The Laryngoscope

Novel Compact Laptop-Based Image-Guidance System: Preliminary Study

Joao F. Nogueira, Jr., MD; Aldo C. Stamm, MD, PhD; Macos Lyra, MD

Objectives: To describe a novel portable laptop-based image-guidance system and its preliminary navigational results.

Methods: An optic-based, specially developed navigational system and a life-size endoscopic sinus anatomic model were used. The model was submitted to computer tomography (CT), and predefined anatomic landmarks were used to test the image-guidance accuracy according to the real model.

Results: All anatomic landmarks were identified by the image-guidance system and all matched with endoscopic or eye views.

Conclusions: This novel compact navigation device was shown to be fast and reliable. A larger series, involving more models, cadavers, and patients, with the evaluation of multiple anatomic points needs to be done before we can reliably determine the overall accuracy of this novel device. However, this new system is promising, and in the future it can be part of the armamentarium of otolaryngologists' personal equipment in order to perform low-cost image-guided surgeries in different places with the same equipment.

Key Words: Navigation system, endoscopy, image-guided surgery.

***Laryngoscope*, 000:000–000, 2009**

INTRODUCTION

Surgeries of the paranasal sinuses and skull base have evolved in the last decades, especially due to advances in surgical instruments, diagnosis procedures, and endoscopic visualization. However, there are still some pitfalls with this technique that can result in serious complications, including intracranial penetration, massive bleeding, loss of vision, and even death.[1–4]

Image-guidance systems are a technology developed to help surgeons to identify critical anatomic landmarks intraoperatively. Initially developed for neurosurgical procedures, these systems use computerized tracking devices to monitor the position of the endoscopes or instruments relative to the patient's anatomic landmarks. The location of these instruments is depicted on a real-time, three-plane video display of the patient's preoperative computer tomographic (CT) or magnetic resonance imaging (MRI) scan.[1–5] However, the cost and lack of portability make the current image-guidance systems unavailable in many institutions and hard to transport to different hospitals.[1,2,6]

The objective of our article is to describe a novel portable laptop-based image-guidance system and its preliminary navigational results.

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Editor's Note: This Manuscript was accepted for publication September 12, 2008.

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DOI: 10.1002/lary.20068

MATERIALS AND METHODS

We used an optic-based navigational system with a stereoscopic camera tracking device (MicronTracker; Claron Technology, Toronto, Canada), patient and instrument localizers, laptop (Toshiba U305 Series, Intel Centrino, Core-2 Duo, 2 Gigabytes (Gb) of RAM memory, 250 Gb of hard drive with a Nvidia Geforce graphics card and a 13.3-inch screen), and specially designed image-guidance software, named Eximius, developed in conjunction with the company Artis (São Paulo, Brazil, www.artis.com.br).

We used a life-size endoscopic sinus anatomic model (SIMONT—Sinus Model Otorhino-Neuro Trainer; Prodelphus, , Brazil) in order to calibrate and compare endoscopic and eye views of real anatomic landmarks with their position according to the image-guidance system. AQ1

The model was submitted to CT with 0.5-mm axial cuts, and the DICOM files were exported into the laptop. The loading and calibration times were measured. A headframe was adapted to hold the patient localizer at the model (Fig. 1). F1

The first step was the calibration of the instruments with the localizers. We used a set of straight and curved instruments.

The second step was the calibration of the image-guidance system (Fig. 2). The calibration reference points were selected in the physical surface of the model and visually matched with the tip of the previously calibrated instrument with a localizer to establish a reference point of 0 mm. Four sites were used: F2

- Lateral edge of right allar cartilage
- Lateral edge of left allar cartilage
- Lateral edge of right eye
- Lateral edge of left eye

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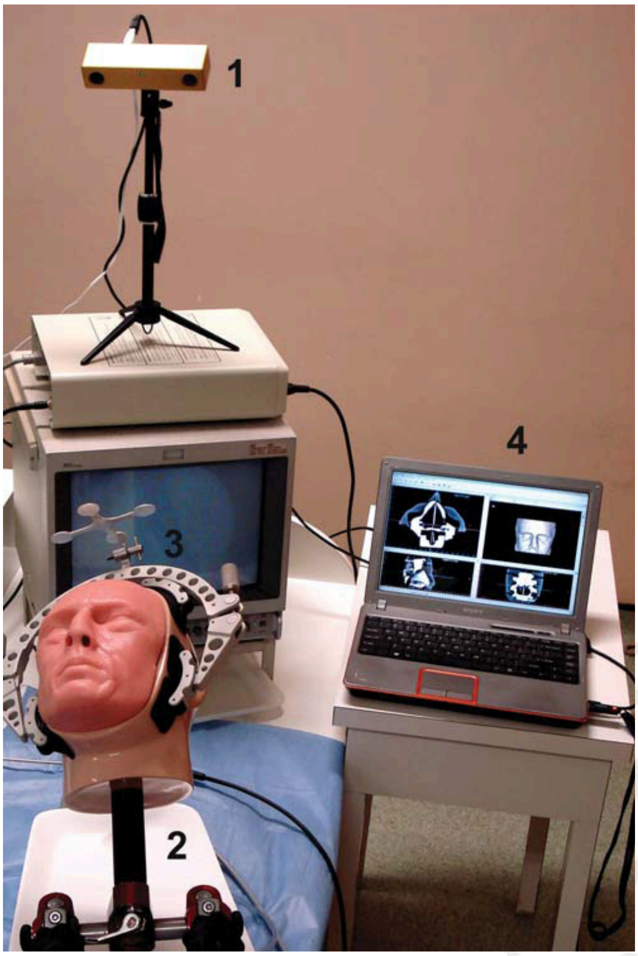

Fig. 1. An optic-based image-guidance device. (1) Tracking stereoscopic camera; (2) life-size anatomic model (SIMONT—Sinus Model Otorhino-Neuro Trainer); (3) headframe with patient localizer; (4) laptop with developed navigation software.

The third step was the positioning of the instrument's tip in some anatomic landmarks (targets). The anatomic landmarks used were:

- Nasal tip
- Center of glabella
- Skull base
- Right middle turbinate
- Left middle turbinate

The accuracy of the device was obtained measuring the distance between the target and the calibration reference points, comparing it with the distance between the reference points and the predicted position of the target on the software. The measurement was done visually in the model with a compass and scale and with a measurement tool available on the software. Due to the nature of this project, no ethics committee approval was needed.

RESULTS

The image-guidance system successfully loaded the DICOM files with a total time of 44 seconds. The calibration was successfully done with a total time of 29 seconds.

All anatomic landmarks were identified by the image-guidance system and all matched with endoscopic or eye views (Figs. 3 and 4). The mean accuracy was 1.16 mm. F3 F4

DISCUSSION

The value and importance of a navigation system is well established nowadays and lies in its ability to allow the surgeon to accurately determine the boundaries of the surgical field and the location of surrounding important structures. This information cannot substitute a thorough knowledge of the surgical anatomy, but it can be particularly valuable in cases with poor anatomic landmarks caused by extensive disease or previous surgery.[1,2,4–7]

However, the use of this new technology is associated with increased costs, mainly due to equipment and surgical time.[2,9] To try to solve this matter, new devices are being developed using technological advances, reducing the size and cost of equipment.[9]

Today there are basically two types of image guidance: optic and electromagnetic based.[1,10,11] All optic-based image-guidance devices use stereoscopic cameras to provide tridimensional orientation.[1,11] The first generation of these cameras uses active markers that emit infrared light. This light is identified by the camera and used to calculate the stereoscopic location and orientation of the instruments. The second generation uses passive markers that reflect infrared light. The third generation uses predefined patterns to identify the position of any object marked with those patterns (Fig. 5). F5

We use a third-generation camera and a predefined black and white pattern for optical tracking. The camera is attached in a holder at a distance from 60 cm to 100 cm from the patient's marker, and it is linked to an up-to-date laptop through a standard firewire port. This

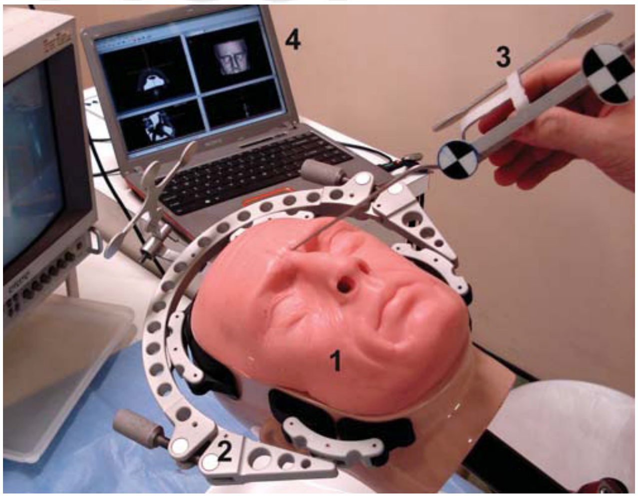

Fig. 2. Calibration of the image-guidance system. (1) Life-size anatomic model (SIMONT—Sinus Model Otorhino-Neuro Trainer); (2) headframe with patient localizer; (3) instrument with localizers; (4) laptop with developed navigation software.

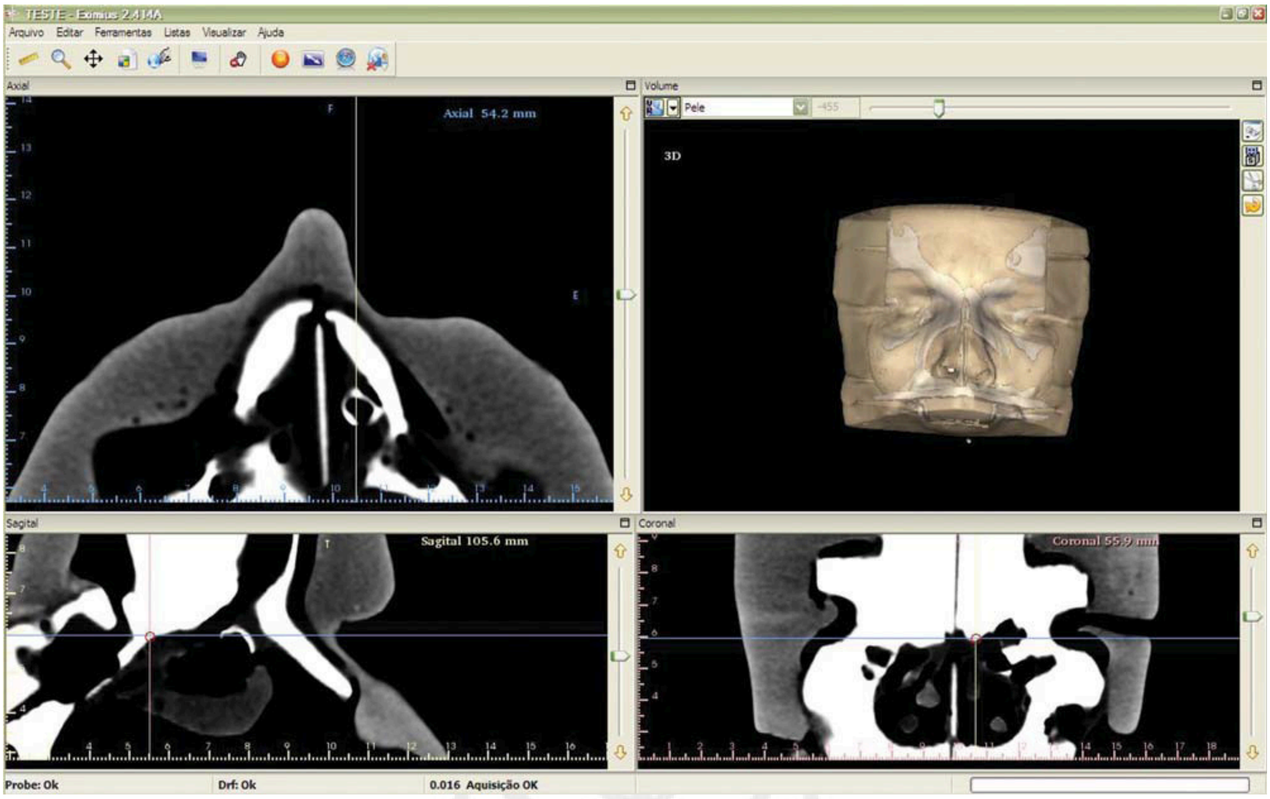

Fig. 3. Screen from the optical-based image-guidance software of the life-size model. The tip of the instrument is located at the skull base, as indicated by crosshairs on axial, coronal, sagittal, and three-dimensional images of the model's preoperative computed tomographic scan. This matches with the endoscopic view of the actual instrument's tip position.

port provides a power supply and a fast hub for information exchange, since the orientation functions need to be performed repeatedly at real-time rates.

We positioned at least three multifaceted black and white markers at each instrument to increase the detection angle range and increase pose measurement accuracy.

Accuracy to within 2 mm is generally acceptable during image-guided surgery.[8] Our laptop-based image-guidance system achieved an accuracy rate of 1.16 mm, showing its effectiveness and possible use in real patients.

A limitation of this study is that we did not obtain the overall accuracy of this system. Because it was a preliminary study, we used only a single model. A much larger series, involving more models, cadavers and patients, with the evaluation of multiple anatomic points will have to be done in the future before we can reliably determine the accuracy of this novel device.

The size and weight of our image-guidance system is also remarkable. It consists of a traditional laptop, in our case we use a compact 13.3-inch-wide screen, which weighs approximately 2 Kg, and a camera (10 × 5 × 5 cm), which can be safely used in operating rooms. The size of the screen did not seem to be a problem. The anatomic images could be well visualized on the 13.3-inch laptop screen. The traditional image-guidance devices have 17-inch or 19-inch screens. Of course, laptops with a similar screen, commercially available, can also be used.

The software used was specially developed and has a friendly interface. The recommended hardware described by the manufacturer is a computer with a Pentium or higher processor, 2 Gb of RAM memory, 100 Gb of hard drive, and a 64-Mb graphics card. It is totally compatible

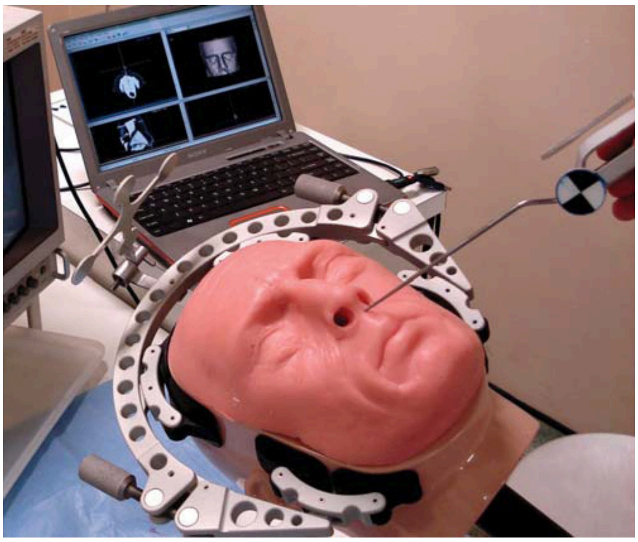

Fig. 4. Direct eye view of the instrument's tip position. It matches with the image-guidance position.

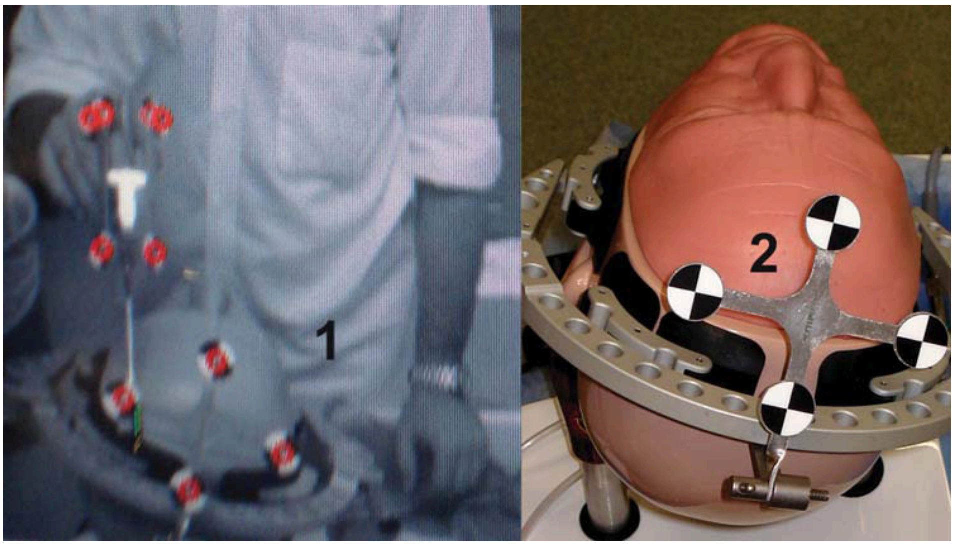

Fig. 5. Identifying patterns. (1) Tracking camera view of predefined patterns; (2) patient's localizer with the predefined patterns.

C O L O R

with the current operational systems available. In our case, we used a laptop with Microsoft Windows XP. No problems were encountered running the program.

CONCLUSIONS

We described a novel compact laptop-based image-guidance system. This compact navigation device was shown to be fast and reliable. A larger series, involving more models, cadavers, and patients, with the evaluation of multiple anatomic points needs to be done before we can reliably determine the overall accuracy of this novel device. However, this new system is promising, and in the future it can be part of the armamentarium of otolaryngologists' personal equipment in order to perform low-cost image-guided surgeries in different places with the same equipment.

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