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Technical Note

Endoscopically Assisted Exoscopic Surgery for Microvascular Decompression of the Trigeminal Nerve with Intraoperative Use of Indocyanine Green

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Abstract: Trigeminal neuralgia (TN) is a chronic condition that is typically caused by a blood vessel exerting pressure on the V cranial nerve at the root entry zone. The gold standard for TN treatment is microvascular decompression (MVD). This illustrative case shows an advanced surgical technique that combines the use of an exoscope and endoscope to treat TN with an innovative addition of intraoperative indocyanine green (ICG) control that can improve arterial and venous compression identification. The use of exoscopes and endoscopes, offering 360° root assessment, represents a significant evolution in surgical approaches. Enhanced visualization with ICG aided in identifying complex neurovascular conflicts, improving decompression accuracy. The use of both exoscope and endoscope, offering a 360° root assessment, represents a significant evolution in the microsurgical approach of TN. The additional use of ICG monitoring in a dynamic mode may be useful in identifying the complex arteriovenous form of neurovascular conflict. The endoscopically assisted exoscopic surgery with the intraoperative use of ICG for MVD of the trigeminal nerve can improve the identification of complex impingements underlining its effectiveness and potential in neurosurgical practice.

Keywords: 3D; exoscope; endoscopic assistance; trigeminal neuralgia; neurosurgery; intraoperative indocyanine green; ICG control; neurovascular conflict

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1. Introduction

Trigeminal neuralgia (TN) is a chronic condition that can cause sudden, intense painful episodes, typically on one particular side of your face, which can disrupt daily activities. The TN is typically caused by a blood vessel exerting pressure on the V cranial nerve at the root entry zone [1]. In world neurosurgical practice, the gold standard for the treatment of TN is the microvascular decompression (MVD) of the trigeminal nerve root entry zone, first performed by Gardner and Míelos in 1959 and popularized by Jannetta in 1967 [2]. The concept of pathogenetic treatment of neurovascular conflict (NVC) through an MVD is still relevant today [3]. However, despite the accumulated experience of surgical treatment of NVC in world neurosurgical practice, in 33% of cases, decompression happens to be incomplete, and patients experience severe pain in the postoperative period [4]. Historically, the most important tool in the neurosurgical practice is the microscope. Nowadays, a modern alternative to the microscope is the exoscope, which is a high-resolution stereoscopic three-dimensional visualization system with an integrated zoom function and image focusing for visualization of the surgical field [5].

High resolution and magnification of 3D images allow you to clearly identify the deep anatomical structures of the narrow corridor of the cerebellopontine angle and carry out safe dissection with an ergonomic position of the surgeon's hands [6,7]. Due to the anatomical variations of the NVC, there is a need for a 360° intraoperative evaluation of the trigeminal nerve root, which can be performed using endoscopic assistance. In order to prevent incomplete decompression of the trigeminal nerve, optical devices are currently being improved, and exoscopes and endoscopes are being developed that allow surgical 360° dissection in 3D mode with maximum magnification of anatomical structures [8]. The possibility of combined use of an exoscope and an endoscope is described by some authors, who note that this ensures safe decompression, prevents additional traction of the cerebellum, unnecessary coagulation of the superior petrosal vein (SPV), and incomplete MVD [8,9].

Objective of the Study

In this paper, in addition to the use of the exoscope with endoscopic assistance, the authors describe the advantageous use of an intraoperative indocyanine green video angiography (ICG VA). In our opinion, intraoperative ICG control can be a good addition for the verification of arterial or venous compression, as well as a tool for detecting hidden conflicts.

2. Illustrative Case

A 42-year-old man presented at the Tyumen Federal Centre with debilitating complaints characteristic of trigeminal neuralgia, specifically targeting the innervation zones of the second and third branches of the left trigeminal nerve. The episodes he experienced were acute, manifesting as shooting pains lasting between 15 to 30 s, a hallmark of this neuropathic disorder. The intensity and nature of these attacks underscored a severe quality of life impairment, as evidenced by his pain scoring a maximum of 10 points on the Visual Analog Scale (VAS) and being classified as level V on the Barrow Neurological Institute (BNI) pain intensity scale, indicating extreme, life-altering discomfort. Notably, the patient's condition proved refractory to pharmacological interventions, with high-dose carbamazepine therapy at 1800 mg/day failing to ameliorate his symptoms. This drug resistance posed a significant challenge, steering the treatment approach towards surgical intervention. Neurological examination did not reveal any pathological changes, which is often the case in trigeminal neuralgia where physical examination results can be normal despite severe pain.

Advanced neuroimaging techniques were instrumental in delineating the anatomical basis of the patient's condition. With the help of the FIESTA (Fast Imaging Employing Steady-state Acquisition) magnetic resonance imaging (MRI) mode and multiplanar reconstruction of the CISS_3D (Constructive Interference in Steady State) sequence, a detailed visualization was achieved. This imaging elucidated a neurovascular conflict (NVC) at the root of the left trigeminal nerve (LTRN), involving the aberrant anatomical juxtaposition with the left superior cerebellar artery (SCA) and the anterior inferior cerebellar artery (AICA), along with sections of the superior petrosal vein (SPV) (Figure 1A,B). Such detailed imaging not only confirmed the diagnosis of trigeminal neuralgia due to vascular compression but also guided the surgical strategy. In response to the diagnostic findings and the patient's drug-resistant pain, the decision was made to proceed with microvascular decompression (MVD) surgery, a procedure renowned for its efficacy in resolving trigeminal neuralgia stemming from neurovascular conflicts. This surgery was innovatively performed using an exoscope with endoscopic assistance, a decision reflecting a commitment to employing advanced surgical technologies to enhance operative precision and outcomes. The incorporation of Indocyanine Green (ICG) fluorescence angiography during the procedure further exemplifies the cutting-edge approach, allowing real-time visualization of blood flow and vessel architecture to ensure the effective decompression of the trigeminal nerve without compromising vascular integrity.

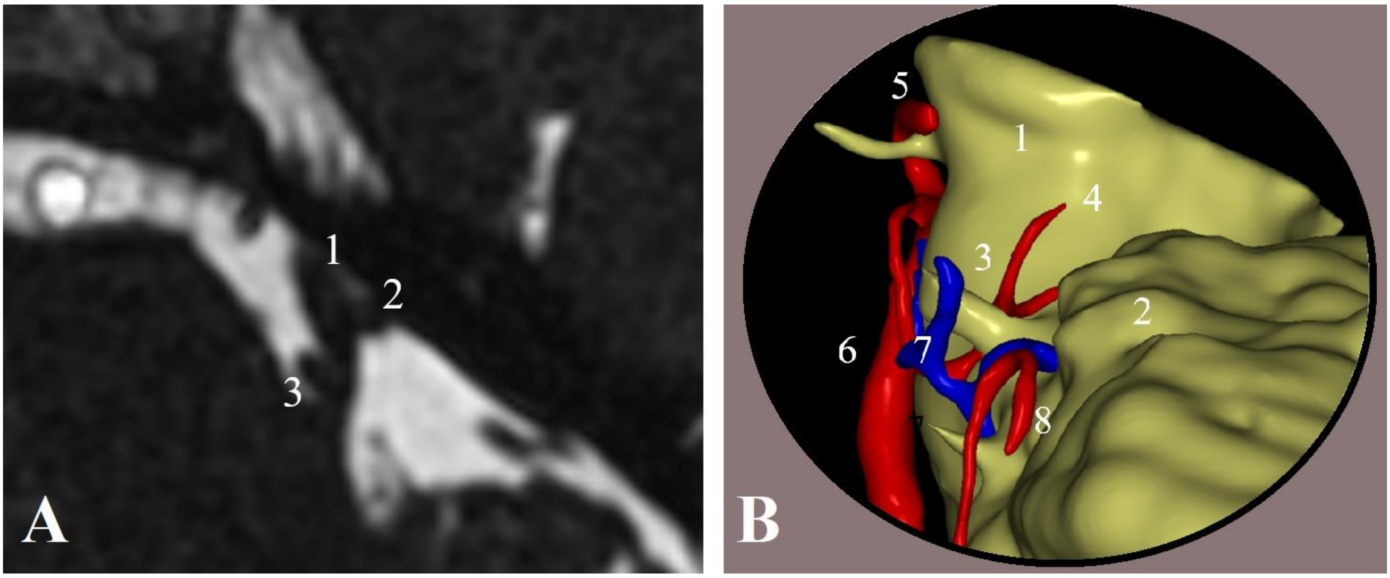

Figure 1. (**A**) MRI tomography of the brain in FIESTA mode, with multiplanar reconstruction of the CISS_3D sequence, visualizes the contact of the left trigeminal nerve root with the SCA loop along the internal contour of the nerve, with its deformation and volume reduction. 1—left trigeminal nerve root; 2—superior petrous vein; 3—superior cerebellar artery loop. (**B**) 3D simulation of endoscopic assistance 360° of NVC of the left cerebellar angle. 1—brainstem; 2—cerebellum; 3—root of the left trigeminal nerve; 4—loop of the superior cerebellar artery; 5—posterior cerebral artery; 6—basirar artery; 7—superior petrous vein; 8—loop of the anterior cerebellar artery.

2.1. Operation Technique

Exoscopic and endoscopic stands were installed on the contralateral site to access in order to broadcast the surgical field from two monitor screens (Figure 2A). A VITOM® 3D (Karl Storz) exoscope was positioned using a pneumatic holder in such a way that the surgical field was not blocked and direct visualization was maintained. A special IMAGE1 PILOT control unit was attached to the table in such a way that the surgeon or assistant had ergonomic access to it. The operation was performed with the patient lying on his back with the head turned to the contralateral side by 70°.

Under exoscopic view, anatomical landmarks were marked for performing a retrosigmoid craniotomy. Lateral to the projection of the sigmoid sinus, a linear soft tissue incision 4 cm long was made, where 1/3 of the incision line was located above the asterion point, and 2/3 below. Next, a craniotome was used to drill a bone flap with a diameter of 3 cm. The cortical section of the bone in the projection of the mastoid cells was drilled with a burr to the inner cortical layer, then the bone flap was detached. The dura mater was opened using a horseshoe-shaped incision. Brain relaxation was achieved by opening the cerebellopontine cistern. When adequate relaxation of the cerebellar hemisphere was achieved, the approach was made to the cerebellopontine angle (CPA), then primary dissection of this area was performed to create sufficient space for safe insertion of the endoscope into the area of interest (Figure 3A). During the initial exoscopic dissection, a partial contact of the trigeminal nerve with the SPV was visualized on the dorsal surface of the LTRN, which ran directly under the dura mater and drained into the superior petrosal sinus. Also in the upper part of the dorsal portion of the LTRN, the SCA loop was visualized.

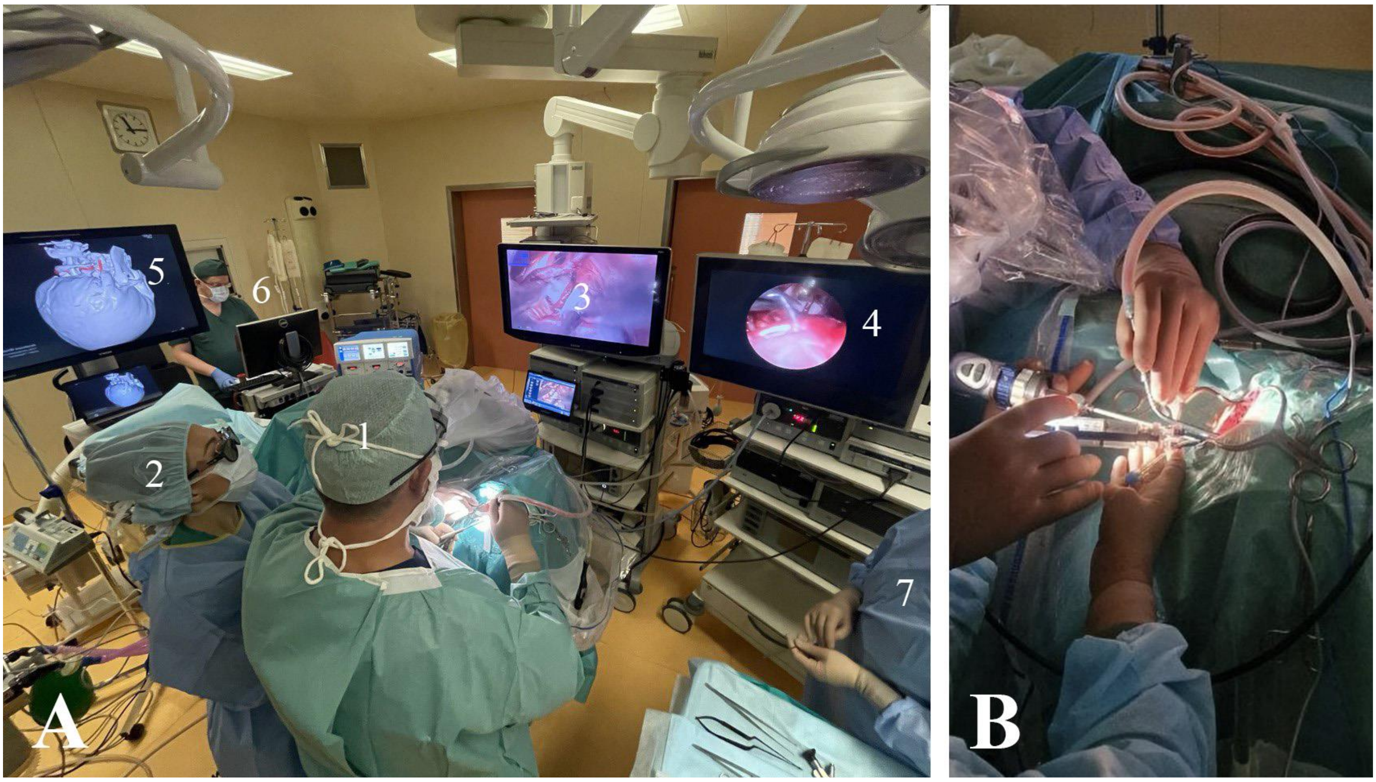

Figure 2. (**A**) General view of the operating room arrangement for microvascular decompression under the control of the VITOM 3D KARL STORZ exoscope. 1—surgeon; 2—assistant; 3—the intraoperative exoscopic view; 4—the intraoperative endoscopic view; 5—preoperative Inobitec 3D model; 6—intraoperativeneurophysiological control; 7—operative nurse. (**B**) Bimanual surgical technique.

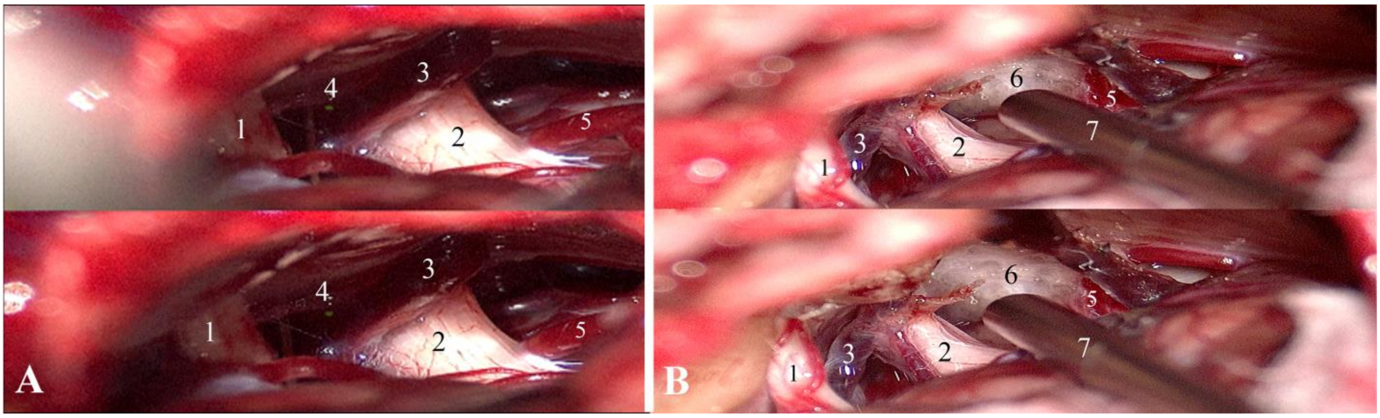

Figure 3. Exoscopic view of the surgical field in 3D format. (**A**) Exoscopic view of anatomical structures of the cerebello-pontine angle. (**B**) Exoscopically controlled guidance of the endoscope. 1—VII/VIII CN pairs; 2—V CN pair; 3—Superior petrosal vein; 4—projection of the drainage of the superior petrosal vein into the superior petrous sinus, 5—SCA; 6—Teflon pad; 7—Endoscope.

In order to determine the extent and degree of contact of the SCA with the LTRN, a Karl Storz video endoscope with a diameter of 4 mm and an angle view of 30° was used in combination with ICG control (Video S1, Supplementary Materials). The endoscope was installed in the target zone under the control of the exoscope without creating traction of adjacent anatomical structures so that its position did not interfere with the operation of microsurgical instruments during dissection. Using the video endoscope, an additional compressing vessel (a branch of the AICA in the prepontine region) was identified. In addition, a loop of the SCA with extensive compression of the ventral surface of the LTRN was present (Figure 4A–C).

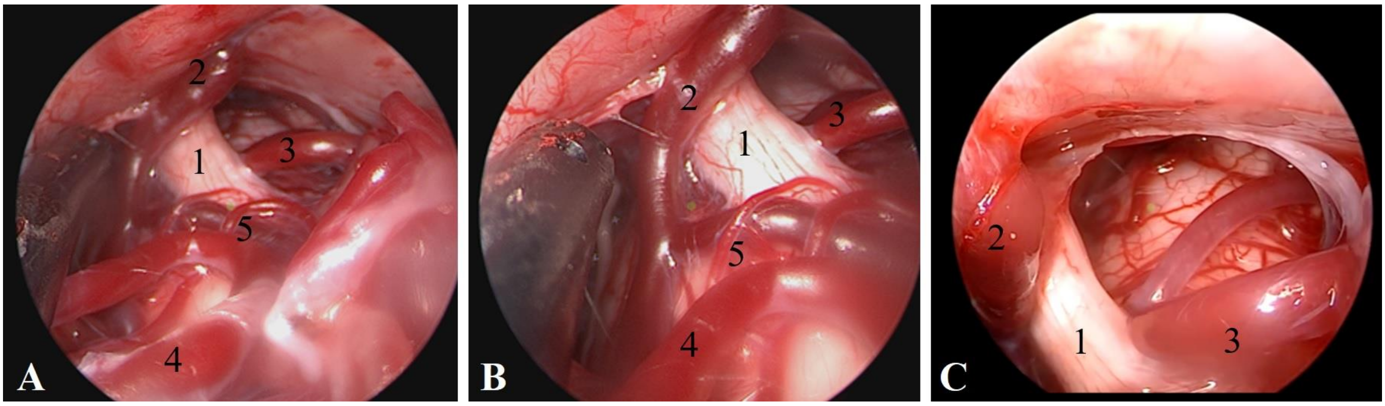

Figure 4. Endoscopic picture of the surgical field. (**A**) 1—V CN pairs; 2—superior petrous vein; 3—the loop of the superior cerebellar artery; 4—the loop of the anterior inferior cerebellar artery. 5—the branches of the anterior inferior cerebellar artery. (**B**) 1—V CN pairs; 2—superior petrous vein; 3—the loop of the superior cerebellar artery; 4—the loop of the anterior inferior cerebellar artery; 5—the branches of the anterior inferior cerebellar artery. (**C**) 1—V CN pairs; 2—superior petrous vein; 3—the loop of the superior cerebellar artery.

In order to verify hidden areas of NVC, intraoperative ICG control was additionally performed. ICG monitoring during NVC in dynamic mode allows to differentiate arterial and venous compression of the nerve (Figure 5A–C). ICG in this case was useful in confirming the complex arteriovenous form of NVC.

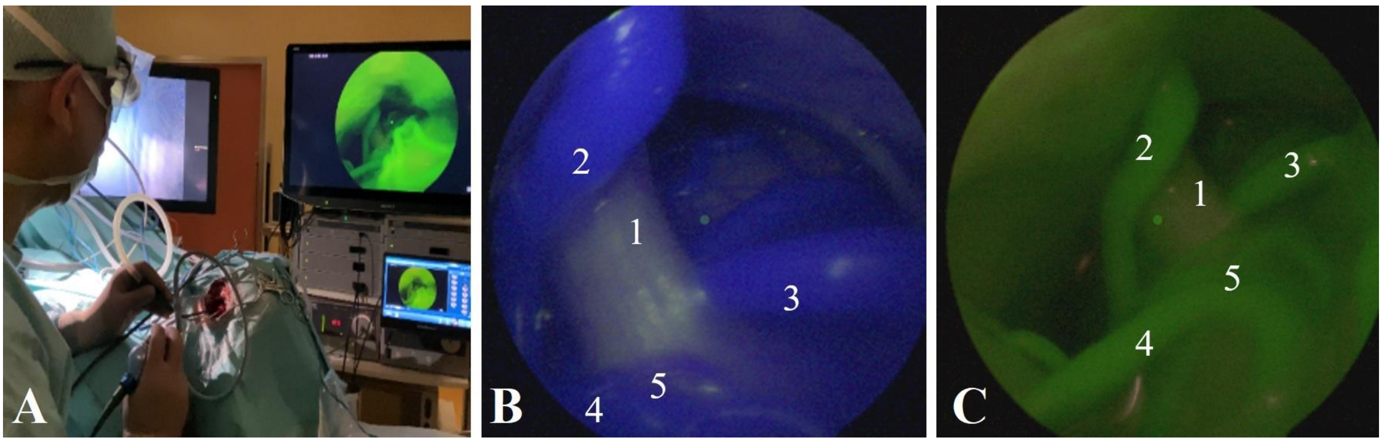

Figure 5. (**A**) Intraoperative ICG control. (**B**) Intraoperative ICG control with blu/yellow lenses in endoscopic view. 1—V CN pairs; 2—Superior petrosal vein; 3—the loop of the superior cerebellar artery; 4—the loop of the anterior inferior cerebellar artery. 5—the branches of the anterior inferior cerebellar artery. (**C**) Intraoperative ICG control with yellow lenses in endoscopic view. 1—V CN pairs; 2—Superior petrosal vein; 3—the loop of the superior cerebellar artery; 4—the loop of the anterior inferior cerebellar artery. 5—the branches of the anterior inferior cerebellar artery.

Then, under the combined control of both the exoscope and endoscope, the compressing artery was mobilized, followed by the installation of a Teflon pad in the upper surface of the LTRN in order to isolate the LTRN from the SCA loop. Next, an additional Teflon pad was installed on the lower surface of the LTRN in order to isolate the trunk from the adjacent SPV and the AICA loop. The Teflon pad was fixed using fibrin sealant (Figure 3B). During surgery, continuous intraoperative monitoring of the trigeminal, facial, and auditory nerves, as well as the caudal group of nerves was carried out. There was no intraoperative decrease in bioelectrical responses.

The closure is performed under an exoscopic view in a standard manner. No postoperative complications were reported, and the patient noted a complete regression of the pain syndrome: VAS scale 0 points and BNI scale I. The patient was discharged on the 4th day after surgical treatment. The procedure aims to reduce risks associated with traditional MVD methods. Strategies include minimizing potential nerve damage, reducing postoperative discomfort, and facilitating a faster recovery.

2.2. Patient Consent and Data Protection

Approval from the Ethics Committee of the Federal Centre of Neurosurgery in Tyumen, Russian Federation, was secured, affirming the study's adherence to ethical standards in medical research. This included ensuring that all research practices were conducted with the highest level of integrity, transparency, and respect for the rights and well-being of the patients involved.

3. Discussion

Today, the gold standard in the treatment of trigeminal neuralgia associated with neurovascular conflict (NVC) is neurovascular decompression [1,10,11]. The effectiveness of this treatment method is widely reported in the world literature; a recent meta-analysis by Katherine Holste et al., including data from 3897 patients from 46 studies, demonstrated an analgesic result from surgical treatment in 76.0% of cases [10].

The main predictor of pain reduction in the postoperative period is intraoperative visualization of compressing vessels, and their safe dissection and repositioning. Over a long period of time, this surgical treatment was performed using a microscope and demonstrated good effectiveness. New opportunities in the treatment of trigeminal neuralgia opened up with the introduction of the exoscope [12]. The last decades have been focused on improving optical devices and robotic technologies that allow surgical treatment in 3D mode with maximum magnification [13]. The beginning of the 3D era in the field of neurosurgery is associated with the advent of the exoscope [14]. High-resolution 3D visualization of anatomical structures, together with intraoperative neuronavigation and neuroimaging, allows the neurosurgeon to select the trajectory as accurately as possible and ensure safe work in the target zone, reducing the risks of developing postoperative complications [7,15,16]. There are a few studies in the literature devoted to the use of an exoscope during MVD [7]. Toda et al. [7], in a video article using several illustrative clinical cases out of 159 studied ones, highlight the advantages of 3D ultra-high definition exoscope imaging for identifying and analyzing neurovascular conflict during MVD. Herta and coauthors [6] demonstrated the advantages and disadvantages of using a three-dimensional (3D) exoscope in a retrospective MVD case series of eight patients with trigeminal neuralgia. The authors describe the advantages of using an exoscope which lie in satisfactory optical quality, the ability to visualize deep structures, and ergonomics for the surgical team. Disadvantages of its use are revealed in overexposure at deep surgical sites and the difficulty of integrating the endoscope.

A comparative analysis of the exoscope and the microscope during MIA is described by Hashikata et al. [17]. According to this publication, the functional performance of the exoscope is superior to that of the microscope ($p < 0.001$). Surgeons described the ease of the use of the exoscope as the absence of the need for manual maneuvering, the ease of manipulation of the exoscope, and the reduction in physical activity and stress due to the ergonomic positioning of the surgeon's torso. Despite the advantages of the exoscope, the authors describe no statistical difference in terms of MVD timing and MVD outcomes [17]. However, despite the surgical and ergonomic advantages of the use of the exoscope, there are some disadvantages associated with limited illumination and pixelation during the work in deep and narrow surgical corridors, as well as the impossibility of assessing neurovascular structures with the 360° view during the surgical procedure. Therefore, due to the narrowness of the anatomical corridor of the CPA, when performing an exoscopic vascular decompression for TN, the need for additional traction of the cerebellum and the risk of damage to adjacent structures, including the SPV, increases. According to the literature, injury to the SPV may be associated with hearing loss, facial anesthesia, Lhermitte's syndrome, and cerebellar edema [18].

Moreover, the lack of 360° exoscopic assessment of the trigeminal nerve root hinders the intraoperative search for adjacent vessels and increases the risk of inadequate decompression, especially in cases of the variant vascular anatomy of the CPA [19].

Klun and colleagues [20], in a cadaver study of 65 heads, described the frequency of occurrence of variants of the trigeminal nerve root arterial compression, where in 53.8% the cause of compression was the SCA, in 25.6% the AICA, in 20.6% the pontine branches of the basilar artery. In turn, Rusu and co-authors [21] in their study noted the possibility of division of the SCA into medial and lateral branches, and also demonstrated options for the contact of the branches of the SCA and AICA to the trigeminal nerve root, or transient passage between the roots of the trigeminal nerve. Fu et al. [22] in 2015 described a clinical case of a rare cause of trigeminal neuralgia resulting from the primitive trigeminal artery, whereas Shulev et al. [23] described in their work NLE caused by vertebrobasilar dolichoectasia.

Considering the anatomical variations of the CPA, the 360° visualization of the anatomical and topographic relationship of the compressing vessel and the trigeminal nerve root is important for the total resolution of the NVC. Intraoperative visualization of 360° opens up with the use of an endoscope [24]. Fully endoscopic microvascular decompression was first described in 2001 by J B Eby et al. [25].

According to the literature, the postoperative results of the solo use of an endoscope in comparison with the standard microsurgical approach do not differ significantly [26,27]. Zagzoog et al. [28] reported a positive effect in the form of pain reduction in 81% after traditional intervention and 88% after endoscopic intervention. The relapse rate in the endoscopic treatment group was 5% lower, while complications such as postoperative CSF leak were similar [28]. Peng et al. [29] in 2023 described the following benefits of complete endoscopic treatment, which can be resumed in 4 points: (1) the different angles of the endoscope lens and the controlled depth of penetration of the endoscope provide a panoramic view of the cerebellopontine angle with 360° assessment of the neurovascular conflict and avoiding the blind spots of traditional microscopy; (2) endoscopic visualization allows protector installation under direct visual control with circumferential positioning verification; (3) endoscopic decompression is possible without grinding away the petrosal tubercle; and (4) endoscope allows to assess the reliability of the installation of the protector after filling the cerebellopontine angle with cerebrospinal fluid.

In addition, the advantages of endoscopic surgery are described in the article by Hongpeng Guan et al., wherein the treatment of 95 patients with the classic variant of TN, 97.9% of patients achieved complete pain relief (score I on the BNI scale) [30]. Despite the advantages of endoscopy, a number of authors describe clinical cases of complications of this treatment method. Wang et al. [31] reported a complication in the form of supratentorial subdural hematoma. Pak et al. [32] described a clinical case of endoscopic decompression, where a complication arose in the form of damage to the vestibulocochlear nerve as a result of stretching the nerve with forceps when inserting a Teflon protector. Amitesh Dubey et al. describe cases of facial nerve injury and postoperative prosoparesis [9]. The whole range of complications is associated with the presence of blind spots in the endoscopic lens. The movement of instruments around the tip of the endoscope, as well as the introduction of instruments into the area visualized by the endoscope, is not visualized, which leads to a potential risk of damage to adjacent neurovascular structures.

Leveling this aspect is carried out using a combined approach. Sachiko Hirata et al. in 2023 retrospectively analyzed 109 patients who underwent endoscope-assisted microvascular decompression. Endoscopic assistance was considered useful in clinical cases of anatomically complex vessels (bifurcation or severe tortuosity) that were visualized in preoperative MR images ($p < 0.005$) [33]. Increasing the effectiveness and safety of surgical treatment using endoscopic assistance was also described by Ming Zhi et al. in the aspect of surgical treatment of hemifacial spasms. Specifically, patients with small posterior fossa volume, abnormal fullness of the cerebellar flocculus, petrosal block, local thickening of the arachnoid commissures, and unidentified offending vessels [34].

Clinical confirmation of the need for 360° assessment of the neurovascular structures of the CPA is described in the literature with the example of endoscope-assisted microscopic vascular decompression. Bohman [35] in his article described 39 cases of ventral localization of the compressing vessel, which in the absence of adequate endoscopic visualization would have led to incomplete regression of clinical symptoms. Jarrahy et al. [36] identified 25% of inadequate MVDs with endoscopic assistance, whereas in 14 out of 51 (28%) cases, adjacent vessels were identified only by endoscopy. In his work, Teo [4] reported a 33% probability of inadequate or negative MVD in the absence of intraoperative endoscopic assistance. Patel et al. [2] used endoscopic assistance in 11 of 17 cases, reporting that the endoscope is useful for hemostasis of the veins in the distal part of the trigeminal nerve in the projection of Meckel's cavity.

Thus, the combined use of a microscope and an endoscope provides a 360° assessment of the NVC and contributes to a more complete decompression. It is necessary to visualize the advancement of the endoscope, and simultaneous control of the micro- and endoscopic images, which is not ergonomic when using a microscope and an endoscope, as far as controlling the immersion of the endoscope it is necessary to defocus the vision on the micro- and endoscopic images. The absence of a free visual axis due to the bulky size of the microscope makes it necessary to switch vision and can lead to destabilization of the position of the surgeon's hands, which when working in the narrow anatomical corridor of the CPA, may lead to fatal complications.

The risk of complications can be reduced when using an exoscope with endoscopic assistance since the free visual axis in front of the monitors ensures simultaneous visualization of the exoscopic and endoscopic parts of the surgical field and facilitates safe immersion of the endoscope without additional movements and visual strain. The use of monitors allows the surgeon and his assistant to better integrate the workflow, freely maneuvering in the area of interest. The assistant can guide the endoscope, and adjust the focus and the zoom so that the surgeon can continue the operation from the most appropriate angle without interrupting the bimanual surgical technique (Figure 2B). In addition, while using endoscopic assistance, the main surgeon remains in the same position, which ensures high ergonomics of work without overstraining the muscles of the cervical spine. In addition to ensuring optimal ergonomics of the working environment, the combined use of an exoscope and an endoscope with the broadcast on two monitors allows the entire operating team and the residents to obtain a high-quality image of the entire course of the surgical procedure.

In this clinical case, we demonstrated the positive aspects of using an endoscopically assisted exoscopic surgery with an ICG control. Thus, according to the intraoperative exoscopic picture, contact of TN with the SPV and superior contact with the SCA loop was visualized on the dorsal surface; during endoscopic control, the extent of contact of the SCA loop was assessed in more detail, and the AICA loop was identified. The additional use of ICG monitoring in dynamic mode in this clinical case was useful in confirming the complex arteriovenous form of NVC. The technology of intraoperative contrasting of cerebral vessels using fluorescent agents in neurosurgery was first demonstrated by Feindel et al. in 1967 [37]. This technology is based on the fluorescent emission of indocyanine green, detected in the process of spectral decomposition in the near-infrared region of the spectrum. Today, ICG intraoperative control is widely used in neurosurgical practice [38,39].

The integration of endoscopically assisted exoscopic technique with ICG guidance represents a significant advancement in neurosurgical techniques for treating trigeminal neuralgia. This approach not only enhances the precision of neurovascular conflict resolution but also minimizes the risk of damaging critical neurovascular structures, thereby reducing postoperative complications and promoting faster recovery [17,40].

The simultaneous visualization provided by the exoscope and endoscope, enriched with real-time feedback from ICG fluorescence, offers a unique advantage in identifying and navigating around the delicate anatomy of the cranial nerves and surrounding blood vessels [41–44]. This method underscores the importance of incorporating cutting-edge technology in surgical practice, emphasizing the need for continuous learning and adaptation to new surgical tools and methods. As such, it sets a new standard for the management of trigeminal neuralgia, aiming for optimal surgical outcomes and enhanced patient satisfaction by meticulously addressing the root cause of the condition with minimal invasiveness [6].

Limitations of the Study

The highly specialized nature of the endoscopically assisted exoscope technique may limit its applicability, particularly in medical settings that lack advanced neurosurgical facilities or expertise. Furthermore, our study does not extensively address the potential variability in outcomes based on the surgeon's experience and skill level. This factor is critical in assessing the reproducibility and consistency of surgical outcomes across different practitioners and clinical settings. The financial aspect is a significant factor that can influence the accessibility and adoption of the procedure in various healthcare environments. Particularly in resource-limited settings, the economic impact on healthcare systems and patients is an important consideration that should be considered. Our study might not fully explore the limitations or challenges associated with the technology used in the procedure. This includes aspects such as equipment availability, maintenance requirements, and handling of technical faults, which are important for understanding the feasibility and practicality of implementing this technique on a wider scale. The study does not address the learning curve associated with mastering the combined use of an exoscope and endoscope, which could influence the reproducibility of the technique across different surgeons and institutions. The initial investment in both time and resources to train surgical teams could be significant and might impact the speed at which this technique is adopted in clinical practice.

4. Conclusions

The integration of endoscopically assisted exoscopic surgical technique with the ICG intraoperative control offers a novel and effective approach to addressing NVC associated with TN. The combined use of a 3D exoscope and endoscope provides a comprehensive 360° assessment of the surgical field, allowing for precise identification and resolution of NVC. This approach significantly reduces the risks associated with conventional MVD techniques, such as incomplete decompression and potential nerve damage. Moreover, the ergonomic benefits for the surgeon, including a better visual axis and reduced physical strain, contribute to the overall safety and effectiveness of the procedure. The application of intraoperative ICG control offers an additional layer of precision, particularly in distinguishing between arterial and venous structures and identifying complex arteriovenous forms of NVC.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/surgeries5020017/s1, Video S1: Intraoperative endoscope assisted view.

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Abbreviations

AICA: anterior inferior cerebellar artery; BNI, Barrow Neurological Institute; CPA, cerebellopontine angle; CISS_3D, Constructive Interference in Steady State; CN, cranial nerve; FIESTA, Fast Imaging Employing Steady-state Acquisition; ICG, intraoperative indocyanine green; LTRN, left trigeminal nerve; MRI, magnetic resonance imaging; MVD, microvascular decompression; NVC, neurovascular conflict; SCA, superior cerebellar artery; SPV, superior petrosal vein; TN, trigeminal neuralgia; VAS, Visual Analog Scale.

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