THE ROLE OF VIRTUAL ENDOSCOPY IN SURGICAL PRACTICE OF OTOLARYNGOLOGY HEAD AND NECK SURGERY: Literature review

Ali Jafar[1], Bader Al Ali[2]

1. University of Texas Health Science Center at Houston, an affiliate of Kuwait University medical school at department of surgery
2. Jaber Al Ahmad Hospital, Kuwait City, Kuwait

Abstract

Virtual endoscopy (VE) is a technique involving the transformation of two-dimensional data into a three-dimensional fly-through image of hollow anatomical structures, enabling a realistic integration of complex anatomical cavities such as sinuses, larynx, and ears. The absence of updated literature on this technology in otolaryngology prompted a review on the utility of this technology in the field. Primary research articles were extracted from PubMed, Scopus, and other online libraries and their abstract was screened for relevance. VE can serve as an educational tool for novice trainees and in pre-operative planning in the field of otolaryngology. The paper is the first updated literature review article on the role of virtual endoscopy in sinus surgery, otology, and upper airway assessment.

Introduction

Virtual endoscopy is a non-invasive technique that generates three-dimensional images of hollow anatomical structures using CT or MRI data. The application of this technology has been widely explored in assessments of the colon and the lower airway dating back to the end of the 20th century. The complex and highly variable cavities of the head and neck cavities warrant an investigation on the utility of VE in current otolaryngology practice. With recent technological advancements, virtual endoscopy has the potential to provide realistic representations of sinuses, ears, and larynx, offering practical and time-saving benefits to both novice and experienced otolaryngologists.

Method

A bibliographic search was performed using: PubMed, Scopus, Embase, Web of Science, and Google scholar using MeSH terms, free text, and Boolean functions. To ensure thorough capture of the literature, the inclusion criteria consisted of: primary research articles, English language, full-text, virtual endoscopy in the context otology, laryngology, and upper airway assessment. The reviewers independently screened and reviewed papers on relevance to the research objective of excluding papers failing to meet the criteria.

Virtual Endoscopy in sinus surgery

Rhinologists in the late 90s first applied VE to visualize paranasal sinus anatomy and the nasal cavity (1,2). Patel et al. 2017 used high-resolution CT data for manual VE creation using 3D rendering software (3). Abarca-Olivas et al. (2022) employed Osirix software to produce virtual endonasal images, aiding evaluation of intra-sphenoidal structures in 67 patients with sellar tumors, even in cases obscured by tumor or bone (4).

Rotariu et al. (2017) used VE to evaluate landmarks (sphenoid os and carotid artery) for endoscopic transsellar surgery (**figure 1**). VE showed adequate similarity to genuine images but had limitations in displaying the sellar floor and content. Occupied or non-aerated sphenoid sinuses hindered clear structure differentiation at the sellar level and prevented simulation of working instruments (5).

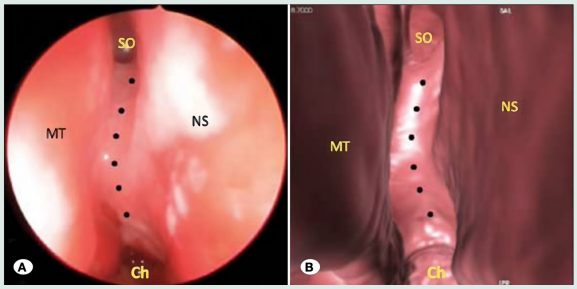

Figure 1. Identification of nasal cavity anatomical structures
A) intraoperative image B) VE image, MT: middle turbinate, NS: nasal septum, SO: sphenoid ostia, Ch: choana, dotted line: sphenoethmoidal recess (SER) (5).

Virtual endoscopy in otology

In examining middle ear pathology, Jiang et al. 2008 used VE to assess ossicular chain integrity post-traumatic ear injury. VE demonstrated accurate detection of incudomalleal and incudostapedial joint dislocation, incal dislocation or fracture, incus shifting and stapes separation. VE replicated intra-operative findings accurately (**Figure 2**), provided superior visualization for traumatic ossicular chain disruption, and detected subtle injuries missed on CT. This prompt identification may minimize diagnostic delays reducing long-term consequences such as conductive hearing loss (6). VE shows promise in evaluating inner ear disorders, Guigou et al. 2015 established how VE can provide surgeons with sufficient insight into the expected intra-operative views allowing for safe and minimally invasive planning of trans-tympanic surgeries (7).

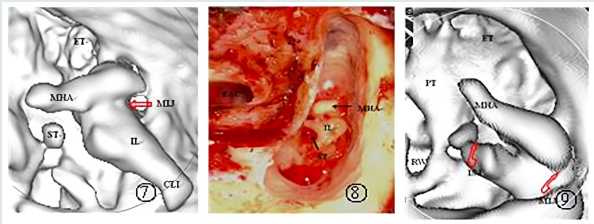

Figure 2. (7) VE of Incal shedding and dislocation. (8) Intra-operative findings consistent with Malleoincudal and incudostapedial joint separation and incal shedding and reversing. (9) Post-operative VE showing malleoincudal and incudostapedial joint connection (6).

Virtual endoscopy in laryngology

VE may appeal to otolaryngologists in planning for safer and more efficient interventions. It offers non-invasive evaluations of upper airway anatomy, including patency, site, morphology, extension, and location of lesions. Guarnizo et al. (2021) demonstrated clear identification of laryngeal structures with moderate to significant inter-observer agreement in 42 cases of laryngeal lesions (8). El-Gerby et al. (2013) compared Virtual laryngoscopy (VL) to nasopharyngoscopy, finding 96% sensitivity and 100% specificity in diagnosing laryngeal lesions in 40 cases (**figure 3**) (9). Rashid et al. (2022) reported an 89% positive predictive value of VL in diagnosing laryngeal carcinoma (10).

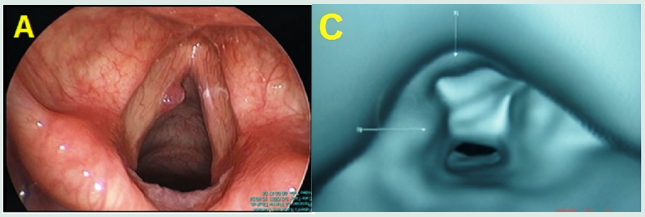

Figure 3. A) Nasopharyngoscope of sessile right VF polyp. (C) VL showing right VC polyp (9).

Limitations

Virtual endoscopy has a limited role in assessing vocal fold motility or tracheomalacia due to its static nature. Poor aeration and CT image settings can affect image resolution and disease severity. Interpreting luminal color, contour, and texture may pose challenges in distinguishing lesions from secretions (8). Additionally, flat or subtle lesions can result in false negative results.

Conclusions

Virtual endoscopy offers valuable applications for otolaryngologists as both a surgical planning and educational tool. It provides interpretable and reliable representations of luminal anatomy. The complex and highly variable head and neck anatomy can pose a challenge to surgeons. Nevertheless, acknowledgement of the limitations of VE is crucial and therefore it should be considered as adjunctive diagnostic tool rather than an alternative to conventional endoscopy.

References

1. Gilani S, Norbash AM, Ringl H, Rubin GD, Napel S, Terris DJ. Virtual endoscopy of the paranasal sinuses using perspective volume rendered helical sinus computed tomography. Laryngoscope. 1997;107(1):25-9.
2. Rogalla P, Nischwitz A, Gottschalk S, Hultema A, Kaschke O, Hamm B. Virtual endoscopy of the nose and paranasal sinuses. Eur Radiol. 1998;8(6):946-50.
3. Patel NS, Dearking AC, O'Brien EK, Pallanch JF. Virtual Mapping of the Frontal Recess: Guiding Safe and Efficient Frontal Sinus Surgery. Otolaryngol Head Neck Surg. 2017;156(5):946-51.
4. Abarca-Olivas J, Bärtschi P, Monjas-Cánovas I, González-López P, García-Garrigós E, Sánchez-Payá J, et al. Three-Dimensional Reconstruction of the Sphenoid Sinus Anatomy for Presurgical Planning with Free OSIRIX Software. J Neurol Surg B Skull Base. 2022;83(Suppl 2):e244-e52.
5. Rotariu DI, Ziyad F, Budu A, Poeata I. The Role of OsiriX Based Virtual Endoscopy in Planning Endoscopic Transsphenoidal Surgery for Pituitary Adenoma. Turk Neurosurg. 2017;27(3):339-45.
6. Jiang LX, Ma YK, Luo D, Yang N, Li YZ. [Evaluation of the virtual endoscopy on traumatic ossicular chain disruption pre- and post-operation]. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi. 2008;43(4):272-6.
7. Guigou C, Bardin F, Afifi WS, Dillenseger JP, Ricolfi F, Grayeli AB. Virtual Endoscopy to Plan Transtympanic Approach to Labyrinthine Windows. Otol Neurotol. 2015;36(8):1338-42
8. Guarnizo A, Glikstein R, Tsehmaister-Abiltbul V, Busca I, El-Sayed S, Odell M. Comparison of diagnostic accuracy of computed tomography virtual endoscopy and flexible fibre-optic laryngoscopy in the evaluation of neck anatomic structures and neoplasms. Neuroradiol J. 2021;34(1):8-12.
9. A R, El-Gerby, M. K., Ahmed, A.F., El-Anwar, et al. Conventional endoscopy versus virtual laryngoscopy in assessment of laryngeal lesions. The Egyptian journal of radiology and nuclear medicine2013. p. 497-503.
10. Rashid N, Noreen A, dogar IH, Mansoor A, hashmi Ks, nawaz F. Positive predictive value of computed tomography virtual laryngoscopy in detecting laryngeal carcinoma taking histopathology as gold standard.: Annals of king Edward medical university; 2022. p. 97-102.