Alternative techniques for failure of conventional inferior alveolar nerve block

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Successful local anesthesia in dental treatment is the most important prerequisite for pain control of patients. However, unlike that in the maxilla, it is difficult to administer local anesthesia in the mandible, and the success rate of conventional inferior alveolar nerve block (IANB) is only 80−85%. It is attributed to various causes such as anatomical variations, extreme anxiety, and technical errors; thus, various alternatives have been devised to improve this. We will analyze the causes of failure in conventional IANB and examine various alternatives that can be applied in these cases.

Keywords: Anatomical Factor; Anesthetic Technique; Inferior Alveolar Nerve Block; Patient Factor; Technical Factor.

INTRODUCTION

Pain control through local anesthesia accompanies various dental treatments including oral surgery, endodontic treatment, periodontal treatment, and prosthetic treatment. It is a prerequisite in the reduction of patient's discomfort and completion of dental procedures, and many patients prefer a dentist who provides painless dental treatment [1].

The mandible mainly uses block anesthesia instead of infiltration anesthesia due to close bone mineral density, limited access to the inferior alveolar nerve, and anatomical variation [2]. However, the success rate of conventional inferior alveolar nerve block (IANB) is only 80−85% [3]. As a result, various anesthetic methods have been devised to replace conventional IANB. For successful local anesthesia, the clinician needs to be familiar with the alternatives and fully understand each feature, indication, and complication. Therefore, this study will present the considerations to avoid failure of conventional IANB and various alternatives.

CONSIDERATIONS TO AVOID FAILURE OF CONVENTIONAL IANB

For the success of conventional IANB, anatomical, patient, and dentist's technical factors must be fully considered.

1. Anatomical factors

1.1. Determination of the insertion point considering the location of the mandibular foramen

IANB is a method of delivering anesthetic solution into the pterygomandibular space bounded by the anterior

buccinator muscle, posterior parotid gland, upward lateral pterygoid muscle, internal medial pterygoid muscle, and external mandibular ramus [4,5]. The inferior alveolar nerve, inferior alveolar vein, and inferior alveolar artery, which form the inferior alveolar neurovascular bundles among organizations in the pterygomandibular space, generally have common anatomical patterns [6,7]. The inferior alveolar neurovascular bundles are located posterolateral of the lingula tip. Inferior alveolar vessels are located posterior or posterolateral to the inferior alveolar nerve, which is generally located at the forefront, while inferior alveolar veins are located at the rearmost outward [5,6,8,9].

For a complete IANB, the anesthetic solution must be delivered as close to the mandibular foramen as possible. The mandibular foramen resides in the sulcus colli, a spooned-out bony depression inside the mandibular ramus [4,5]. The mandibular foramen is located posterior to the midline of mandibular ramus [10-16]. Thangavelu et al. reported that the mandibular foramen is 2.75 mm posterior to the midpoint of the anteroposterior width of the ramus, 3 mm above the midpoint of the sigmoid notch and inferior border height at the level of occlusal plane of lower molars, and 19 mm from the coronoid notch [11]. The anterior border of the sulcus colli is the crista endocoronoidea, a thick bony protrusion that prevents the mechanical injury of the inferior alveolar nerve by needle as well as the lingula [6,8]. Considering that the ideal anesthetic solution injection point is directly superior to the lingula, the crista endocoronoidea is the site where the needle tip should be located [6]. Additionally, as the lingula is attached by the sphenomandibular ligament, a dense fibrous band of tissue that prevents anesthetic solution from spreading in case the anesthetic solution is injected just below the lingula, the needle tip should be placed above the tip of the lingula [6,8,17-21]. Moreover, due to the sphenomandibular ligament, a relatively low proportion of loose areolar tissue is distributed in the pterygomandibular space at the height of the lingula, and the ratio of loose areolar tissue increases in the upward direction. It is recommended to insert the needle through the loose areolar tissue for minimum resistance, reduced likelihood of damaging important structures, and reduction of patient's discomfort during the IANB; thus, the insertion point should be located above the lingula [6].

1.2. Anatomical variations of IAN

Variations of normal anatomy, such as communication among mandibular nerve branches, can cause local anesthesia failure [22-25]. Desantis and Liebow have described anatomical variations that may hinder the success rate of IANB, including the presence of the accessory mylohyoid nerve, bifid mandibular nerve, and retromolar foramen and contralateral innervation of the anterior teeth [2,26]. The nerve to the mylohyoid muscle generally follows the anteroinferior course of the medial side of the mandibular ramus but provides accessory innervation to the mandibular teeth when part of the course of the nerve is an intra-osseous component [17,27-30]. Furthermore, the long buccal nerve and great auricular nerve, which travel through the retromolar foramina, can provide additional innervations to the mandibular teeth [31,32]. If an accessory innervation is placed, the pain cannot be resolved by repeating IANB. This symptom can be diagnosed when the patient develops numbness of the lower lip after IANB but is still responds sensitively when stimulated, which is especially common in the mandibular molars [4]. The bifid mandibular nerve develops with a prevalence of 0.35−1%, attributed to the anatomical variations of the inferior alveolar nerve in the development of mandibular bone through the intra-membranous ossification. The most problematic type of the bifid mandibular nerve is a case of two independent mandibular foramina with a portion of inferior alveolar nerve entering both simultaneously [17,33-36].

2. Patient factors

2.1. Psychological factors

Extreme anxiety and fear of the patient are often major causes of anesthesia failure. In terms of the neuro-

physiological perspective, even if nerve conduction is blocked, the patient may feel exaggerated or imagined pain when hearing the handpieces [4,17,37]. To resolve this, it is helpful to discuss with the patient about the fear of anesthesia, and if necessary, minimal sedation using nitrous oxide can be considered [4,37].

2.2. Inadequate mouth opening

The inferior alveolar nerve travels along the medial wall of the mandibular ramus. When mouth opening is inadequate, the nerve is relaxed, away from the lingula tip where the anesthetic solution is injected; thus, the effect of IANB does not work efficiently. Therefore, when IANB is performed, it is necessary to let the patient open the mouth wide so that the inferior alveolar nerve runs as close to the medial wall of the ramus as possible. For this reason, patients with trismus require the use of closed-mouth block anesthesia [38,39].

2.3. Skeletal patterns

For successful IANB, extraoral landmarks, such as degree of ramal flaring and height and width of the mandibular ramus as well as intraoral landmarks should be considered [17,40]. You et al. reported that the IANB failure rates were significantly higher in the retrognathic mandible (14.5%) than in the normal mandible (7.3%) and prognathic mandible (9.5%) [41]. It is because the distance from the mandibular foramen to the condylar tip is significantly shorter in the retrognathic group, and accordingly, the position of the mandibular foramen is higher in the retrognathic group than that in the normal group. As a result, when the needle is inserted above the occlusal plane with a conventional IANB method, anesthetic solution is infused inferior to the mandibular foramen, resulting in high failure rates. Moreover, in the retrognathic group, insufficient mouth opening due to short condyle length is considered to be the cause of inappropriate IANB [38,41]. In contrast, since the mandibular foramen is located lower in patients with prognathic mandibles than that in the normal group, anesthetic solution can be infused superior to the mandibular foramen. In addition,

sufficient mouth opening enables easy identification of anatomical structures [41]. Keros et al. also reported that the location of the mandibular foramen was lower in patients with successful IANB [42]. Therefore, in patients with retrognathic mandibles, anesthetic solution should be infused at a higher point, and Gow-Gates and Akinosi methods that do not depend on the position of the mandibular foramen can be considered [41].

2.4. Local pathological changes such as infection and inflammation

If there is an infection in the mandibular nerve branch or pterygomandibular space, it becomes histologically acidic, which may interfere with the onset of anesthesia [43]. The failure rates of IANB in the mandibular posterior teeth with irreversible pulpitis are extremely high at 30–81% [44-47], which results from activation and sensitization of the nociceptors and stimulation of a greater number of nerve fibers [48-51]. Therefore, the risk of IANB failure can be reduced by depositing the anesthetic solution as far from the infected area as possible.

3. Technical factors of the clinician

3.1. Intravascular injection

Since the inferior alveolar vessels, especially inferior alveolar veins, are located the most posterolaterally among the components of the inferior alveolar neurovascular bundle and located outside of the lingual and the protective shadow cast by the crista endocoronoidea, it is more exposed to trauma from an inserting needle when IANB is performed [6]. Intravenous injection should be prevented through accurate aspiration before anesthetic solution injection. After the needle tip is inserted and comes in contact with the bone, it must be withdrawn 1–2 mm before aspiration because the inferior alveolar vein may be pinned to the bone during bone contact, resulting in a false-negative aspiration response [4,6].

3.2. Haste

Malamed et al. have recommended that onset of

anesthesia in IANB is within 3−5 min and that the time is complied before starting the treatment [3,38]. In contrast, waiting for > 5 min after IANB does not increase the success rate of anesthesia [10].

3.3. Improper needle placement

Penetrating the needle tip forward or backward excessively beyond the target area is a common mistake by clinicians [43]. The needle should be inserted to a precise depth of 20−25 mm to the pterygotemporal depression between the pterygomandibular raphe and coronoid notch [3]. This depth was determined by the distance from the anterior border of the ramus to the midpoint of the mandibular foramen (19 mm), considering that the IAN may move about 4 mm posteriorly when a patient opens the mouth [11]. Additionally, it was reported that when injected into one-fourth of the ramus anteriorly, the success rate was lower than that into three-fourths of the ramus posteriorly, resulting in 3.94 times higher need for additional anesthesia [10].

ALTERNATIVES FOR CONVENTIONAL IANB

1. Repeat IANB

Repeat injection has been described as the first option when the initial injection is unsuccessful and may be effective in some cases. On the contrary, Kanna et al. reported a success rate of repeat IANB to be as low as 32% [52]. Repeated injections in the same area can lead to post-injection pain and even trismus [3].

2. Buccal infiltration

Simpson et al. have reported a success rate of 24−38% in the mandibular teeth with irreversible pulpitis in the case of buccal infiltration of 1.8 mL with 4% articaine with epinephrine after IANB failure [53]. Kanaa et al. have reported a success rate of 84% for additional buccal infiltration with articaine after IANB failure, which was significantly higher than that in intraligamentary injection with 2% lidocaine with epinephrine (48%) or repeat

IANB (32%) [52]. Anesthetic solution used for buccal infiltration is known to be more effective with 4% articaine than 2% lidocaine [54].

3. Intraligamentary injection

Intraligamentary injection is performed by spreading a local anesthetic solution to the cancellous medullary bone surrounding the teeth through the periodontal ligament using high injection pressure. It is the most commonly used method after IANB failure in the treatment of mandibular posterior teeth with irreversible pulpitis [33]. While the use of special syringes and needles is simpler, it is equally effective with a standard 27-G needle. The clinician inserts the needle at the mesiobuccal aspect of the root and advances it until maximum penetration is achieved. At this time, keeping the bevel toward the root makes it easier to be penetrated [55]. Afterward, approximately 0.2 mL of anesthetic solution per root is injected slowly under pressure to prevent pain and extrusion of the teeth [56].

Walton and Abbot reported a success rate of 63% in the first intraligamentary injection and 92% in the reinjection in the IANB failure group for endodontic procedures [57], while Smith et al. reported a success rate of 93% in intraligamentary injection after IANB failure [56].

Since intraligamentary injection has a shorter onset of anesthesia compared to IANB and requires only a small volume of local anesthetic solution, it rarely has the risk for systemic toxicity and nerve damage, and there is much lesser pain on injection [58,59]. It also prevents possible rupture, vascular trauma, and excessive bleeding potentially occurring with IANB in patients with bleeding tendency, such as hemangioma [60], and cardiovascular disturbance, such as tachycardia, is less likely to occur [61,62]. In contrast, intraligamentary injection has an anesthesia duration as short as 30−45 min [58]. Malamed recommended not to perform intraligamentary injections in inflamed or infected periodontal sites [63]. Antibiotic prophylaxis should be considered as there is a risk of bacteremia and bacterial endocarditis due to intraliga-

mentary injection even when administered to a healthy periodontal tissue [64]. As enamel hypoplasia or hypo-mineralization of the permanent teeth adjacent to the injection site has been reported, it is not recommended for primary teeth [65].

4. Intraosseous (IO) anesthesia

IO anesthesia, which was first published in 1910 [66], was not widely used initially as a rejection of drilling on the cortical bone. However, frequency of its use has increased with the introduction of specialized equipment for IO anesthesia such as the X-tip and Stabident systems. It can also be implemented with standard dental instruments [67]. The clinician infiltrates the gingiva in the area of penetration with 0.2 mL anesthetic solution and gently drills at 5 mm apical to the buccal papilla until the cancellous bone is reached. Afterward, a 27- or 30-G needle is inserted into the cortical bone to administer 0.2−0.5 mL anesthetic solution. There is immediate onset of anesthesia, and anesthesia with vasoconstrictor has a duration of about 60 min, while anesthesia without vasoconstrictor has a duration of 15-30 min [58,68-70]. When IO injection was performed after IANB failure, success rates of 66−91% were reported, which were significantly higher than those in repeat IANB at 32% and intraligamentary injection at 48% [52,71,72]. Administration of an IO injection of 1.8 mL of 2% lidocaine with 1:100,000 epinephrine may cause an increase in heart rate in approximately 60% of patients. Therefore, injections without epinephrine such as 3% mepivacaine without a vasoconstrictor should be used in patients with cardiovascular disease [68,69].

IO anesthesia should be avoided in the case of extensive periodontal disease or acute periapical infection as a fistula may form. IO anesthesia is difficult to be applied to thick cortical plates such as distal to the mandibular second molar or in the case in which the roots of teeth are so close that they preclude clear access to the interdental trabecular bone [63].

5. Intrapulpal injection

Since intrapulpal injection achieves anesthesia as a result of pressure, not as a result of the local anesthetic solution, it also has the same effect when performed using saline solution. While this method has an advantage of rapid onset of anesthesia, it has a low indication as it is only available for endodontic procedures with exposed pulp [38].

6. Gow-Gates mandibular nerve block

The objective of Gow-Gates mandibular nerve block is to administer the local anesthetic solution to the neck of the condyle near the mandibular branch, the superior nerve of the inferior alveolar nerve [4]. As the intraoral landmark for anesthesia, the external oblique ridge of the anterior surface of the ramus, coronoid process, and temporalis muscle, which attaches to the coronoid process, are palpated. The temporalis muscle must be missed when inserting the needle. The syringe barrel is placed in the contralateral mandibular canine or premolars while the patient keeps the mouth open as wide as possible, and the needle tip should be inserted just below the mesial cusp of the maxillary second molar. It penetrates parallel to the imaginary line connecting the intertragic notch and corner of the mouth and is advanced slowly until it comes in contact with the neck of condyle. Bone contact happens at an average depth of 25 mm. Injection should not be performed before the needle tip comes in contact with the bone, and in case, the needle shall be redirected until it comes in contact the neck of the condyle. After bone contact, withdrawal 1 mm and aspiration are followed by administration of 1.8 mL cartridge. Patient should keep their mouths open for at least 20 s after the injection is performed so that the mandibular branch can be positioned closer to the injection site [4,73]. Gow-Gates mandibular nerve block anesthetizes the inferior alveolar nerve and branches (mandibular nerve and mental nerve), lingual nerve, mylohyoid nerve, auriculotemporal nerve, and buccal nerve [3]. Therefore, this nerve block may be useful when IANB fails due to accessory innervation from mylohyoid and auriculotemporal nerves [4,38].

The onset of anesthesia of the Gaw-Gates mandibular nerve block is presented in a range of 5−25 min, which

is longer than that in IANB [74-77]. Failure and complication rates may be higher than those in IANB methods when performed by beginners [76], while success rates by experienced clinicians are reported to be > 95% [33]. When the mandibular posterior teeth with irreversible pulpitis were administered with anesthesia in three experiments (2 Gow-Gates mandibular nerve block injections of 3.6 mL, 2 IANB injections of 3.6 mL, and 1 Gow-Gates mandibular nerve block plus 1 IANB injection of each 1.8 mL), the success rates were 40%, 44%, and 70%, respectively, showing a significantly good result in a combination of Gow-Gates mandibular nerve block and IANB [44].

7. Closed-mouth block (Vazirani/Akinosi block)

As the Akinosi block is an anesthetic method targeting the mandibular branch of the trigeminal nerve similar to the Gow-Gates mandibular nerve block, it is especially useful in case of anatomical variation, including accessory innervation [4,74,78,79]. This method is commonly used when there is trismus or difficulty in finding soft tissue landmarks used in conventional IANB procedures [78,79]. After palpating the coronoid process while patient's mouth is closed, the needle is inserted at the height of the mucogingival junction of the maxillary posterior teeth between the maxillary tuberosity and coronoid process. The needle should not penetrate the temporalis muscle similar to that in Gow-Gates mandibular nerve block. During anesthesia, the masticatory muscles should remain relaxed, which prevents mastication from interfering with the diffusion of an anesthetic solution by obliterating the pterygomandibular space. The syringe is inserted to a depth of 25 mm parallel to the maxillary posterior occlusal plane, and at this time, the needle tip is placed between the medial pterygoid muscle and mandibular ramus. There should be no bone contact during insertion. Premature bone contact occurs in most coronoid processes when the insertion point is too far laterally. Aspiration is followed by injection of 1.8 mL of anesthetic solution [4]. Onset of anesthesia is relatively short with 5–7 min, and the inferior alveolar, lingual, mylohyoid, and buccal nerves are anesthetized [4].

Although possibilities of over-inserting the needle and injuring the vessels in the pterygoid plexus cannot be excluded with no bony landmarks available [80], it is a relatively safe technique that could replace IANB [38].

8. Modified IANB

8.1. Modified IANB by Thangavelu et al.

After palpating the anterior border of the ramus while the patient is advised to open the mouth fully, the needle is inserted at 6–8 mm above the midpoint between the upper occlusal plane and lower occlusal plane and 8–10 mm posterior to the anterior border of the ramus. The needle is advanced until it comes in contact with the medial side of the mandibular ramus, while the syringe barrel is placed at the canine and premolars of the contralateral side, and advanced to the mandibular foramen with continuous bone contact. The insertion depth is 21–24 mm. After the syringe is placed at the contralateral side, 1–1.5 mL of local anesthetic solution is deposited [74]. This technique has a disadvantage of traumatizing the periosteum of the medial side of the mandibular ramus [22], while it shows a high success rate of 95%, and there are no complications, such as trismus, positive aspiration, hematoma, needle breakage, and nerve injury [74].

8.2. Arched needle technique

Since the needle on insertion of the tissues approaches the medial surface of the ramus at an acute angle in conventional IANB, needles are likely to come in contact with the bone too far posteriorly, resulting in complications such as transient facial paralysis [81,82]. To improve this, the needle is bent into an arch shape so that the arched needle approaches the medial surface of the ramus almost perpendicularly, which showed the same onset of anesthesia with 3–5 min and success rates of 98% [81].

8.3. Modified IANB by Palti et al.

IANB using two wires was devised to locate the

mandibular foramen. One wire passes from the mesio-buccal groove and the middle point of the slope of the distolingual cusp of the contralateral mandibular permanent first molar or primary second molar, and the other wire must follow the occlusal plane on the ipsilateral side so that the tip of the orthodontic wire coincides with the center of the mandibular foramen. Coincidence is particularly effective in pediatric patients with 93% rate compared to 82% in adults. Although the standard deviation is extremely small even with errors and the actual success rate of anesthesia is presumed to be higher, further clinical studies are needed in the future [2].

While successful local anesthesia is essential for both clinicians and patients in dental treatment, conventional IANB alone has limitations in mandibles that are difficult to anesthetize. Therefore, clinicians should be familiar with various alternatives and be able to use them properly, if necessary.

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NOTE: The authors have no conflicts of interest to declare.

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