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Review Article

The role of virtual endoscopy in surgical practice of otolaryngology head and neck surgery: a review article

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ABSTRACT

Virtual endoscopy involves the acquisition of data to generate a three-dimensional view of hollow anatomical structures. This interface would allow for the realistic integration of anatomical structures in complex cavities involving sinuses, larynx, and ears. Current literature lacks updated review on the role virtual endoscopy in otolaryngological practice. This paper serves to highlight the use of virtual endoscopy in amongst three main domains: otology, rhinology and laryngology. Review of literature were conducted using various databases including, Pubmed, Scopus, Embase, Web of Science, google scholar. Only papers in full text, English language, and relevant to our objectives were included. A critical descriptive review of the papers were performed to illustrate the strength and weakness on the utilization of virtual endoscopy as a surgical planning tool in otorhinolaryngology practice. The advantages of applying VE in our practice serves two folds; as an educational tool for novice trainees mainly for surgical skill acquisition and as a pre-op planning to understand complex anatomical narrow operative fields. Our paper is the first to demonstrate the most updated commentary review article of the application of virtual endoscopy in sinus surgery, laryngeal airway evaluation and the assessment of ear surgery.

Keywords: Virtual endoscopy, Laryngology, Sinus, Otology

INTRODUCTION

Virtual endoscopy (VE) involves the acquisition of CT/MRI data to generate a three-dimensional view of hollow anatomical structures. The application of VE into otolaryngology practice extrapolates from its initial widespread use for diagnostic purposes in colonic and lower airway anatomical evaluation. This interface would allow for realistic integration of anatomical structures in complex cavities involving the larynx, ears, and paranasal sinuses. The advantages of applying VE in our practice can be twofold. Firstly, it may serve as an educational tool for novice trainees where incremental attainment of knowledge and skills is required. Secondly, it has the potential for use as a pre-operative planning tool for surgeons.

The non-invasive feature of VE for assessment of complex anatomical configurations in sinus cavity for example or upper airway evaluation of lesions can well be implemented into our practice. Previously VE was seen as a laborious, impractical, and time intensive approach; however, with novel advancements of technology this could be overcome. In this review, we explored the literature for utilisation of VE across multiple major disciplines in otolaryngology. To our

knowledge this paper will serve as the only most updated review of literature on utilisation of virtual endoscopy in otolaryngology practice to date.

LITERATURE SEARCH CRITERIA

Advanced bibliographic search was conducted through an online database which included: Pubmed, Scopus, Embase, and Web of Science on February 5, 2023. Our inclusion criteria included: primary research articles, English language, full text, virtual endoscopy in context of domains including rhinology, otology and upper airway evaluation. To provide adequate capture of the literature the search consisted of a combination of free text and MeSH terms along with Boolean functions (and/or). The search equation deemed optimal was formulated: (virtual and endoscopy or endoscopic) and (laryngology or larynx or airway or sinus or otology or otological or ear) to ensure relevant articles were filtered. Duplicate papers were removed. The abstracts were screened by two reviewers to include most relevant studies serving the purpose of the research subject. We excluded studies on virtual reality, augmentation reality, virtual lower airway bronchoscopy, and non-English text.

VIRTUAL ENDOSCOPY IN SINUS SURGERY

Preoperative surgical planning plays a vital role in sinus surgery. From the standard evaluation of pre-operative CT scans in the orthogonal plane to the highly variable anatomy of the sinus cavity, these create an operative challenge for rhinologists. The introduction of VE in sinus surgery may help in rendering fly through pathways especially during dissection of the frontal recess. Given the increased variability of cellular configurations around the frontal outflow tract, careful surgical dissection is required to avoid injuries to critical nearby structures.

The application of this technology for rhinology and skull base surgery was pioneered by a number of academic papers. The early application of VE in paranasal sinus anatomy was demonstrated back in the late 90s by Gilani et al.[1] Rogalla et al demonstrated use of VE to visualise the nasal cavity and paranasal sinus.[2] Patel et al used high resolution computed tomography studies and manually created virtual endoscopic views using 3D reconstruction modelling software.[3] With the advancement of sinus navigation platform, TruDi has a built in feature to render virtual endoscopic views from DICOM files using automated algorithm. To date there has not been any studies to evaluate this feature. In skull base surgery, Abarca et al evaluated CT scans from a series of 67 patients operated for sellar tumours. The free Osirix software was utilised to demonstrate important 3D intra-sphenoidal structures from an endonasal view. The advantage of Osirix view when using the region of interest allowed for preoperative assessment of the internal carotid artery's parasellar course even in those cases hidden by tumour or bone. It also provided clear differentiation between tumour and pituitary gland when both structures were in contact with the sellar floor.[4] Another study by Daniel et al using Osirix on 22 cases of pituitary adenoma proposed for an endoscopic transsellar approach.

Osirix software converted views into a virtual endoscopic landscape, permitting the evaluation of important landmarks, such as being able to identify the sphenoid os and carotid artery. They showed that VE had a good similarity to genuine images, and all of the nasal cavity's structures could be detected with excellent agreement. The negatives were that VE provided no information regarding sellar content and failed to display the condition of the sellar floor. Other limitations were when sphenoid sinus was fully occupied by a tumour or not aerated, there was an inability to clearly differentiate structures at the level of the sella, and impossibility to stimulate working instruments.[5]

VIRTUAL ENDOSCOPY IN OTOLOGY

Pre-operative planning of otological surgery forms a vital task which can be enhanced by visualisation of middle ear ossicular chain integrity and inner ear anatomy. Visualising ossicular deformities can offer valuable insight for surgeons prior to operating. Hence, leading to the formulation of a targeted surgical approach (open mastoidectomy vs endoscopic tympanoplasty) when conducting ossicular chain reconstruction on the middle ear. Lixin et al studied the use of virtual endoscopy to assess ossicular chain integrity in post-traumatic ear injury. They reported that use of VE had superior visualisation capabilities than solely relying on high resolution CT images.

Precision of diagnostic ability of VE was assessed by evaluating 35 cases of temporal bone fractures. They identified VE was precise in detecting incudomalleal and incudostapedial joint dislocation, incal dislocation or fracture, incus shifting and stapes separation. They found that ossicular chain disruption evident on VE was consistent with intraoperative findings in all participants. Interestingly virtual otoscopy was able to detect subtle injuries missed on CT demonstrating superior capabilities in assessing traumatic ossicular chain disruption. This may assist in reducing delays and inaccuracies in diagnosis, preventing long term sequelae such as prolonged conductive hearing loss due to ankylosis.[6] The development of virtual endoscopic technology has both diagnostic and therapeutic possibilities because inner ear disorders can occasionally be difficult to detect on conventional imaging techniques. Guigou et al studied VE in the evaluation of the labyrinthine windows in relation to the therapeutic benefits of this technology, providing insights into who would be a candidate for minimally invasive trans-tympanic surgery. They showed that VE enables the surgeon to become sufficiently familiar with intraoperative views, allowing for proper planning of safe trans-tympanic approaches.[7]

VIRTUAL ENDOSCOPY IN ASSESSMENT OF UPPER AIRWAY AND LARYNGEAL ANATOMY

Virtual endoscopic airway assessment has been investigated both in the anaesthetic literature as well as in otolaryngology literature. The attraction to this technology stems from its ability to non-invasively evaluate airway anatomy, as well as any pathological obstructing lesions; including size, location, degree of patency, which is crucial when dealing with potentially fatal situations. Pre-operative planning and assessment can aid anesthesiologists as well as head and neck surgeons to perform procedures in a safe and efficient manner. Guarnizo et al compared the visual compatibility of flexible fibreoptic views to CT-based virtual endoscopic views of the aerodigestive tract amongst 42 cases of head and neck neoplasms. They scored clarity of images, easiness of identification, and inter-observer agreement. Significant agreements were found between interpretations of VE when compared to fibre optic laryngoscope of vallecula, and a moderate degree of agreement for epiglottis, glosso-epiglottic folds, and pyriform sinus. However, the VE visualisation of the vocal folds was found to be inferior to the flexible scopes possibly due to the nature of two touching surfaces, adynamic visualisation, or presence of secretions.[8] VE offers an advantage in its ability to assess subglottic and tracheal regions. An accurate and non-invasive evaluation of lesion morphology and extension can be performed. Thus, offering guidance for optimal therapeutic planning in a range of airway pathologies. Furthermore, this was demonstrated in a study where 3 complex cases of upper airway pathologies (glottic, subglottic and multi-level disease) had the recordings of fiberoptic scopes compared to virtual laryngoscopic images. The study concluded that VE offered high quality imaging that adequately reflects conventional endoscopy findings.[9] The perks of this tool compared to a conventional nasendoscopy is that it avoids patient discomfort; these fly through videos offer a user-friendly interface and can be constructed in less than 20 minutes. Limitations of this study include a small cohort with limited variety of pathologies and a reliance on visual interpretation rather than objective comparisons to conventional fiberscope.

The most extensive study in the literature that further reinforces the diagnostic capabilities of virtual endoscopy was performed by Ragheb et al. They compared virtual laryngoscopy (VL) of 40 patients with various laryngeal lesions to direct laryngoscopic findings. VL was able to assess location and extension of 100% of laryngeal carcinoma and subglottic stenosis. VL had 96% sensitivity and 100% specificity in the detection of laryngeal lesions.[10] Similar findings were shown by Rashid 2022 et al who determined the positive predictive value of CT-based virtual laryngoscopy to be 89.3% in 56 histologically proven cases of laryngeal carcinoma.[11] The major limitations of virtual endoscopy are similar to those of any assessment tool. First off, its limited utility in situations of tracheomalacia and paralysis of the vocal cords stems from its inability to assess dynamic airway movements as a static diagnostic instrument. CT-based VE images can also have inferior image resolution quality; particularly in cases of poor aeration. Furthermore, inappropriate settings, for instance, lower threshold display setting may create an exaggerated level of stenosis and vice versa. The inability of VE to provide information about lumen color, contour, or texture can make it difficult to distinguish between genuine lesions and secretions. In contrast to traditional endoscopy, lesion characteristics including abnormalities, keratosis, and vascular pattern cannot be understood. There is a likelihood of missing subtle, early, or flat mucosal lesions, potentially giving false negative results. Thus, despite VE being an effective diagnostic tool, surgeons need to consider its limitations and should acknowledge its adjunctive role rather than a replacement to conventional endoscopy.

CONCLUSION

Virtual endoscopy provides interpretable and reliable representation of luminal anatomy. This promising technology comes with practical uses that can serve both practising and future otolaryngologists. Its application in the practice of otolaryngology includes the appreciation of the complex and highly variable anatomy and provides insight in pre-operative surgical planning. Further research is warranted to confirm objective comparisons to conventional diagnostic tools.

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