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CLINICAL TECHNIQUES AND TECHNOLOGY

Three-dimensional endoscopic sinus surgery: Feasibility and technical aspects

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The development of endoscopic techniques for a variety of sinonasal disorders has paralleled advances in technology and instrumentation including angled endoscopes, multi-chip cameras, and image guidance. Despite the progressive technological innovations in modern endoscopic surgery, the visualization that is currently used remains 2-dimensional (2D). This is associated with significant limitations, notably a lack of depth perception. Although visual and haptic cues allow for a surgeon to understand the spatial relationships of the various structures, current visualization technology fails to provide the 3-dimensional (3D) perspective that is available in open and microscopic surgery. The development of a miniature stereoscopic camera and its adaptation to rigid endoscopes allows for performance of 3D endoscopic sinus surgery. It is hypothesized that incorporation of 3D visualization may enhance the spatial resolution required in advanced endoscopic approaches with a theoretical potential to improve outcomes.

TECHNOLOGY

Following Institutional Review Board approval and a trial in a cadaver laboratory, a prospective study of 3D endoscopic sinus surgery with a miniature stereoscopic camera (Visionsense Ltd, Petach Tikva, Israel) was carried out. All patients underwent fully endoscopic, endonasal approaches to the anterior skull base with a 6.5 mm, 3D 0 degree stereoscopic endoscope (Figs 1 and 2). The procedures were performed by the senior authors (VKA, THS). The endoscope was used for the entire sinonasal approach and select portions of the intracranial aspect of the procedure. At the time of the study, only a 0 degree 3D endoscope was available. Angled 2D endoscopes were, therefore, also used for suprasellar and lateral visualization.

Twelve patients underwent endoscopic, endonasal, transsphenoidal surgery during this study. The indication for surgery included pituitary lesions in nine cases, cerebrospinal fluid leaks in two patients, and craniopharyngioma in one patient. Bilateral transnasal sphenoidotomies were carried out in each patient with the 3D endoscope. One patient additionally underwent a complete ethmoidectomy for further visualization of a spheno-ethmoidal encephalocele. There were no intraoperative or postoperative complications noted during the study. Qualitative assessments by the surgical team revealed improved depth perception and improved recognition of anatomic structures especially the carotid artery and optic nerve prominences in the lateral sphenoid wall. There was no subjective increase in the operative time with the incorporation of the 3D endoscopes.

DISCUSSION

The application of rapidly developing technology has spurred modern surgical advances that include endoscopic and robotic surgery. The associated improved precision and visualization have the potential for a significant impact on overall outcomes. As the breadth of endoscopic procedures grows more complex, so to does the need for improved technology. Depth perception is integral to nearly all surgical procedures, given the 3-dimensionality of human anatomy. This has been demonstrated by Way et al[1] who showed the primary cause of error in laparoscopic surgery is secondary to a visual perceptional illusion.

The importance of 3D visualization in endoscopic sinus surgery is based on the close proximity of critical neurovascular structures and the multiple layers of anatomic structures. To date, an understanding of the 3D aspects of a given structure are based on spatial recreation with triplanar imaging and 3D models. It is believed, that 3-dimensionality enables improved hand–eye coordination, better tissue understanding and decreased learning curves. Significant decreases in the "endoscopic handicap," performance time, and error rates have been demonstrated with a 3D versus 2D scope in other fields,[2] even in surgeons experienced with 2D endoscopy.[3] This improvement may also be more significant as tasks increase in complexity.[4]

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There are several current technologies available that create stereoscopic 3D images. These include: dual channel video (daVinci robotic system, Intuitive Surgical, Sunnyvale CA), where a dual-channel optical scope is connected to two video cameras to deliver two pictures to the viewer on a stereoscopic display; dual chip-on-the-tip, which similarly uses a dual-channel video generated by two video chips; shutter mechanism, that relies on the principle that the camera is never absolutely still. The main disadvantages that exist with dual-camera technology are related to user side-effects such as fatigue, headache, dizziness, and eye strain, that result from viewing two images that differ in picture angle, brightness, color, optical distortion, and sharpness.[5]

The endoscope described in this study uses the "insect-eye" technology that incorporates a microscopic array of lenses in front of a single video chip on the end of the scope.[5] It has the advantage of generating an image from a single charge coupled device, to avoid the problem of dual-camera technologies. The use of a microarray of lenses creates multiple small images that are then divided into simultaneous left and right images. The viewer's eyes then simultaneously pick up two slightly different images of the same object. This provides a natural stereoscopic perspective, which is the 2-eyed ability to judge depth, volume, or distance accurately.

Several technical issues, which include the large size of the current endoscope (6.5 mm) and lack of angled visualization, will likely be addressed with future developments. It was additionally noted that the 3D image is more sensitive to poor visualization when soiled. The unit also requires the use of polarizing glasses or clip-ons. If there are parts of the procedure where stereovision is not used, the glasses must be removed representing another disadvantage.

The increased spatial orientation of 3D endoscopy represents a significant advance in endoscopic sinus surgery. In addition to improvement in task completion, it will likely

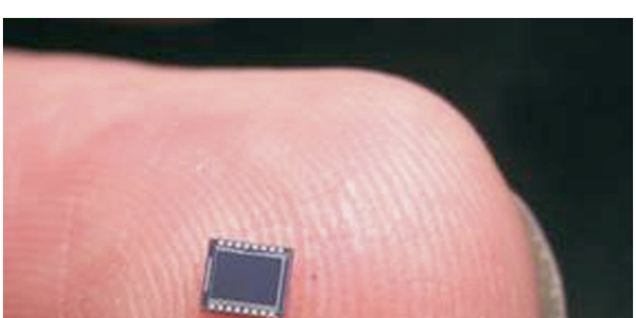

Figure 1 The camera component of the 3D visualization system.

Figure 2 The display tower of the 3D system. The endoscope and camera are combined as a single unit that is connected to the display tower.

decrease the barrier of entry into endoscopy by surgeons experienced with microscopic binocular vision. Future applications of this technology include the ability to fuse an

MR scan with the endoscopic picture to enable surgeons to have a view beyond that which is normally visible. These merged images will likely in the future be able to work with the next generation of image-guidance systems to allow surgeons to continue to expand minimally invasive surgery intracranially. Future study incorporating larger case series are required to determine the role of this technology.

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