**HEAD & NECK**

# Endoscopic transvestibular anatomy of the infratemporal fossa and upper parapharyngeal spaces for clinical surgery: a cadaver study

Yi Fang[1] · Haitao Wu[1] · Weidong Zhao[1] · Lei Cheng[1]

## Abstract

**Aims** To investigate the anatomy of the infratemporal fossa (ITF) and to discuss the practicality of endoscopic transvestibular surgery for an ITF tumor.

**Methods** Five fresh cadaveric specimens (10 sides) with vascular silicone injection were prepared for endoscopic anatomy. A transvestibular vertical incision was made along the ramus of the mandible, and pivotal nerves, arteries, and muscles were exposed to sculpt the anatomic landmarks of the ITF.

**Results** The endoscopic transvestibular approach exposed the detailed structure of the ITF. The buccinator muscle and the adjoining superior pharyngeal constrictor muscle shaped the paramedian border of the ITF, while the medial pterygoid muscle (MPM) and the lateral pterygoid muscle formed the lateral border. The ITF was delimited by the skull base in the upper margin, and it was proximal to the parapharyngeal space in the inferior part. The inferior alveolar nerve was the first reference point, and the maxillary artery and the lateral pterygoid muscle were also the landmarks of the ITF. The lingual nerve, the eustachian tube (ET), and the middle meningeal artery were also located in the posterior part of the ITF.

**Conclusion** The endoscopic transvestibular approach provides a feasible and facile corridor to the ITF. With accurate hemostasis, this approach may provide another option for accessing the ITF for removal of tumors.

**Keywords** Anatomy · Regional · Video-assisted surgery · Infratemporal fossa · Surgical oncology

## Abbreviations

| | |
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| ITF | Infratemporal fossa |
| SPCM | Superior pharyngeal constrictor muscle |
| MPM | Medial pterygoid muscle |
| LPM | Lateral pterygoid muscle |
| PPS | Parapharyngeal space |
| ICA | Internal carotid artery |
| IJV | Internal jugular vein |
| MCP | Mandibular coronoid process |
| IAN | Inferior alveolar nerve |
| PMR | Pterygomandibular raphe |
| MMA | Middle meningeal artery |
| ET | Eustachian tube |
| TMJ | Temporomandibular joint |

✉ Lei Cheng
tomorrowhot@163.com

1 Department of Otorhinolaryngology-Head and Neck Surgery (Shanghai Key Clinical Disciplines of Otorhinolaryngology), Eye, Ear, Nose and Throat Hospital, Fudan University, Fenyang Road Num83, Xuhui District, Shanghai 200031, China

## Introduction

The infratemporal fossa (ITF) is a virtual space that contains crucial neurovascular structures of the head and neck: it lies inferior and medial to the zygomatic arch. Decades ago, due to its anatomical complexity and lack of appropriate approaches for surgical exposure, removal of a lesion in the ITF was considered a major challenge, sometimes not even possible. In the 1950–1960s, the parallel work of Conley [1] and Barbosa [2] conquered the difficult problem and made the ITF surgery practical. In the following 5 decades, an approach with a preauricular incision to expose the ITF became the most common strategy, which was used by surgeons worldwide [3].

However, traditional open approaches and the endoscopic nasal approach have insurmountable limitations as they require either external incisions or continuously adjustable vision to expand the accessibly visible margins for surgery.

Furthermore, insufficient knowledge of the natural anatomy of the ITF adversely affects the control of critical nerves and vessels in surgery, resulting in irreversible comorbidities in the postoperative period, such as the paresthesia or disfunction of facial muscles. Therefore, a novel treatment strategy that has a minimally invasive approach and an effective clinical value is urgently needed. The purpose of this study is to investigate the natural anatomy of the ITF and to discuss the practicality of endoscopic transvestibular surgery for an ITF tumor.

## Materials and methods

This research was approved by the ethics committee and instrumental committee of Fudan University, and it was performed at the Anatomic Department of the Eye, Ear, Nose, and Throat Hospital, Fudan University. All the next to kin of the donators gave their consent for the storage and dissecting of the cadavers. Five fresh cadaveric specimens were prepared and injected with silicone through the internal carotid artery (ICA) and the internal jugular vein (IJV; red and blue color, respectively). The specimens were considered valuable if the small vessels of the tongue were fully perfused.

The cadaveric heads were fixed and positioned in the same manner as in thyroid surgery. A Crowe-Davis oral retractor (Storz, Heidelberg, Germany) was introduced to expand the visible margins of the oropharynx. The primary manipulator performed a two-handed operation while standing on the lower right side of the specimen, and a supporting frame (Storz, Heidelberg, Germany), substituted by an assistant if necessary, kept the telescopic endoscope in position.

A vertical incision along the ascending ramus of the mandible was performed from the lateral border of the third molar in the upper alveolar part to the mandibular coronoid process (MCP). After lateralization of the buccal muscle, the inferior alveolar nerve (IAN) was located in the anterior layer, and it crossed the endoscopic corridor obliquely. Further dissection identified the maxillary artery, as surrounded by the pterygoid plexus, which could be defined as the anatomic plane that divides the posterior layer from the anterior part. The lingual nerve, the eustachian tube, the middle meningeal artery, and the ICA were detected in the posterior layer until exposure of the skull base.

## Results

The specimens were carefully selected before the project, the quality of the cadaver could be guaranteed and the small vessels of the tongue were fully perfused, ensuring the availability of all the five specimens. During the dissection of cadaver, due to the difference between the specimens of skull size, degree of muscular development, the distance from the incision to anatomic key points were variable, and there was a little difference of the running of neurovascular structure. But the bony structures in the skull base were conservative and consistent between the specimens, and it was almost symmetrical between sides. All the pictures were gained from the same cadaver with ideal exposure of neurovascular structures.

### Surgical anatomy

As expected, the ITF was a deep and narrow space located in the inferolateral skull, as shown in Fig. 1. To avoid unnecessary removal of normal structures while keeping the working corridor effective, surgical margins of the ITF encompassed the region bordered anteromedially by the upper alveolar part and the maxillary tuberosity, superiorly by the sphenoid bone, medially by the buccal muscle and the adjoining superior pharyngeal constrictor muscle (SPCM), laterally by the medial fibers of the lateral pterygoid muscle (LPM), and inferiorly by fibers of the medial pterygoid muscle (MPM).

### Inferior alveolar nerve exposure

To provide a wide-open cavity for two-handed operation, a vertical incision on the buccal muscle was made from the lateral margin of the third molar of the upper alveolar part to the transverse level of the uvula, strictly along with the ascending ramus of the mandible and passing the MCP, as shown in Fig. 2a. The pterygomandibular raphe (PMR) was found to be a reliable reference line to distinguish the buccal muscle from the SPCM located posteromedially. Lateralization of the buccal muscle provided adequate exposure of the IAN, which was the first reliable structure for endoscopic identification. The IAN commonly crossed the visible field obliquely into the buccal muscle, followed by the inferior alveolar artery. The fibers of the MPM were further exposed along the inferolateral border of the operation (Fig. 2b).

### Maxillary artery handling

The anterior compartment of the ITF was filled with buccal fat pad, which obscured the optical cavity and necessarily needed partial dissection to enlarge the vision while preserving the natural facial appearance. After blunt dissection of the IAN and removal of fat pad, the lingual nerve was tracked by following it superior to the IAN, and it was commonly found to lie on the medial side of the inferior alveolar artery. The MPM terminated as tendons attached to the medial surface of the mandibular angle, as seen in Fig. 3a. Further dissection and lateralization of the MPM provided wide optical exposure of the pterygoid plexus, which was found to lie below the IAN and the related artery.
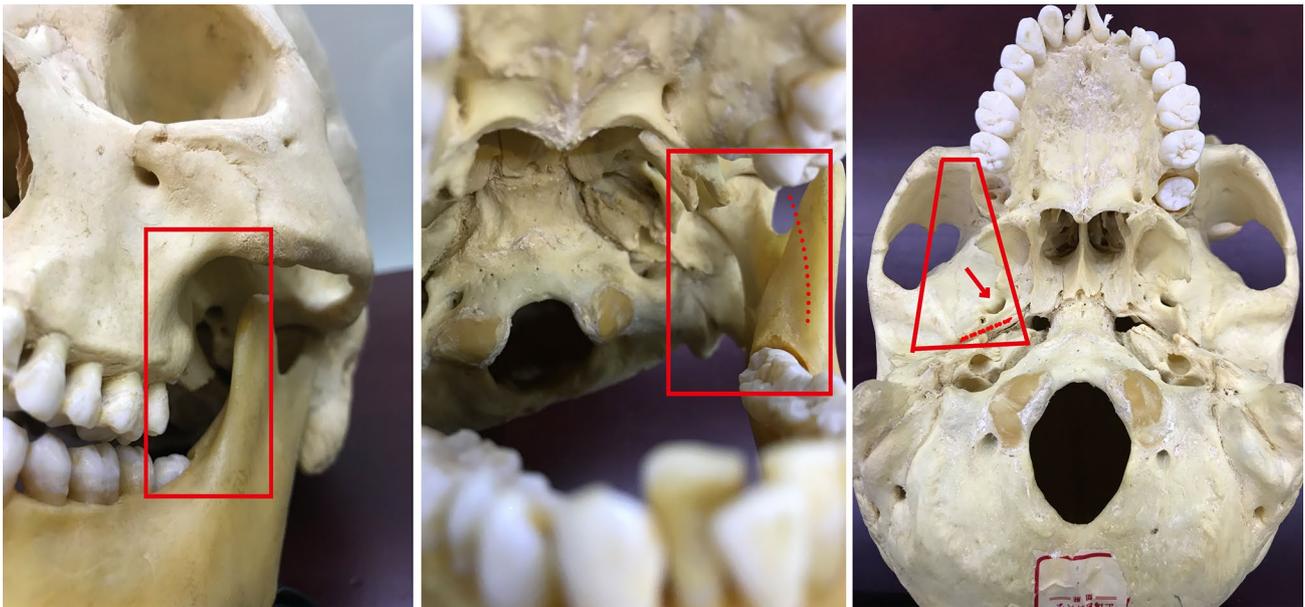
**Fig. 1** The figure on the left showed the bony outline of the Infratemporal fossa. The middle figure demonstrated the transvestibular vision of dissection. The incision is shown by the dotted line. In the figure on the right, the infratemporal fossa was identified by the trapezium, and the oramen ovale pointed by the arrow, the Eustachian tube groove in the dotted line

Morphologically, shaped like a vascular network covering the deep structures, we defined the pterygoid plexus as the demarcation plane that divided the anterior layer (marked mainly by the IAN) from the posterior layer (Fig. 3b). Accurate hemostasis was inevitably required for full resection of the pterygoid plexus as its variability and complexity limit the exposure of deeper neurovascular landmarks, as well as specific lesions in clinical surgery. Being surrounded by the pterygoid plexus, the maxillary artery was located relatively lateral to the IAN in the posterior layer (Fig. 3c). For preserving the integrity of the maxillary artery, careful dissection and continuous control of vessels were required throughout the procedure. By moving upwards, the origin of the inferior alveolar artery was visualized as the artery passing through the anterior layer with the IAN was actually the lingual branch of the inferior alveolar artery. However, the submental branch of the inferior alveolar artery passed through the MPM after a short course from branching of the maxillary artery (Fig. 3d).

### Skull base exposure

Adequate detachment of soft tissues in the posterior layer facilitated the exposure of the main trunk of neurovascular structures. With blunt dissection and lateralization of the maxillary artery, traffic branch of the cavernous sinus was described as the vascular net posterior to the pterygoid plexus, and it was defined as the landmark proximal to the skull base (Fig. 4a). The trajectory of the IAN was then followed to attempt localization of the mandibular nerve (V3) in the foramen ovale. After skeletonization of the skull base with full resection of the venous plexus, the course of the IAN was tracked from the anterosuperior direction towards the backside. Fibers of the MPM and tendons of the lower head of the LPM were found to form the respective borders of the safety corridor (Fig. 4b). The foramen ovale on the greater wing of the sphenoid bone was partly covered by the LPM. The mandibular nerve (V3) gave two main branches shortly after passing through the skull base, the anterior branch and the posterior branch, while the latter contained the IAN and the lingual nerve (Fig. 4c). Sphenoid spine is a bony protrusion on the sphenoid bone, and it lies lateral to the foramen ovale. It can be located easily, and it serves as the landmark superior to the foramen spinosum. By means of careful dissection backwards, the middle meningeal artery (MMA) was exposed while passing through the foramen spinosum into the cranial cavity (Fig. 4d).

### Internal carotid artery identification

As another bony reference point in the ITF, the lateral pterygoid plate was found to lie anatomically outside the eustachian tube. With blunt dissection backwards and adequate traction superior to the lingual nerve, posterior to the MMA, the ET was visualized as a cylindrical passway composed of cartilage and muscle (Fig. 5a). As the paramount artery in upper PPS and also ITF, further dissection of the posteromedial tissues exposed the C1 segment of the ICA, which
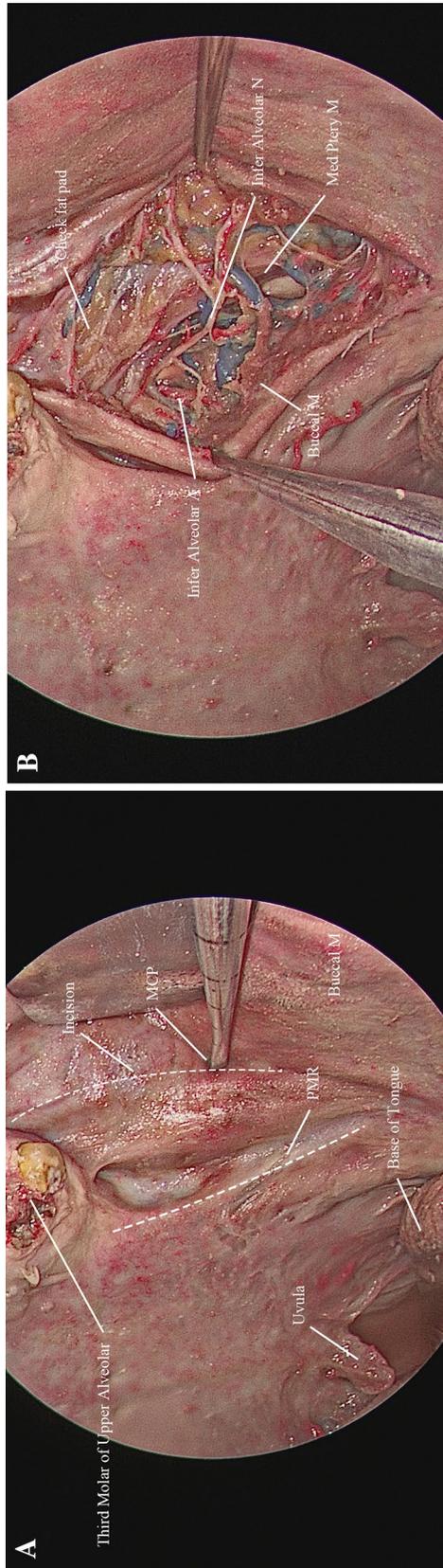
**Fig. 2** A vertical incision for exposure of the inferior alveolar nerve. **a** A vertical incision is made along the ascending ramus of the mandible. **b** The inferior alveolar nerve is exposed. *MCP* mandibular coronoid process, *PMR* pterygomandibular raphe

coursed between the main trunk of the mandibular nerve and the MMA and passed through the carotid canal just behind a generous soft tissue, as seen in Fig. 5b.

## Discussion

The ITF, due to its specific anatomic relationship with the temporomandibular structure, poses a formidable challenge for otolaryngologic surgeons, neurosurgeons, and stomatologists. The narrow working space and complicated neurovascular complex delimits the development of surgical treatment in this domain. Despite the outstanding contributions of Conley and Barbosa in the 1960s, intended to challenge the concept of treatment without surgery, more than 6 decades were required to achieve the goal of being able to completely remove ITF lesions with the expectation of minimal postoperative morbidity.

In the 1970s, surgery was performed using the retroauricular transmastoid approach. Fisch et al. classified and reported the approach with posterior auditory dissections after subtotal removal of the mastoid bone and facial nerve transposition, and a wide-open optical corridor was introduced for dissection of tumors in the ITF [4, 5]. However, several morbidities, such as jaw opening or mastication difficulty and transient facial nerve paralysis, commonly occurred during the hospitalization time period, which made the traditional surgical method aggressive and impractical. During the 1980s, the preauricular infratemporal approach was further optimized for the treatment of lateral skull base lesions involving the ITF [6]. Regardless of the ideal exposure of basicranial tumors, postoperative comorbidities such as cosmetic deformities due to the vertical long incision, and cranial nerve injury caused by aggressive manipulations during surgery, as well as temporomandibular joint (TMJ) ankylosis, pose challenges to the surgeons. In the following decades, other approaches, such as the transoral, transmandibular, and several combined operations, were developed by surgeons worldwide [7, 8]. These approaches provided shorter and wider surgical corridors to the pathological mass with continuous control of critical vessels, but they still failed to overcome the common deficiencies, resulting from the need for sacrificing the normal function and anatomy, which included cranial nerve injury, impaired masticatory function, trismus, and cosmetic deformity.

The introduction of endoscopy into otolaryngologic surgery facilitated the exposure of targeted lesions due to its inherent strength in manipulating inside the deep and narrow cavities, typically in the nasal cavity and sinus. The transnasal approach to handle lesions in ITF was a typically successful application of endoscopy. Regardless of the removal of unrelated structures and influence of normal nasal function, this strategy could increase the surgical safety while
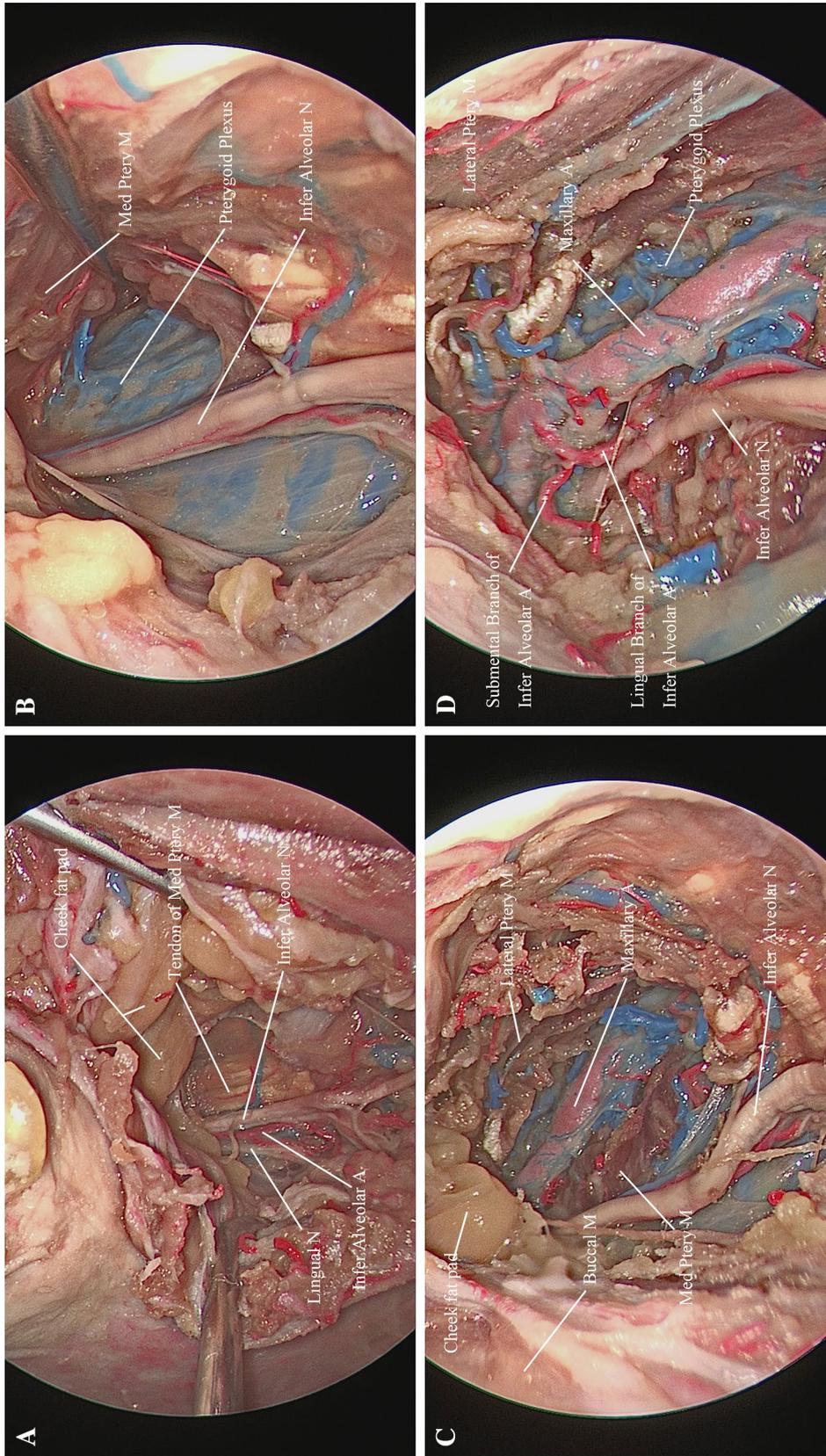
**Fig. 3** Handling the maxillary artery and the pterygoid plexus. **a** The inferior alveolar artery and the pterygoid plexus. **b** The inferior alveolar artery and the lingual nerve. **c** Exposure of the maxillary artery. **d** The origin of the inferior alveolar artery
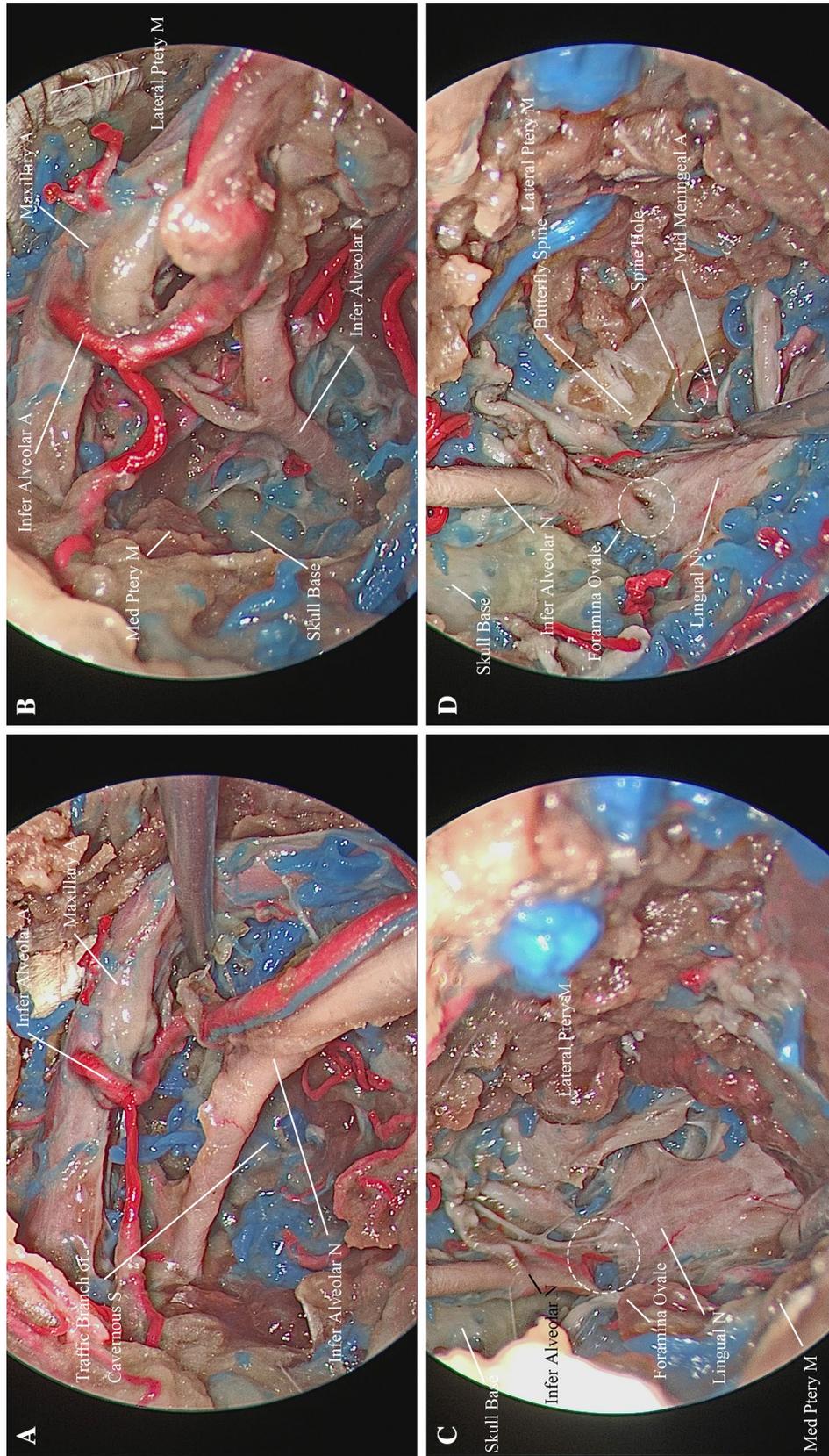
**Fig. 4** Exposure of the neurovascular structures in the skull base. **a** Traffic branch of the cavernous sinus. **b** Tracking of the inferior alveolar nerve. **c** Mandibular nerve (V3) in foramen ovale. **d** Location of the middle meningeal artery
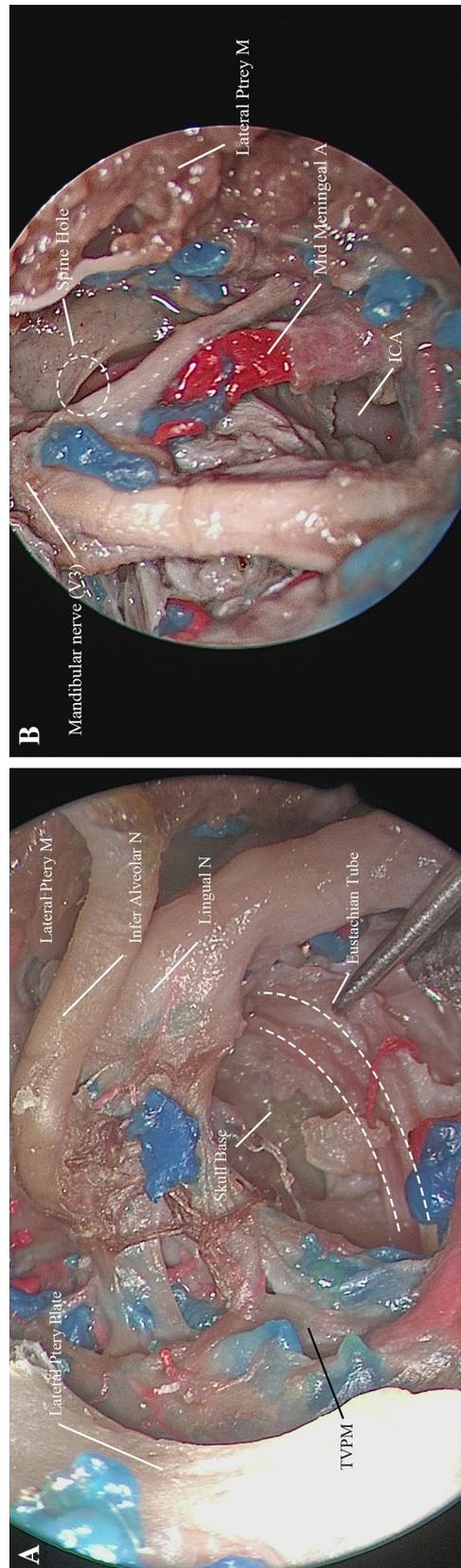
**Fig. 5** Identification of the C1 segment of the internal carotid artery. **a** Exposure of the eustachian tube. **b** Exposure of the C1 segment of the internal carotid artery. *ICA* internal carotid artery

reducing the operative time. Also, the extended application of video-assisted technologies in ITF- and parapharyngeal space (PPS)-related surgeries was reported to be feasible and facile in exploring this difficult to access region [9]. Chan et al. first described this surgical corridor to manage the middle cranial base in four cadavers, which was described to offers direct and minimally invasive access to lesions in PPS and ITF [10]. After that, further investigations of the approach in clinical practice were made by otolaryngologic surgeons worldwide, and recently Torres-Gaya et al. has reported a case of ITF schwanoma treated with the trans-vestibular endoscopic approach and received encouraging outcome [11].

The IAN is the first reliable structure that is identified in the ITF. Integral exposure of the IAN is of paramount importance for further tracking of the lingual nerve (Fig. 3a), and it serves as a key landmark preventing the lost in the deep region of the ITF. Based on our experience, a strictly superficial incision along the inner face of the ascending ramus of the mandible with a precise anatomic layer is critical in the beginning of surgery (Fig. 2) and the IAN can be continuously tracked until exposure of the mandibular nerve (V3) in foramen ovale (Fig. 4d).

Despite the intra- or extra-surgical approaches chosen for treatment strategies, the maxillary artery is inevitably encountered, and it needs careful handling during the operation. The maxillary artery originates from the external carotid artery proximal to the mandibular ramus, and it branches off the main vessels as the inferior alveolar artery, the MMA, the descending palatine artery, the sphenopalatine artery, and the infraorbital artery during its trajectory into the pterygopalatine fossa [12]. Defined as the second segment of all the three parts below the lateral skull base, the main trunk of the maxillary artery, together with the inferior alveolar artery and the MMA, can be consistently located between the MPM and the LPM in the ITF (Figs. 3c, d, 4a, b). Therefore, we strongly underline the importance of careful dissection and effective hemostasis of the maxillary artery and surrounding vessels in this layer to ensure a bloodless surgical field, with the use of hemostatic agents, bipolar coagulation, and other assistive measures.

The medial pterygoid muscle, as running from the fossae pterygoidea to pterygoid tubercles, is a "watershed" during the dissection. In the beginning of exposing the working corridor, fibers of the MPM provided the inferior border to locate the IAN and the inferior alveolar artery. And in the view of the critical function of the ascending pharyngeal artery and palatine artery to support the pharyngeal muscle groups and oropharynx, careful protection of them can reduce the clinical complications after surgery. According to our personal experience, clearly shaping and following of MPM to perform further dissection laterally was paramount. While in the deeper layer of dissection, MPM separated

the lateral ITF from the relatively inferior PPS, served as the border to select the suitable corridor for exposing the lesions. The lateral pterygoid muscle also serves as the key endoscopic reference point in the lateral layer of the ITF. The inferior head of the LPM originates from the lateral pterygoid plate, and along with the upper head from the greater wing of the sphenoid bone, it ends in the temporomandibular joint (Fig. 5a). As described above, the maxillary artery generally lies medial to the LPM. We personally suggest that there is a need to perform manipulation with lateralization of the LPM. Moreover, the butterfly spine on the sphenoid bone exposed by transposition of the LPM can provide a clue for the location of the underlying foramen ovale.

Notably, the transnasal approach had been acknowledged as a typical and effective method to deal with lesions in ITF [13, 14]. The transnasal approach provides a corridor from inferomedial to superiolateral. For the fully exposing of ITF, a working window should be made on the anterior wall of maxillary sinus, and the posterolateral wall need also be removed by micro-grinding drill. The sphenopalatine artery and pterygoid canal nerve need be sacrificed to assure the bloodless and clear corridor for further dissection. The internal maxillary artery can be exposed after the removal of fat and soft tissue in pterygopalatine fossa and ITF. Then the LPM comes into light as the lateral border of ITF, and the dissection of it from the lateral pterygoid plate can help to reveal the middle cranial fossa base. With drilling the lateral pterygoid plate and the greater wing of sphenoid bone, the MMA and the sphenoid spine can be located posteriorly. While the sphenoid spine can serve as the landmark to expose the parapharyngeal segment of ICA inferiorly. In common, with angled endoscopy, it provided more feasible vision of the large or high-position lesions than the transvestibular approach. Comparing to the transnasal approach, our working corridor provides the exposure of ITF from inferiolateral to superoinferior, and prevents the handling of bony structures, such as the greater wing of sphenoid bone. The middle cranial fossa base can be reached with the detachment of soft tissue and dissection of MPM and LPM, which is a remarkable advantage to reduce unnecessary injury in clinical practice.

However, regardless of the versatile exposure of lesions and simplified identification of landmarks in the ITF, the endoscopic transvestibular approach has some deficiencies that have been encountered in our anatomic study and other reports. First, the skull base area is still distant from the incision in oral mucosa, regardless of the direct working corridor provided by transvestibular approach. And the inevitable lateralization or removal of ET may be relative with the post-surgical complication. A combined strategy with transnasal approach may be considered to handle with huge mass in ITF or closely relevant to skull base. Second, uncontrollable

hemorrhage should be highly emphasized as a disastrous complication during surgery. As a deep and narrow working corridor, the endoscopic approach provides a view that can be easily obscured by continuous bleeding. Therefore, practical ways of securing strict hemostasis are needed for further development of this approach. Third, it is controversial about the integrity and flexibility of transvestibular endoscopic vision. Kuet et al. underlined the concerns of intra-surgical tumor rupture and incomplete removal of lesion mass after reviewing 1293 reported cases [15]. During the operation of malignant tumors, the natural border of lesions is obscured and accurate resection of tumors without disturbing the normal structures becomes impractical. However, benign pathologies, such as the majority of tumors in the ITF, commonly contain a pseudocapsule, and the tumor bed itself can create a working corridor for surgery, which facilitates complete removal of the tumor [16].

Above all, the endoscopic transvestibular approach is extremely positive as a minimally invasive surgery strategy. With more work to establish the utility and safety of the approach in clinical practice, this method may serve as a prospective, minimally invasive surgical strategy in the near future.

## Conclusion

Surgery is the mainstay for the treatment of tumors in the ITF. With anatomic practice on cadavers through the endoscopic transvestibular approach to expose the ITF, the IAN, the maxillary artery, and the lateral pterygoid muscle can serve as the key landmarks. More practice and technologies are required in the future for refining the surgical strategy for clinical treatment.

## Compliance with ethical standards

**Conflict of interest** There is no financial relationship and conflict of interest among all authors.

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