. Ultrasound-guided intermediate cervical plexus block for carotid endarterectomy using a new anterior approach: a two-centre prospective observational study. Anaesthesia 2015; 70: 445-51.

90. Kim JS, Lee J, Soh EW, Ahn H, Oh SE, Lee JD, et al. Analgesic effects of ultrasound-guided serratus-intercostal plane block and ultrasound-guided intermediate cervical plexus block after single-incision transaxillary robotic thyroidectomy: a prospective, randomized, controlled trial. Reg Anesth Pain Med 2016; 41: 584-8.

91. Kim JS, Joe HB, Park MC, Ahn H, Lee SY, Chae YJ. Postoperative analgesic effect of ultrasound-guided intermediate cervical plexus block on unipolar sternocleidomastoid release with myectomy in pediatric patients with congenital muscular torticollis: a prospective, randomized controlled trial. Reg Anesth Pain Med 2018; 43: 634-40.

92. Leblanc I, Chetrev V, Rekik M, Borea B, Costanzo A, Burel P, et al. Safety and efficiency of intermediate ultrasound-guided cervical plexus block for carotid surgery. Anaesth Crit Care Pain Med 2016; 35: 109-14.

93. Mądro P, Dąbrowska A, Jarecki J, Garba P. Anaesthesia for carotid endarterectomy. Ultrasound-guided superficial/intermediate cervical plexus block combined with carotid sheath infiltration. Anaesthesiol Intensivmed Ther 2016; 48: 234-8.

94. Seidel R, Zukowski K, Wree A, Schulze M. Ultrasound-guided intermediate cervical plexus block and perivascular local anesthetic infiltration for carotid endarterectomy: a randomized controlled trial. Anaesthesist 2016; 65: 917-24.

95. Alliet A, Petit P, Devaux B, Joly C, Samain E, Pili-Floury S, et al. Ultrasound-guided intermediate cervical block versus superficial cervical block for carotid artery endarterectomy: the randomized-controlled CERVECHO trial. Anaesth Crit Care Pain Med 2017; 36: 91-5.

96. Herring AA, Stone MB, Frenkel O, Chipman A, Nagdev AD. The ultrasound-guided superficial cervical plexus block for anesthesia and analgesia in emergency care settings. Am J Emerg Med 2012; 30: 1263-7.

97. Tran DQ, Dugani S, Finlayson RJ. A randomized comparison between ultrasound-guided and landmark-based superficial cervical plexus block. Reg Anesth Pain Med 2010; 35: 539-43.

98. Flores S, Riguzzi C, Herring AA, Nagdev A. Horner’s syndrome after superficial cervical plexus block. West J Emerg Med 2015; 16: 428-31.

99. Senapathi TGA, Widnyana IMG, Aribawa IGNM, Wiryana M, Sinardja IK, Nada IK, et al. Effects of bilateral cervical plexus block on the hypoglossal nerve. Okajimas Folia Anat Jpn 1993; 69: 361-7.

100. Cvetko E. Sternocleidomastoid muscle additionally innervated by the facial nerve: case report and review of the literature. Anat Sci Int 2015; 90: 54-6.

101. Paraskevas G, Lazaridis N, Spyridakis I, Koutsoufianiotis K, Kitsoulis P. Aberrant innervation of the sternocleidomastoid muscle by the
transverse cervical nerve: a case report. J Clin Diagn Res 2015; 9: AD01-2.
104. Hayward R. Observations on the innervation of the sternomastoid muscle. J Neurol Neurosurg Psychiatry 1986; 49: 951-3.
105. Caliot P, Bousquet V, Midy D, Cabanié P. A contribution to the study of the accessory nerve: surgical implications. Surg Radiol Anat 1989; 11: 11-5.
106. Tubbs RS, Sorensen EP, Watanabe K, Loukas M, Hattab E, Cohen-Gadol AA. Histologic confirmation of neuronal cell bodies along the spinal accessory nerve. Br J Neurosurg 2014; 28: 746-9.
107. Bremner-Smith AT, Unwin AJ, Williams W. Sensory pathways in the spinal accessory nerve. J Bone Joint Surg Br 1999; 81: 226-8.
108. Pu YM, Tang EY, Yang XD. Trapezius muscle innervation from the spinal accessory nerve and branches of the cervical plexus. Int J Oral Maxillofac Surg 2008; 37: 567-72.
109. Fitzgerald MJ, Comerford PT, Tuffery AR. Sources of innervation of the neuromuscular spindles in sternomastoid and trapezius. J Anat 1982; 134: 471-90.
110. Yoshizaki E. Innervation of sternocleidomastoid muscle of man and the rabbit. Okayama Igakkai Zasshi 1961; 73: 159-71.
111. Verzingatians KL. Thyroidectomy under local analgesia: the anatomical basis of cervical blocks. Ann R Coll Surg Engl 1989; 71: 207-10.
112. Missaghi B. Sternocleidomastoid syndrome: a case study. J Can Chiropr Assoc 2004; 48: 201-5.
113. Min SH, Chang SH, Jeon SK, Yoon SZ, Park JY, Shin HW. Posterior auricular pain caused by the trigger points in the sternocleidomastoid muscle aggravated by psychological factors - A case report-. Korean J Anesthesiol 2010; 59 Suppl: S229-32.
114. Bodes-Pardo G, Pecos-Martín D, Gallego-Izquierdo T, Saloni-Moreno J, Fernández-de-Las-Peñas C, Ortega-Santiago R. Manual treatment for cervicogenic headache and active trigger point in the sternocleidomastoid muscle: a pilot randomized clinical trial. J Manipulative Physiol Ther 2013; 36: 403-11.
115. Shinozaki T, Sakamoto E, Shiiba S, Ichikawa F, Arakawa Y, Makihara Y, et al. Cervical plexus block helps in diagnosis of orofacial pain originating from cervical structures. Tóhoku J Exp Med 2006; 210: 41-7.
116. North American Symptomatic Carotid Endarterectomy Trial Collaborators, Barnett HJM, Taylor DW, Haynes RB, Sackett DL, Peerless SJ, et al. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. N Engl J Med 1991; 325: 445-53.
117. Bonati LH, Dobson J, Featherstone RL, Ederle J, van der Worp HB, de Borst GJ, et al. Long-term outcomes after stenting versus endarterectomy for treatment of symptomatic carotid stenosis: the International Carotid Stenting Study (ICSS) randomised trial. Lancet 2015; 385: 529-38.
118. Parrot D, Fontaine P, Coulon C, Guyon P, David M. Carotid endarterectomy under cervical plexus block. Cah Anesthesiol 1988; 36: 255-9.
119. Schechter MA, Shortell CK, Scarborough JE. Regional versus general anesthesia for carotid endarterectomy: the American College of Surgeons National Surgical Quality Improvement Program perspective. Surgery 2012; 152: 309-14.
120. Unic-Stojanovic D, Babic S, Neskovic V. General versus regional anesthesia for carotid endarterectomy. J Cardiothorac Vasc Anesth 2013; 27: 1379-83.
121. Kfoury E, Dort J, Trickey A, Croby M, Donovan J, Hashemi H, et al. Carotid endarterectomy under local and/or regional anesthesia has less risk of myocardial infarction compared to general anesthesia: An analysis of national surgical quality improvement program database. Vascular 2015; 23: 113-9.
122. de Sousa AA, Filho MA, Faglione W Jr, Carvalho GT. Superficial vs combined cervical plexus block for carotid endarterectomy: a prospective, randomized study. Surg Neurol Med 2005; 63 Suppl 1: S22-5.
123. Umbrain VJ, van Gorp VL, Schmedding E, van den Brande PM, von Kemp K, van der Worp HB, de Borst GJ, et al. A randomized controlled trial examining the effect of the addition of the mandibular block to cervical plexus block for carotid endarterectomy. J Cardiothorac Vasc Anesth 2013; 32: 877-82.
124. Einav S, Landesberg G, Prus D, Anner H, Berlatzky Y. A case of nerves. Reg Anesth 1996; 21: 168-70.
125. Kavrut Ozturk N, Kavakli AS, Sagdic K, Inanoglu K, Umot Ayoglu R. Beneficial effect of carotid endarterectomy during cervical plexus block anesthesia. J Neurosurg Anesthesiol 1994; 6: 21-3.
126. Campbell EJ. The role of the scalene and sternomastoid muscles in breathing in normal subjects; an electromyographic study. J Anat 1955; 89: 378-86.
127. Harris RJ, Benveniste G. Recurrent laryngeal nerve blockade in patients undergoing carotid endarterectomy under cervical plexus block. Anaeseth Intensive Care 2000; 28: 431-3.
128. Kwok AO, Silbert BS, Allen KJ, Bray PJ, Vidovich I. Bilateral vocal cord palsy during carotid endarterectomy under cervical plexus block. Anesth Analg 2006; 102: 376-7.
129. Castresana MR, Masters RD, Castresana EJ, Stefansson S, Shaker IJ, Newman WH. Incidence and clinical significance of hemidiaphragmatic paresis in patients undergoing carotid endarterectomy during cervical plexus block anesthesia. J Neurosurg Anesthesiol 1994; 6: 21-3.
130. Campbell EJ. The role of the scalene and sternomastoid muscles in breathing in normal subjects; an electromyographic study. J Anat 1955; 89: 378-86.
131. Lisboa C, Paré PD, Pertuzé J, Contreras G, Moreno R, Guillemin S, et al. Inspiratory muscle function in unilateral diaphragmatic paralysis. Am Rev Respir Dis 1986; 134: 488-92.
132. Bonnevie T, Gravier FE, Ducrocq A, Debeaumont D, Vleкроze C, Cuvelier A, et al. Exercise testing in patients with diaphragm paresis. Respir Physiol Neurobiol 2018; 248: 31-5.
133. Stoneham MD, Wakefield TW. Acute respiratory distress after deep cervical plexus block. J Cardiothorac Vasc Anesth 1998; 12: 197-8.
134. Lookman AA. Brachial plexus infiltration, single injection technique. Anaesthesia 1958; 13: 5-18.
135. Warshafsky D, Goldenberg D, Kanekar SG. Imaging anatomy of deep neck spaces. Otolaryngol Clin North Am 2012; 45: 1203-21.
136. Shibata Y, Fujiwara Y, Komatsu T. A new approach of ultrasound-guided stellate ganglion block. Anesth Analg 2007; 105: 550-1.
137. Urmey WF, Talts KH, Sharrock NE. One hundred percent incidence of hemidiaphragmatic paresis associated with interscalene brachial plexus anesthesia as diagnosed by ultrasonography. Anesth Analg 1991; 72: 498-503.
138. Suzuki S, Yasunaga H, Matsu H, Fushimi K, Saito Y, Yamasoba T. Factors associated with neck hematoma after thyroidectomy: a retrospective analysis using a Japanese inpatient database. Medicine (Baltimore) 2016; 95: e2812.
139. Carmichael FJ, McGuire GP, Wong DT, Crofts S, Sharma S, Montanera W. Computed tomographic analysis of airway dimensions after carotid endarterectomy. Anesth Analg 1996; 83: 12-7.
140. Kwok OK, Sun KO, Ahchong AK, Chan CK. Airway obstruction following carotid endarterectomy. Anaesth Intensive Care 2004; 32: 818-20.
141. Reifkenberger G, Prior R, Deckert M, Wechsler W. Epidermal growth factor receptor expression and growth fraction in human tumours of the nervous system. Virchows Arch A Pathol Anat Histopathol 1989; 414: 147-55.
142. Fokkema M, de Borst GJ, Nolan BW, Indes J, Buck DB, Lo RC, et al. Clinical relevance of cranial nerve injury following carotid endarterectomy. Eur J Vasc Endovasc Surg 2014; 47: 2-7.
143. Hye RJ, Mackey A, Hill MD, Voeks JH, Cohen DJ, Wang K, et al. Incidence, outcomes, and effect on quality of life of cranial nerve injury in the carotid revascularization endarterectomy versus stenting trial. J Vasc Surg 2015; 61: 1208-14.
144. Hertzer NR, Feldman BJ, Beven EG, Tucker HM. A prospective study of the incidence of injury to the cranial nerves during carotid endarterectomy. Surg Gynecol Obstet 1980; 151: 781-4.
145. Bagent TE, Tondini D, Lyons D. Bilateral hypoglossal-nerve palsy following a second carotid endarterectomy. Anesthesiology 1975; 43: 595-6.
146. Weiss A, Isselhorst C, Gahlen J, Freudenberg S, Roth H, Hammerschmitt N, et al. Acute respiratory failure after deep cervical plexus block for carotid endarterectomy as a result of bilateral recurrent laryngeal nerve paralysis. Acta Anaesthesiol Scand 2005; 49: 715-9.
147. Espinoza FI, MacGregor FB, Doughty JC, Cooke LD. Vocal fold paralysis following carotid endarterectomy. J Laryngol Otol 1999; 113: 439-41.
148. Casutt M, Breitenmoser I, Werner I, Seelos R, Konrad C. Ultrasound-guided carotid sheath block for carotid endarterectomy: a case series of the spread of injectate. Heart Lung Vessel 2015; 7: 168-76.
149. Elsharkawy H, Pawa A, Mariano ER. Interfascial plane blocks: back to basics. Reg Anesth Pain Med 2018; 43: 341-6.
150. Avidan A, Horner’s syndrome is not a complication of a brachial plexus block. Reg Anesth Pain Med 2004; 29: 378.
151. Civelek E, Karasu A, Cansever T, Hepgul K, Kiris T, Sabanci A, et al. Surgical anatomy of the cervical sympathetic trunk during anterolateral approach to cervical spine. Eur Spine J 2008; 17: 991-5.
152. Standing S. Gray’s Anatomy. 41th ed. London, Churchill Livingstone Elsevier. 2017, p 468.
153. Ahmad M, Hayat A. Horner’s syndrome following internal jugular vein dialysis catheter insertion. Saudi J Kidney Dis Transpl 2008; 19: 94-6.
154. Nason RW, Abdulrauf BM, Stranc MF. The anatomy of the accessory nerve and cervical lymph node biopsy. Am J Surg 2000; 180: 241-3.
155. Symes A, Ellis H. Variations in the surface anatomy of the spinal accessory nerve in the posterior triangle. Surg Radiol Anat 2005; 27: 404-8.
156. Tubbs RS, Salter EG, Hellons JC 3rd, Blount JP, Oakes WJ. Superficial landmarks for the spinal accessory nerve within the posterior cervical triangle. J Neurosurg Spine 2005; 3: 375-8.
157. Townsley P, Ravenstron A, Bedforth N. Ultrasound-guided spinal accessory nerve blockade in the diagnosis and management of trapezius muscle-related myofascial pain. Anaesthesia 2011; 66: 386-9.