Interactive navigation-guided ophthalmic plastic surgery: The techniques and utility of 3-dimensional navigation

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ABSTRACT •

Purpose: To demonstrate the techniques and utility of 3-dimensional reconstruction (3DR) of the target pathologies for subsequent navigation guidance in ophthalmic plastic surgery.
Study design: Prospective interventional case series.
Methods: Stereotactic surgeries using 3D reconstruction of target lesions as the intraoperative image-guiding tool were performed in 5 patients with varied etiopathologies. All the surgeries were performed using the intraoperative image-guided StealthStation system in the electromagnetic mode. 3DR was performed using StealthStation 3D model software. The utility of 3D reconstruction for extensive orbital mass lesions, large orbital fractures, intraconal foreign body, and delineation of perilesional intricate structures was studied. The intraoperative ease and usefulness for the navigation of a 3D lesion at crucial phases of the surgery were noted.
Results: Intraoperative geometric localization of the 3D lesions was found to be enhanced and precise. 3D reconstruction of the lesion along with the major vessels and nerves in the vicinity helped the surgeon to prevent potential injuries to these structures. The fracture defects could be navigated in a 3D plane and this helped in moderate customization of the implants intraoperatively. Foreign body located in difficult access positions could be accurately targeted for geometric localization before safe retrieval. Detailed preoperative 3D reconstruction by the surgeon was found to be beneficial for successful outcomes.
Conclusions: Three-dimensional navigation is very useful in providing detailed anatomical delineation of the targets and enhances the precision in certain complex cases in ophthalmic plastic surgery.

Navigation-guided ophthalmic plastic surgeries are being increasingly performed for complex cases because of the advantages of accurate intraoperative target localization, better orientation, and enhanced safety.[1–14] The effect of real-time navigation has been studied in animal models[15]; however, the three-dimensional (3D) navigation has been mostly used in complex spinal, skull base, and maxillofacial surgeries.[16–20] Interactive navigation-guided surgeries based on 3D reconstruction (3DR) of the lesions have been reported to enhance operative insights, better trajectory information, increased surgeon's orientation of the operative fields at critical locations, minimal collateral damage, and overall better patient safety.[16–20] To the best of the authors' knowledge, the literature is sparse on the use of 3DR navigation guidance in ophthalmic plastic surgery and is limited to cadaver studies, a single case of a foreign body, or part of major craniofacial reconstructions.[20–23] The authors of the present study report their techniques and utility of 3DR of lesions for subsequent navigation-guided ophthalmic plastic surgeries.

Methodology

Institutional review board approval and patient consents were obtained before the surgery. 3DR of target pathologies was performed preoperatively in 5 patients with varied etiopathologies. Stereotactic surgeries were then performed using the 3D reconstructed lesions as the additional intraoperative image-guiding tool. All the surgeries were performed using the intraoperative navigation-guided StealthStation S7 system (Medtronic, Minneapolis, MN) in the electromagnetic mode using the AxiEM technology. The utility of 3D reconstruction for extensive orbital mass lesions, large orbital fractures, intraconal foreign body, and delineation of perilesional intricate structures was studied. The intraoperative ease and usefulness for the navigation of a 3D lesion at crucial phases of the surgery were noted.

Technique of 3D Reconstruction

For intraoperative navigation, contiguous computed tomography (CT) scans of 1 mm thickness were performed from the superior aspect of the horizontal portion of mandible to the vertex as per the manufacturer's guidelines. The CT scans were uploaded to the StealthStation and a 3DR was performed using StealthStation 3D model software. At first, the threshold values of the CT scans were adjusted between the soft tissue and bony windows as per the requirement, which is based on the density of the target lesion (Fig. 1A). Planes of CT cuts are chosen, one at a time. For example, all coronal cuts can be chosen first.

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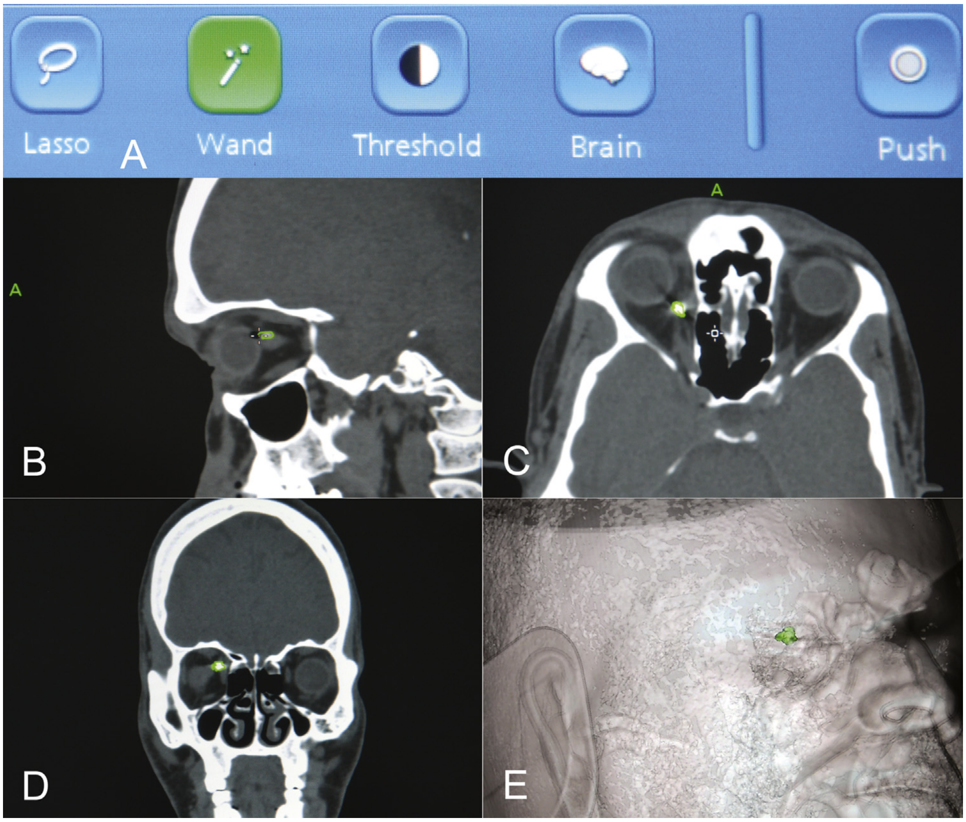

Fig. 1—Steps of 3D reconstruction of a foreign body. Software bar showing the various 3D reconstruction options for the surgeon (A). Computed tomography scan, sagittal section, showing the surgeon marking the boundaries of the foreign body (B). The foreign body is delineated in axial (C) and coronal (D) cuts. Three-dimensional reconstruction of the foreign body (*green*) ready for 3D navigation (E).

All representative cuts demonstrating the lesion are isolated and studied. Markers of various colours can then be used to demonstrate to the computer the extent of the lesion (Fig. 1B). Different colours are chosen for different structures. This marking can happen point wise (the wand mode) or area wise (the lasso mode) (Fig. 1A). Upon completion of the boundaries the lesion automatically illuminates in the designated colour (Fig. 1C and D). Such outlining of the lesion was performed in all the specified plane cuts that demonstrate the lesion. Occasional errors in marking can be erased either completely to restart marking that particular cut section or can be modified using the inbuilt push mode options (Fig. 1A). After completion of marking in one plane, the other planes (axial and sagittal) are marked similarly. Once marking of a plane—say, the coronal—is complete, the surgeon can shift to axial or sagittal and repeat the process (Fig. 1B–D). Although the computer is capable of interpolating the markings in one plane to another, the authors believe that manual marking of the target in all the planes enhances the computer's ability for a detailed anatomical delineation. Once the surgeon completes the marking, the computer would then build 3D models (Fig. 1E and Figs. 2–6) with multiple navigation-enabled functions.

After 3D delineation of the main target lesion, adjacent crucial structures such as major blood vessels and nerves can be marked separately in a different colour and reconstructed back in a 3D format as discussed earlier in the techniques. It is important to understand that CT angiography would help the surgeon immensely in 3D reconstruction of the blood vessels. For this the CT angiography should be merged with the regular CT using StealthMerge software, before beginning the 3DR.

Results

We illustrate 5 cases with a focus on demonstrating the utility of 3DR navigation guidance in ophthalmic plastic surgery.

Orbital Mass Lesions

To exemplify the usefulness of active 3DR navigation for orbital mass lesions, the authors present a case of a 22-year-old female with a left-sided proptosis of 3 years' duration. The CT scan showed an extensive left orbital lesion with bony expansion (Fig. 2A). The left orbital lesion was 3D reconstructed (red) as discussed earlier (Fig. 2B). The 3D reconstructed lesion could then be examined with great clarity in relation to surrounding anatomy before and during the navigation surgery. The