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TESI DI DOTTORATO

Comparison between 2D and 3D Endoscope in endoscopic endonasal surgery, an anatomical dissection study

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Introduction

Aim of the thesis

Introduction

The endoscopic technique is currently the best option for treating several endonasal and skull base pathologies. Improvements in image quality and instrumentation have significantly contributed to advances in endoscopic sinus surgery (ESS) and led to use of endoscopic approaches in skull base surgery too (1).

The main advantage of endoscopy is giving access to deep structures of the nervous system without any cerebral retraction. Angled endoscopes (30°or 45°) provide angled view and access to areas that could not be reached by the direct straight view offered by microscope.

Nowadays high definition (HD) endoscopic tools allow access to the ventral midline of the skull base by providing precise visualization of key anatomical landmarks (2). Compared to microscope, the endoscope improves peripheral visualization of the sella and surrounding structures within the sphenoid sinus and nasal cavities. But traditional endoscopes has some limitations like, 2D vision with lack of binocular vision (3). This results in the lack of depth perception and impairment of size estimation (4). Therefore, tactile and visual cues deriving from the interaction of instruments or the continuous movement of the endoscope are essential to better understand the third dimension.

This lack of stereoscopy strongly contributes to the steep learning curve existing in endoscopy (5) The development of novel three dimensions (3D) visualization systems overcame some limitations of 2D technology and few publications have demonstrated its effectiveness and safety during sinonasal and skull-base surgery (5). Therefore, stereoscopic visualization improves depth perception, efficiency of surgical movement, and surgeon confidence (2).

Stereoscopic vision is crucial for understanding surgical anatomy and leads to better hands-eyes coordination, reduces mistakes in movement, resulting in improvement of surgical performance. However, poor image quality and visual fatigue have restrained the wide spread use of 3D endoscopes in clinical practice (1). Recently, these devices regained some popularity because new technological improvements have made possible the addition of HD in 3D endoscopes.

Very few cadaveric studies that compared the 2D endoscopy with the 3D endoscopy are currently available. These studies reported improved depth perception and spatial orientation with the 3D system, which facilitated surgical tasks and instrument maneuverability. All authors concluded that 3D endoscopy is efficient for endonasal surgery and comparison studies reported that 3-D endoscopy is superior to 2-D endoscopy because of better understanding of anatomy in 3-D (3). Despite these advantages, some major limitations of the 3-D technology remain, what makes the HD 2D endoscopy superior in terms of ease of use and clinical utilization. (2,3).

The aim of this study was to compare the HD 2D endoscope with the HD 3D during anatomical dissection in a wide spectrum of situations to evaluate the strengths and weaknesses of each technology in a systemic manner.

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CHAPTER 1

Cadaver Lab and training for the surgeons

1.1 Introduction

Cadaveric dissection has been considered fundamental for understanding the human body and training surgeons since the beginning of modern studies in anatomy. Neurosurgeons have to spend many hours amounting to years in anatomic laboratories during their period of residency and even after they become highly experienced to develop a "sixth sense" in which their scientific knowledge and manual skills converge. As pointed out by Yasargil (1-3), "Microneurosurgery is a new neuroanatomic, neuropathological, and neurosurgical concept in combination with the application of microvascular surgical techniques, the bipolar coagulation technique, cerebrospinal fluid release from basal cisterns, non-invasive cisternal access to lesions, the accurate dissection of the vessels, and the complete elimination of lesions with respect to their specific predicted sites." It is correct that the "imperative requirement of laboratory training to acquire expertise in all avenues of microtechniques" stressed by Yasargil (3-5) should also be extended to neuroendoscopy because it is an optical supplement that requires different training curves: "the better we see, the more we know," and "the more we know, the more we see" (3-6). Endoscopy is simply a different means that offers a different perspective of the same anatomy: Anatomy does not change, only the way of visualizing and approaching it. The goal of each operation is cure, and anatomic knowledge is the keystone for success. Microscopy and endoscopy are different but complementary modalities that can be used alternatively, preferentially, or together for the same purposes. More recently, it has been shown that endoscopy can be used in most types of skull base approaches to reach the anatomic area from the crista galli (7) to the jugular foramen (8) and the ventral craniocervical junction (9). It is often said that endoscopic procedures require a long training curve, but it may be more appropriate to say that neuroendoscopy simply requires a specific training curve. Imitation is the most powerful means of learning (10); whenever possible, the “gold standard” approach for residents, beginners, or experienced surgeons learning new techniques should be to observe experts and then try to reproduce the results of their observations. Endoscopic training in an anatomic laboratory should be compulsory for all surgeons wishing to perform neuroendoscopic approaches to the brain and skull base, and the presence of an anatomic laboratory should be a conditio sine qua non of any major university hospital (11-17).

1.2 Importance for beginners and experts

As the use of endoscopic procedures to treat intracranial pathologies has become increasingly more common in recent years, training with cadaveric dissection is becoming an essential means of acquiring sufficient practical knowledge of surgical anatomy and microsurgical and endoscopic dissection techniques. Anatomic laboratories should simulate the setup and conditions of operating theaters to offer the best training for surgeons preparing to operate endoscopically on living patients. A cadaver laboratory is a suitable place in which beginners can train and experts can test their skills.

1.3 Training model

Endoscopic endonasal surgery (EES) utilizes endoscopic visualization through direct ventral corridors to minimize the need to manipulate neural and vascular structures when compared to open skull base approaches (18,19) The endoscopic endonasal approach has been reported to reduce postoperative morbidity and recovery time, shorten hospitalization, and decrease cost of care (19). Acquisition of endoscopic dissection techniques is a difficult task, and there is an extended learning curve(20–24). The endonasal route requires the use of long surgical instruments with which the surgeon must perform microsurgical-like dissection under non-stereoscopic visualization provided by the endoscope (25,26). Surgical training model for EES is needed (27,28). The use of surgical simulation allows trainees to develop basic technical skills in a risk-free environment for patients without wasting valuable operating room time. The gold standard is anatomical dissection, but this is an expensive resource with limited availability (29).

Training with virtual reality (VR) simulators has shown great promise (29), but existing models are expensive or have technical limitations. For example, the endoscopic sinus surgery (ES3) simulator has been shown to be a very effective training tool with particularly strong content, construct, and concurrent validity (30), but it is no longer in production as it was cost prohibitive for most medical centers. The less expensive VR models have limited options for instrumentation and tend to lack haptic feedback, which significantly impairs their ability to mimic actual surgery. Chicken wing model is a low cost, availability, feasibility, reproducibility, and vascular properties (31).

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CHAPTER 2

The learning curve and technical skills of Endoscopic Endonasal Surgery

2.1 Introduction

Endoscopic endonasal surgery (EES) has developed into a preferred approach for many skull base pathologies. The learning curve and technical skills associated with EES are long and different from microscopic neurosurgery (1). EES provides a unique set of technical challenges and psychomotor skills that must be overcome while progressing along this learning curve. These challenges include working with reduced depth perception and lack of stereoscopic vision, operating via minimal-access corridors, and the use of long-shaft instruments (1-5).

2.2 Learning curve

Surgery of the ventral cranial base is evolving with the introduction of transnasal endoscopic techniques (1). Parallel to the evolution of other surgical specialties, surgery of the skull base has transitioned from maximally invasive to minimally invasive surgery. Each time that there is a paradigm shift in surgical disciplines, there is an adjustment period as surgeons acquire new surgical skills and gain experience. The time that it takes to become proficient is often referred to as the “learning curve.” This curve may be short (easy to acquire the necessary skills or knowledge) or long (difficult to master). Unfortunately, the learning curve is often associated with an increase in complication rates as surgeons gain experience. Endonasal brain surgery is team surgery that requires the learning of unfamiliar surgical anatomy, the use of new technologies, and the development of new surgical skills. The learning curve for endonasal brain surgery is long, and the training process should reflect this. The group of Pittsburgh developed guidelines from surgeons with substantial expertise in endonasal brain surgery regarding the proper training for surgeons interested in performing endonasal brain surgery. The principles are an incremental training program that requires mastery of simpler procedures before proceeding to the next level of difficulty.

2.3 Pathology of Endonasal Approach

The training program reflects the incremental experience of the Pittsburgh group over the last 9 years performing over 600 endonasal brain surgeries for a variety of different pathologies (Table I). The surgical team (otolaryngology and neurosurgery) gained initial experience working together endoscopically resecting pituitary tumors and repairing cerebrospinal fluid leaks. Once these procedures were mastered and new instrumentation was developed, surgeries gradually progressed from the sphenoid sinus along the skull base in the sagittal and coronal planes.

TABLE I
Pathology: Expanded Endonasal Approach

Cerebrospinal fluid leak
Trauma
Optic nerve decompression
Infection
Epidural abscess
Mucocele
Benign neoplasms
Pituitary adenoma
Meningioma
Craniopharyngioma
Angiofibroma
Malignant neoplasms
Sinonasal malignancies
Esthesioneuroblastoma
Chordoma
Chondrosarcoma
Metastases
Rathke's cyst
Dermoid cyst
Arteriovenous malformation

Each level is designed to provide training in basic skills (surgical access, identification of anatomical landmarks, hemostasis, dural repair, etc.) that are necessary for the next level. Mastery of a procedure is defined as the ability to complete the surgery endoscopically in multiple cases without excessive morbidity.

2.4 Endonasal Skull Base Surgery Training Program

The training program is divided into five stages or levels of difficulty (Table II). It is expected that the surgeon should not progress to the next level unless the procedures in the preceding level have been mastered (6-15).

TABLE II
Endonasal Skull Base Surgery Training Program

Level I
Endoscopic sphenoethmoidectomy
Sphenopalatine artery ligation

Level II
Endoscopic frontal sinusotomy
Cerebrospinal fluid leaks
Sella/pituitary (intrasellar)

Level III
Sella/pituitary (extrasellar)
Transodontoid approach (extradural)
Transclival approaches (extradural)

Level IV
Transplanum approach (intradural)
Transclival approaches (intradural)
Transodontoid approach (intradural)

Level V
Aneurysms
Vascular malformations and highly vascular tumors

2.5 Acquisition of new surgical skills

The acquisition of new surgical skills is an ongoing challenge for surgeons. Much of what the surgeon do is learned after residency training in an unstructured environment with limited access to training facilities. A suggested progression of training includes attendance at courses with anatomic models and laboratory skills sessions, observing/ assisting an experienced surgeon, performing cases with supervision, and finally performing cases independently. Although much learning occurs in the operating theater, it is necessary that sufficient time be spent in the classroom or dissection laboratory to acquire sufficient anatomic knowledge and familiarity with endoscopic techniques before proceeding to live surgeries. This should include both basic and advanced endoscopic surgery courses, preferably with an emphasis on skull base applications.

Courses should be followed by additional practice in the laboratory with cadaveric dissections whenever possible. Cadaveric work continues to be valuable even after lower level procedures have been mastered. It provides an enhanced understanding of anatomic relationships that cannot be adequately explored in the operative setting. It is also useful to receive additional training after level II procedures (pituitary surgery) have been mastered because the educational needs and focus of the surgeon change with experience. Many surgeons may plateau at mid-level procedures (level II and III) and may not desire or need to progress to more difficult procedures. If surgeons choose to perform level IV procedures, there needs to be a commitment to endoneurosurgery with the development of a stable surgical team that operates together regularly with an adequate volume of cases. More generally, adherence to training guidelines may prevent negative experiences that will stall the growth and advancement of endoneurosurgery.

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CHAPTER 3

Comparison 2D and 3D endoscope, an anatomical dissection study

3.1 Materials and Methods

The present study was performed in the Surgical Neuroanatomy Laboratory of the Department of Neurosciences, Neurosurgical Unit at the University of Torino.

Real operating room settings were created in the laboratory, which is equipped with HD 2D endoscopic system (Karl Storz, Inc.), and HD 3D endoscope (Visionsense, Ltd., PetachTikva, Israel); a high-speed drill, suction, irrigation, and a wide array of neurosurgical, endoscopic skull base, and other micro dissection instruments. Six light embalmed and injected cadaveric heads were used for this study.

Visionsense III (Visionsense Ltd, PetachTikva, Israel) is a 150 mm length 3-D endoscope with an outer diameter of 4.9 mm at the distal end. Cold light (LED) is integrated on the tip and the effective working distance is between 15 and 50 mm. The endoscopic images are captured at the distal end of the scope by a charge-coupled device camera. They are transmitted to the computer, the graphic data are processed for 3D imaging and the images are immediately sent to the display unit. The stereoscopic technology is based on the ability to acquire and present different images to the left and right eyes simultaneously. A computer program is used to reconstruct natural stereovision from the raw data. The system requires the use of passive (polarizing) glasses, which, in combination with a 3D screen, emulates the normal visual process of stereopsis, or spatial perception.

Both 2D and 3D endoscopes were compared in our laboratory during the dissection of 6 anatomical specimens to reproduce endoscopic endonasal approaches to the skull base: approaches to the sella and parasellar region, hypophysectomy, orbital apex, planum sphenoidale, ethmoid sinus, clivus, occipitocervical junction, foramen magnum, pterygopalatine and infratemporal fossa. In all approaches particular attention was taken to recognize the main anatomical landmarks such as the opticocarotid recess, optic nerve, internal carotid artery, location of the vidian nerve, superior clival recess, foramen magnum.

The parameters used for comparison were:

- Image quality
- Definition of anatomical structures and landmarks
- Perceived depth of field with the different tools, coordination of movements and hand-eye coordination
- User side-effects, dizziness
- Color perception, light perception, sharpness, contrast
- Confidence in the tool handling, ergonomics, and easiness of use
- Learning curve in the use of the endoscope
- Fragility of the instruments
- Cost of the two different products

Since image capturing is especially useful for teaching and research purposes, we evaluated the quality of the images captured by each system during the dissections. Photoshop CS6 Software was used to analyze the pictures captured by the 2D and the 3D systems. For sharpness evaluation we zoomed in the picture 10x and qualitatively compared the images.

3.2 Results

The anatomical dissection benefited from the 3D technology because of the stereoscopic vision, allowing better hand-eye coordination especially in deep procedures and helping in the perception of distances between tools and anatomical structures (Table 1) (10,11).

Table 1: Endoscopes effects during use

	2D endoscope	3D endoscope
Perceived depth of field	++	++++
hand-eye coordination	+++	++++
User side-effects, dizziness	No incidents	Few incidents

Legend:

+ : Lower level

++++ : Hight level

2D technology offered better image quality, allowing better recognition of anatomical structures and reducing time of surgical movement. The main drawbacks of 3D technology was the inferior contrast, sharpness and brightness compared to the 2D system, especially during the early phases of the approach (10,11) (Table 2).

Table 2: Quality of the images during dissection

	2D endoscope	3D endoscope
Image quality	++++	+++
View anatomical structures and landmark	++++	+++
Color and light perception	++++	++
Sharpness	++++	++
Contrast	++++	++
Resolution of the images stored	1920 x 1080 pixels	960 x 720 pixels

Legend:

+ : Lower level

++++ : Hight level

The 2D system stores the images in a 1920 x 1080 pixels resolution, while the 3D system stores it in 960 x 720 pixels resolution. This characteristic makes the images captures in the 2D system sharper than the 3D system if compared on monitor of same size, due to the pixel density (Fig. 1)

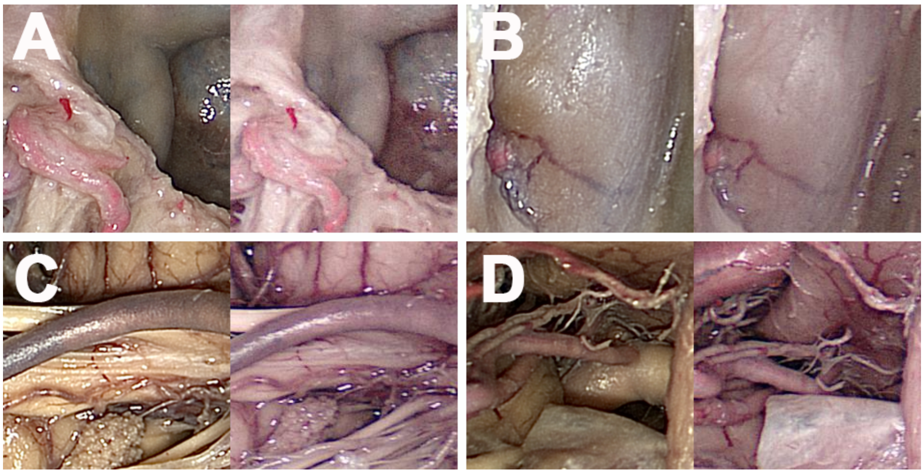

Fig. 1: (A) Zoomed picture of sphenopalatine artery and comparison with 2-D and 3-D endoscope. (B) Zoomed picture of Frontal lobe dura and comparison with 2-D and 3-D endoscope. (C) Zoomed picture of lower cranial nerve and comparison with 2-D and 3-D endoscope. D) Zoomed picture of pituitary gland and pituitary stalk and comparison with 2-D and 3-D endoscope.

In the first steps of the dissection, the Visionsense III accuracy is limited because of the narrow corridor that is represented by the nasal cavity. Once the intial steps of the procedure are completed and the resection of the nasal structures is done, the advantages of 3-D imaging become increasingly clear (3,11,12,13,14). The benefit of 3D viewing was especially useful in the pterygopalatine fossa, the posterior ethmoid and sphenoid sinuses, allowing the recognition of the relationship of different structures like pyterigopalatine artery, internal carotid artery, optic nerve and optic carotid recess (Fig.2) (1).

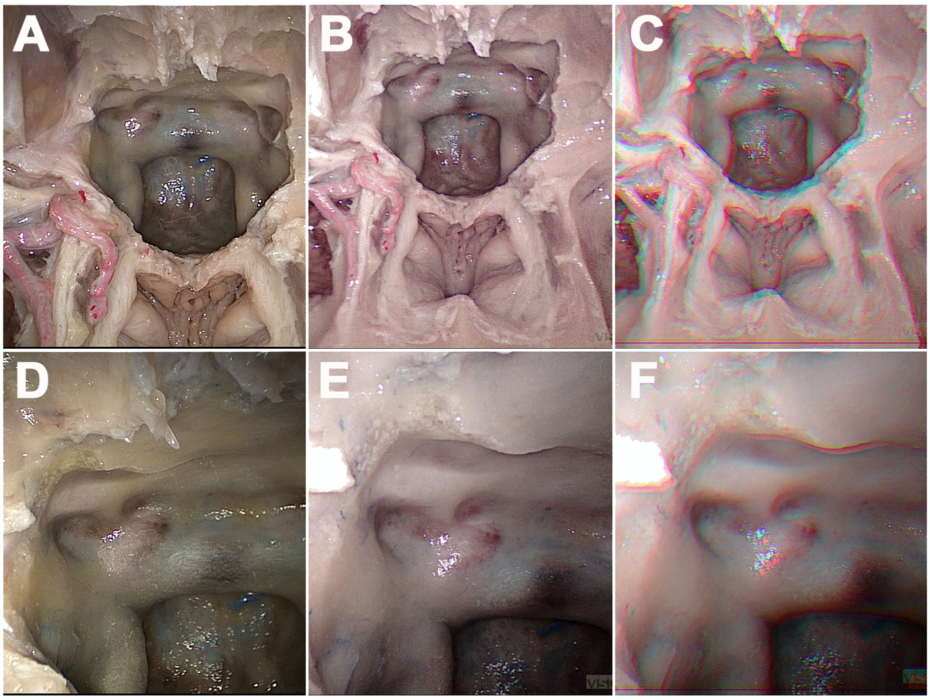

Fig. 2: (A) 2D endoscope picture of right sphenopalatine artery in the Pterygopalatine fossa. (B) 2D picture of 3D endoscope of right sphenopalatine artery in the Pterygopalatine fossa. (C) 3D picture of 3D endoscope of right sphenopalatine artery in the Pterygopalatine fossa (D) 2D endoscope picture of posterior ethmoid and sphenoid sinuses. (E) 2D picture of 3D endoscope of posterior ethmoid and sphenoid sinuses. (F) 3D picture of 3D endoscope of posterior ethmoid and sphenoid sinuses.

In the posterior and superior portion of the nasal cavity, 3D endoscopic image provided superior perception of depth than 2D endoscopy (Fig.3).

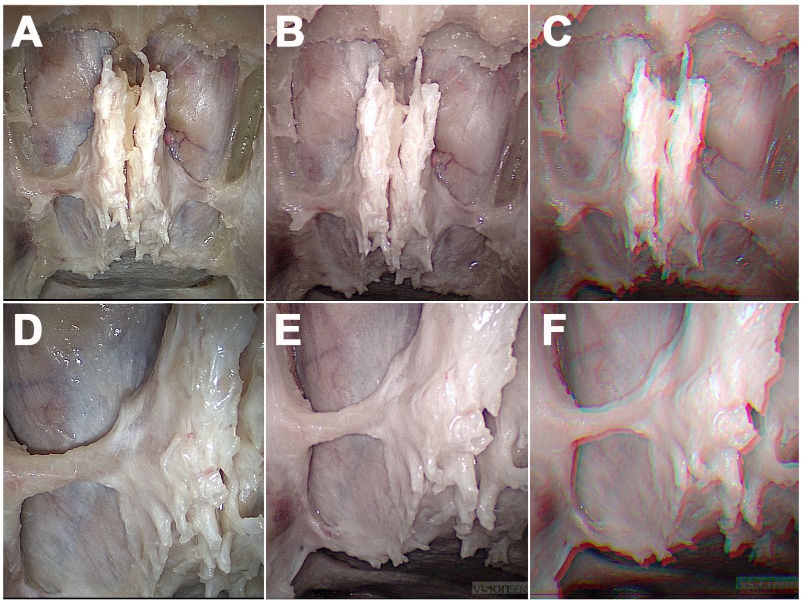

Fig. 3: (A) 2D endoscope picture of superior portion of nasal cavity, cresta galli and dura that cover frontal lobe. (B) 2D picture of 3D endoscope of superior portion of nasal cavity, cresta galli and dura that cover frontal lobe. (C) 3D picture of 3D endoscope of superior portion of nasal cavity, cresta galli and dura that cover frontal lobe (D) 2D endoscope picture of anterior ethmoidal artery. (E) 2D picture of 3D endoscope of anterior ethmoidal artery. (F) 3D picture of 3D endoscope of anterior ethmoidal artery.

Also in infratemporal dissection, better depth perception of the 3D endoscope improved the ability to identify muscles, vessels and nerves (Fig. 4).

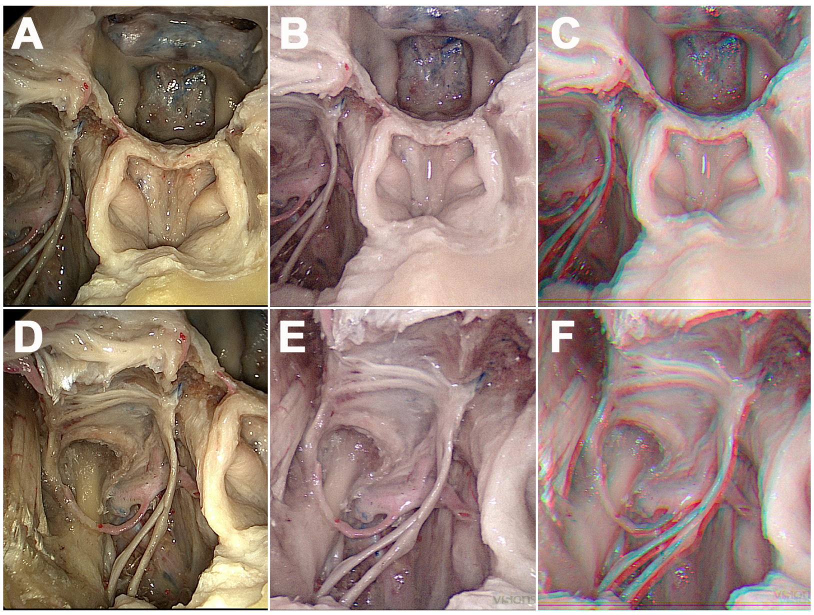

Fig. 4: (A) 2D endoscope picture of Infra temporal fossa. (B) 2D picture of 3D endoscope of infra temporal fossa. (C) 3D picture of 3D endoscope of infra temporal fossa. (D) 2D endoscope picture of V3 and maxillary artery in the infra temporal fossa. (E) 2D picture of 3D endoscope of V3 and maxillary artery in the infra temporal fossa. (F) 3D picture of 3D endoscope of V3 and maxillary artery in the infra temporal fossa

This improvement in hand-eye coordination allowed by the 3D endoscope permitted safest dissection in deep and narrow areas such as craniovertebral junction (Fig. 5).

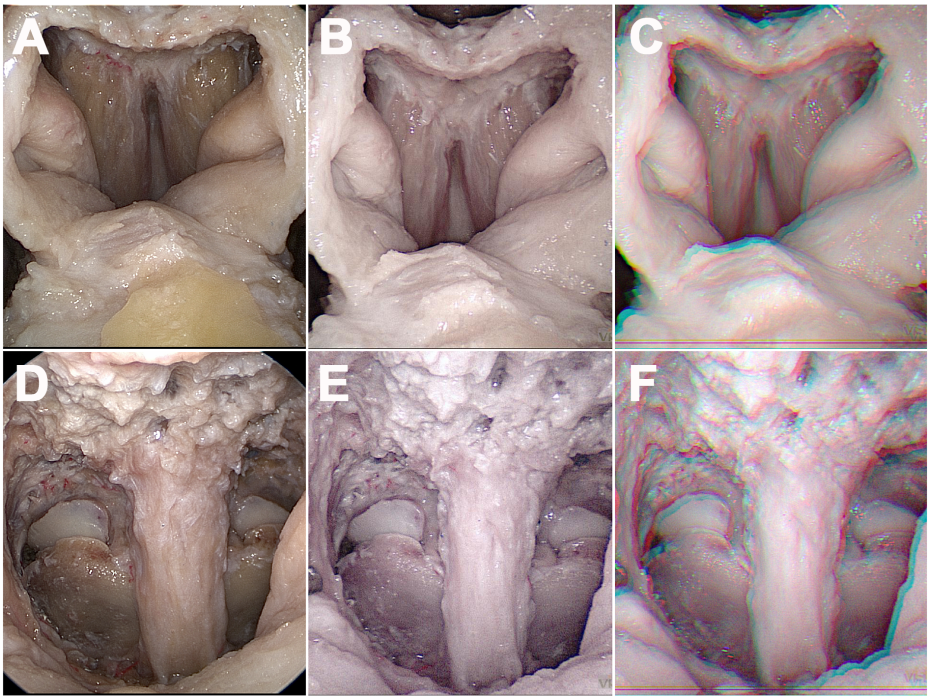

Fig. 5: (A) 2D endoscope picture of the 2 eustachian tube and behind the lungus capitis muscle. B) 2D picture of 3D endoscope of the 2 eustachian tube and behind the lungus capitis muscle. (C) 3D picture of 3D endoscope of the 2 eustachian tube and behind the lungus capitis muscle. (D) 2D endoscope picture of crania-vertebral junction with in the middle the anterior longitudinal ligament. (E) 2D picture of 3D endoscope of crania-vertebral junction with in the middle the anterior longitudinal ligament. (F) 3D picture of 3D endoscope of crania-vertebral junction with in the middle the anterior longitudinal ligament.

During intrasellar or intradural procedures, the better depth perception of the 3D endoscope improves the ability to identify neurovascular structures like optic nerves, optic chiasma, internal carotid arteries, basilar artery, vertebral arteries, brainstem and cranial nerves, as well as their relationships with the surrounding structures (Fig. 6) (10,15,16,17,18). Better coordination of movements was provided by the 3D endoscope specially when approaching lateral structures, such as the medial wall of the orbit (Fig.6).

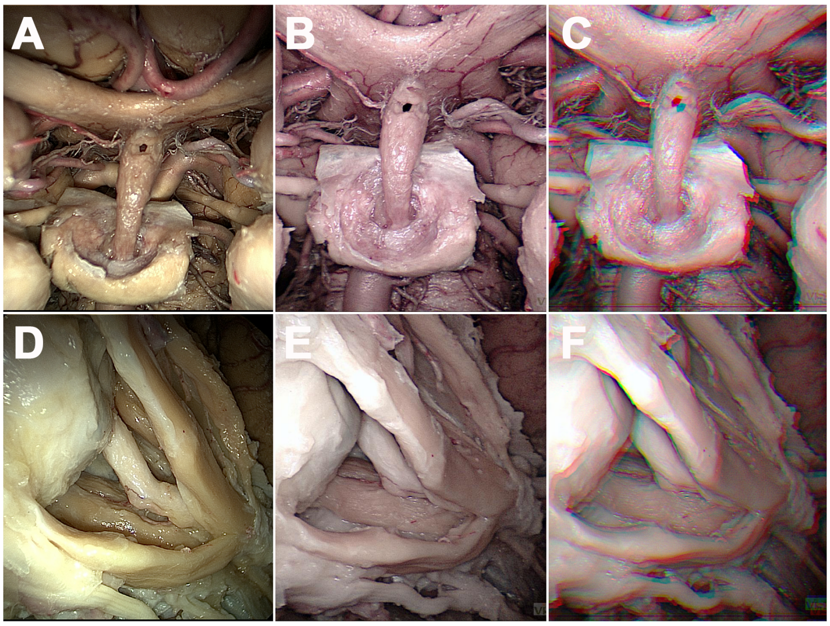

Fig. 6: (A) 2D endoscope picture of pituitary gland and pituitary stalk. (B) 2D picture of 3D endoscope of pituitary gland and pituitary stalk. (C) 3D picture of 3D endoscope of pituitary gland and pituitary stalk. (D) 2D endoscope picture of orbita dissection. (E) 2D picture of 3D endoscope of orbita dissection. (F) 3D picture of 3D endoscope of orbita dissection.

The sharp bimanual dissection that is usually performed with the microscope is easily accomplished with this depth perception and better hand-eye coordination.

The preference and ease of handling of two different instrument depends upon the individual but a surgeon trained with 2D endoscope may need more time to adapt to the noval 3D instrumentation and technology. 3D glasses are required during the whole time when using the 3D endoscope, resulting in more eye fatigue specially in the beginning of the dissection or until the eyes adapt to the field of vision (Table 3) (1).

Table 3: Endoscopes technical features

	2D endoscope	3D endoscope
Ergonomy, and easiness handle	++++	++
Fatigue in the use of glass	Not necessary glass	++
Fragility of the instruments	More easy to damage	Less easy to damage
Cost of the endoscope	Low cost	Hight cost

Legend:

+ : Lower level

++++ : Hight level

No dizziness was noted during the use of the 3D endoscope, but few episodes of headaches and nausea were reported in the beginning of dissection. No lost of 3D perception after long time of dissection were note from the users with the use of 3D glasses. We also noted 3D scope to be more fragile compared to 2D scope, especially in case of micro injury that can occur during contact of drill bit with the camera during dissection.

We have categorized our findings in a tabular form. Table 1 compares ergonomics and effects of usage, table 2 compares quality of image and table 3 differntiate technical features of both the scopes.

Comparison between 2D and 3D endoscopic images. 3D Red-cyan glasses are recommended to view the 3D images correctly

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CHAPTER 4

Discussion and Conclusion

4.1 Discussion of the study

Improvements in image quality and refinement of instrumentation have contributed immensely to advancement and popularity of endonasal endoscopic surgery (EEA) (1). The development of 3D visualization systems overcame some of the limitations of 2D system, resulting in better depth of field and coordination of hand-eye movement during surgical procedures (2-12). Although surgeons noticed improved spatial perception with stereoscopic technology, its widespread clinical use, including ESS, has been limited for many reasons. Poor image resolution of early 3D endoscopes, which often used 1-chip-camera technology (2), bulky endoscopes, need for eyewear during the procedure and surgeons reluctance to adopt this technology contributed to limited use of 3D scopes in clinical practice. Subtle differences in image quality resulted in user side-effects like headaches, nausea, and ocular fatigue. Recently developed HD 3D endoscopes are far better at image generation (13), resulting in improvement of the performance and quality of the procedures (2). New generation endoscopes use an "insect eye" technology, with a single video chip, and HD images are the newest advantage of 3-D technology.

The number and the accuracy of required movements are affected by the clarity of visual feedback and the experience of the surgeon. Moreover, depth perception is critical in order to obtain precise movements (14,15). Two different aspects of the control of fine surgical movements have been described: the first involves the gross starting movements in the desired direction; the second involves the multitude of little adjustment movements based on the feedback of visual clues (6). The lack of tactile clues and 2D visualization represent an important barrier to the efficiency and accuracy of movements (16). The acquisition of endoscopic skills includes inherently the ability to transform a 2D image in a mental 3D representation of an area. The surgeon has to see a 2D image while the hand is working in a 3D field (17). Despite the ability to compensate the lack of binocular vision, studies on human kinematic have shown the negative consequences of monocular vision, including a longer time for movements and a certain tendency to underestimate the distance between objects (6). Schroeder and Nelsen pointed out the importance of having a HD image during skull base surgery (18). Beyond the obvious importance of a clear image, the lack of tridimensional view could be the main limitation of endoscopic surgery. Becker et al. first described the 3D endoscope in the 1993, emphasizing the better recognition of the relationships of anatomical structures and precise differentiation of tissue layers (19). In addition, the relevant importance of 3D view depends on the greater depth of field provided compared to that of 2-D endoscope.

Another important point about the 3D endoscope is the role that can have in reducing the learning curve of novice surgeons (3), considering that endoscopic surgery has a long learning curve compared to traditional microsurgery (20), this aspect often is the barrier to start using this technique.

The number and accuracy of required movements needed to complete a given task in the endonasal corridor are directly correlated to the quality of visualization and the experience of the surgeon. Therefore, trainees often perform excessive movements of the endoscope to gain motion parallax depth cues for 3-D perception, increasing the time and number of movements needed to complete the same task. There are several articles that demonstrated that the depth perception gained with the 3D endoscope shortens the learning curve for novice surgeons (1,2,3,10,11,21,22). Error rates and execution times are significantly shorter for novice surgeons, suggesting that trainees who are accustomed to working in a 3-D environment may benefit most from these endoscopes. For example while drilling complex sphenoidal septations, there were fewer incidences of “air drilling,” and residents more often correctly applied Kerrison punches to the target. Stereoscopy allows even the observer to naturally develop a mental map of the surgical corridor when observing surgical movements. The 3D endoscope may be a valuable tool to train the next generation of skull base surgeons (1,3).

Despite the recent addition of HD version to 3D endoscope, the main disadvantage of 3D technology compared to the traditional 2D is still lack of optimal image quality. Improvement in image quality would allow better recognition of the structures during surgical procedures and consequently better understanding of the anatomy and definition of anatomical structures and landmarks.

Other aspect that limits the use of 3D is the high cost of the equipment and the maintenance when compared to the 2D system. 3D glasses are required during the whole time when using the 3D endoscope, resulting in more eye fatigue specially in the beginning of the dissection. Finally, the time to become familiar with this new equipment should not be underestimated by surgeons already using previous technology.

4.2 Limitations and Future applications

The limitations of the study presented here include the lack of strong objective and reproducible parameters that can certificate the better use of the 3D endoscope rather than 2D endoscope. In addition most of the parameters used are subjective and depend on the personal judgment of the individual surgeon and his habit of using a type of technology rather than other. Future directions include a development of an inter-observer comparison for a scientific, more accurate result also for future developments.

4.3 Conclusion

3-D technology has features that can compensate for the current limitations of 2D technology using stereoscopic vision, resulting in better depth of field perception and hand-eye coordination of movement during surgical procedures. This could also result in improvement of the performance and reduce learning curve of novice surgeons. The main disadvantage of the 3D technology compared to the traditional 2D is the worse image quality, despite the recent HD 3D endoscope. Apart from that higher costs of the 3D technology, the difficulties in adapting to the 3D vision using glasses (23), and the fact that experienced surgeons are able to overcome spatial and depth informations loss with spatial depth cues, still reamin challenges for the wide spread use of 3-D systems.

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