Next-Generation Surgical Navigation Systems in Sinus and Skull Base Surgery

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KEYWORDS

• Surgical navigation • Endoscopic sinus surgery • Computer-aided surgery
• Augmented reality • Microsensors

KEY POINTS

- Surgical navigation, also known as image-guided surgery, has been widely adopted for endoscopic sinus and skull base surgery because most surgeons find the technology useful for facilitating procedures of moderate-to-high complexity.
- For surgical navigation to be useful, the accuracy (more formally known as target registration error [TRE]) must be 2 mm or better. Commercially available systems often achieve TRE of 1.5 to 2.0 mm but, too often, TRE is greater than 2.0 mm. For this reason, surgeons cannot completely trust the technology.
- A next-generation surgical navigation system should strive for a TRE of 1.0 to 1.5 mm (or even 0.5–1.0 mm) with a "tight" error range, levels that will push technical boundaries. Innovations in hardware and software will be necessary to achieve this transformation.
- Augmented reality technology (which provides additional visual cues or annotations to real-world images) can also be incorporated into surgical navigation.
- Microsensors for electromagnetic tracking systems will open new opportunities for surgical navigation, with unique applications for balloon catheter placement and targeted drug delivery.

INTRODUCTION

Since the early 1990s, surgical navigation has emerged as a critical tool during the era of endoscopic surgery of the paranasal sinuses and adjacent skull base. From its inception, surgical navigation (also known as image-guided surgery, or IGS)

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provided a way for surgeons to track an instrument tip relative to the preoperative imaging data set. Through successive iterations of the hardware and software, the technology has become more robust and user-friendliness has improved dramatically; yet, the core features have remained essentially unchanged. In fact, today's systems greatly resemble first-generation systems, which is a remarkable fact in light of the technological progress of related devices and software over the past 20 years. Recently, new surgical navigation systems have been introduced into the United States and global markets, and companies are developing innovative surgical navigation technology, which is likely to be commercially released relatively soon. Thus, it is an opportune time to assess current technology trends.

CURRENT STATE OF THE ART

Surgeon surveys performed over the past decade suggest greater availability of surgical navigation technology in most ear, nose, and throat (ENT) operating rooms in the United States and confirm that a large number of sinus surgeons are comfortable with the technology, especially for more advanced sinus cases.[1–3] These survey data are consistent with the theme of wide-spread surgeon acceptance across all types of operating room settings. In 2002, the American Academy of Otolaryngology—Head and Neck Surgery first issued its position statement on computer-aided surgery, an inclusive term that includes surgical navigation, and has periodically updated it.[4] This statement emphasizes that, although use of the technology is at the discretion of the operating surgeon, the technology should not be deemed experimental and has wide indications, including revision sinus surgery, skull base surgery, frontal sinus surgery, and so forth.

Obviously surgeons choose to use surgical navigations to achieve better clinical outcomes. Data that prove this point are relatively sparse. At least 2 studies suggest that surgical navigation is associated with lower intraoperative blood loss.[5,6] One study did demonstrate better Rhinosinusitis Outcome Measure (RSOM)-31 scores in patients whose endoscopic sinus surgery (ESS) was performed with surgical navigation.[7] A reduction in revision surgery has been associated with the use of surgical navigation.[8] However, other studies tried to show similar advantages and were not successful in proving this point.[9–12]

Anecdotally, surgeons report that surgical navigation has a positive influence on the performance of the surgical procedure. Numerous studies suggest that surgical navigation actually may lengthen the procedure,[6,13–16] but that is not the point. In an early retrospective study, Reardon[13] showed comparable complication rates in cohorts of patients whose sinus surgery was performed with and without surgical navigation, although the subjects in whom surgical navigation was used tended to have more sinuses entered. This suggests that the surgeon's comfort zone expanded through the use of surgical navigation. In a novel study, Strauss and colleagues[17] assessed the impact of surgical navigation by capturing the intraoperative change of surgical strategy associated with the application of the navigation device. In approximately, 50% of individual localizations, the use of the technology resulted in a change in surgical strategy. This study corroborates the reports of almost all surgeons who use surgical navigation and find it distinctly helpful.

From the time of its introduction, surgical navigation held the promise of a reduction in complication rates. In practice, it has been difficult to confirm this intuitive supposition. Some studies have shown no reduction in complications.[18,19] In a retrospective review, Fried and colleagues[5] noted a lower complication rate in subjects whose ESS