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Cervical plexus block

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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.

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, which is used to easily identify various important landmarks including muscles, cervical vertebrae, large vessels, nerves, and the cervical fascia [17]. Particularly, understanding the detailed configuration of the cervical fasciae

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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-

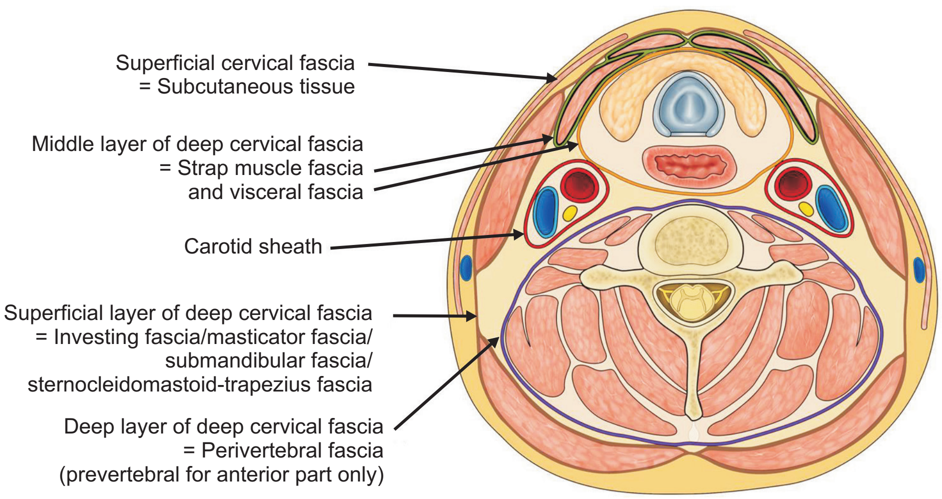

Fig. 1. The layers of cervical fascia (C6 transverse section) as suggested by Guidera et al. [35]. The illustration is adapted from Smoker and Harnsberger [41].

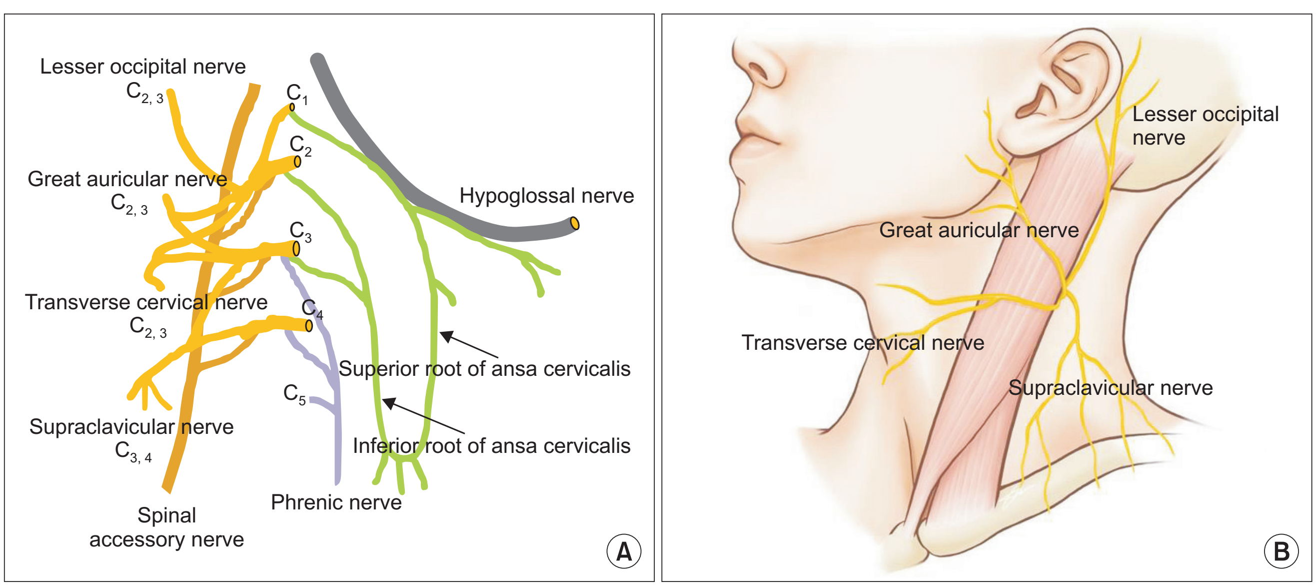

Fig. 2. Schematic drawing of the deep cervical plexus and superficial cervical plexus. (A) Four superficial branches of the cervical plexus are depicted using yellow color, and deep branches of cervical plexus (ansa cervicalis) are depicted using green color. The cervical plexus is known to anastomose with several cranial nerves and the sympathetic trunk. (B) The superficial cervical plexus emerges behind the posterior border of the SCM (sternocleidomastoid) muscle and innervates the head, neck, and shoulder areas. The illustration is adapted from Restrepo et al. [52].

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 subarachnoid 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

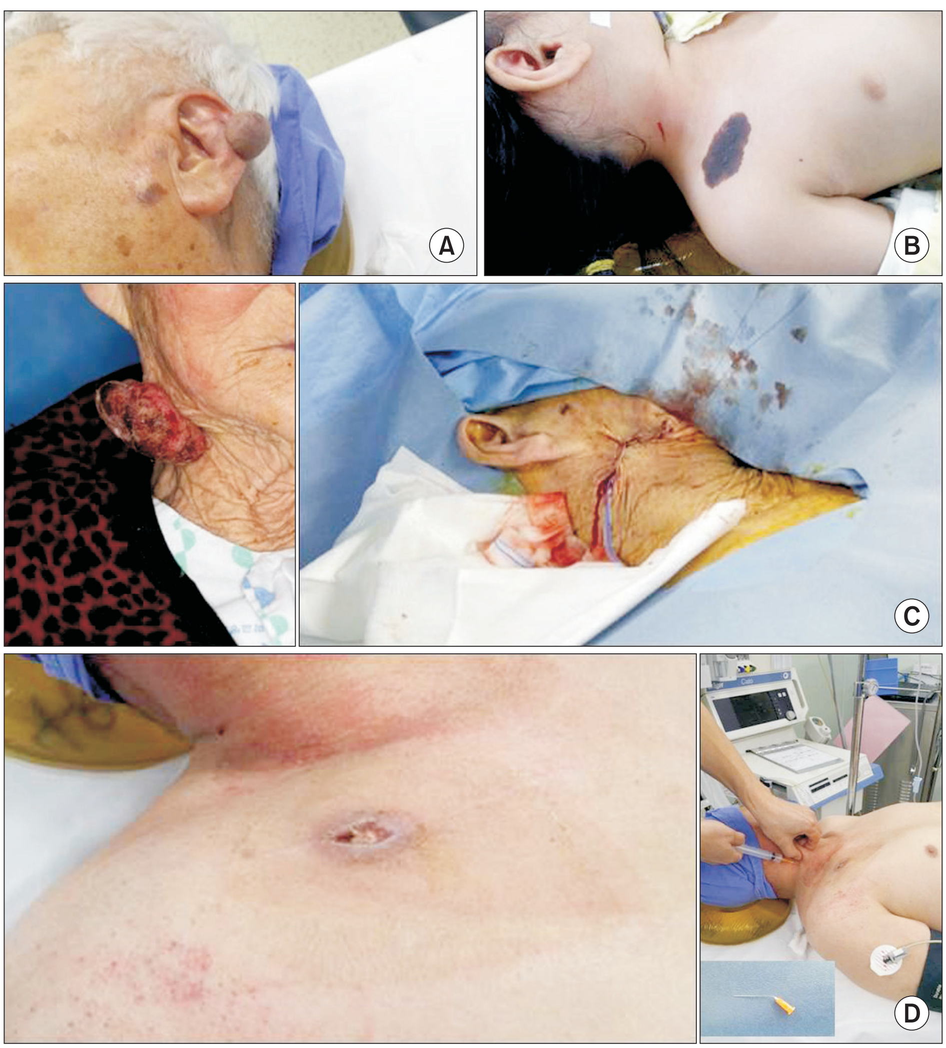

Fig. 3. Landmark-based superficial cervical plexus blocks have been performed for ear, neck, and upper chest wall surgeries to obtain adequate anesthesia and/or analgesia in Ajou University Hospital. (A) Great auricular and lesser occipital nerve blocks were performed in a 77-year-old male patient undergoing 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.

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], tympanomastoid 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 plastinations in cadavers, but their results are still controversial [24,35,36]. Interestingly, in the 41th 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 el 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 CPBs; 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 regional techniques during CEA [89]. According to Leblanc et al. [92], USG intermediate CPB is easy to perform, safe and reliable. In contrast, some authors [96–99] performed USG intermediate CPBs in the PCSs, but they described these as USG superficial CPBs. In the review of regional anesthesia for CEA by Stoneham et al. [55], CPB is described as five techniques: superficial, deep, USG superficial, USG deep, and USG intermediate CPBs. In this review, Stoneham et al. [55] described the USG superficial CPB as the method that involves advancing the block needle adjacent to cervical plexus underneath the prevertebral fascia. However, if the block needle pierces the prevertebral fascia, it is no longer classified as an intermediate CPB, as Telford and Stoneham, [14] and Pandit et al. [12,15] originally suggested, nor the classical superficial CPB; therefore, the use of term “superficial” is not appropriate in this occasion.

The reason for the above discrepancies in the nomenclatures of the CPB methods seems to be due to the location where the block is performed and the branch of the cervical plexus being blocked. A CPB that is performed at the cervical paravertebral space (C2–C4) can block both superficial and deep branches of the cervical plexus simultaneously [53], although we term it a deep, rather than superficial CPB, given the position at which the block is performed. Accordingly, the nomenclature of the CPB technique that is performed in the PCS resulting in interfascial spread of local anesthetic would be more appropriate to be termed an intermediate CPB than superficial CPB, even though the intermediate and superficial CPBs are essentially targeting same superficial branches of the cervical plexus.

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 [48,52,108–110]. 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 [90] or resection of the SCM muscle [91]. Similarly, Yerzingatsian [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.

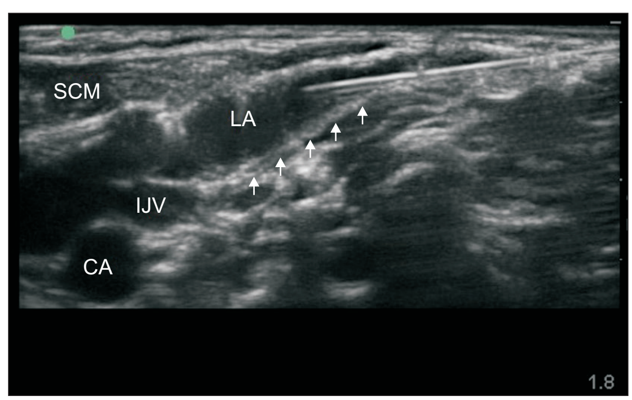

Fig. 4. Ultrasound image of the posterior approach for an intermediate cervical plexus block at C4-5 level in a 3-year-old torticollis patient undergoing unipolar sternocleidomastoid (SCM) release with myectomy. Hydrodissection of the posterior cervical space between the SCM muscle and prevertebral fascia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

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 artery 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 block, 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 capitis 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 41th 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].

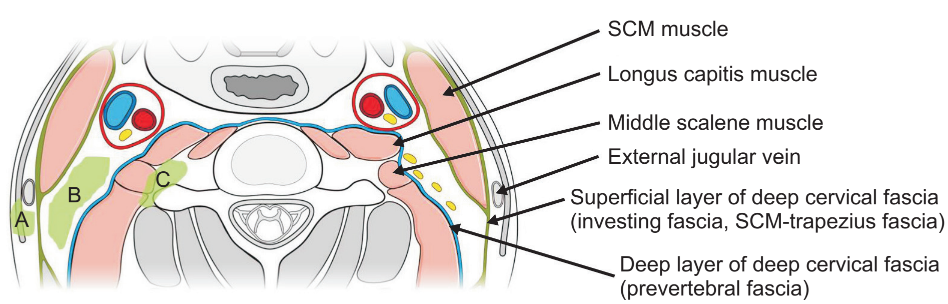

Fig. 5. Three different target areas of cervical plexus blocks (CPBs) in the cervical fascial spaces are depicted schematically (C4 transverse section). (A) The target area for superficial CPB is subcutaneous tissue around the mid portion of posterior border of the sternocleidomastoid (SCM) muscle. (B) 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.

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