Abstract

Outcome Objectives: No integrated system exists to plan skull base operations, nor to design and test new surgical approaches. Our objective was to develop a method of surgical planning, selection of optimal surgical approach(es), and design of surgical corridor geometry using a computer model that creates physical models for iterative optimization, pre-surgery approach trial, and surgical education and evaluation.

Methods: The analysis was applied to a specific clinical scenario of accessing the lateral cavernous sinus. A computer analysis was performed to select the optimal surgical approach portal. Once derived, the specific geometry of the surgical corridor was designed for optimal visualization and instrumentation, while applying retraction limit constraints on specific soft tissue structures. A physical model of the surgical pathway was produced for testing, and the resultant approach was performed on 4 cadaver specimens.

Results: A lateral retrocanthal transorbital approach was selected based on computer analysis. The pathway length was 55.6 mm (SD: 4.4) to 67.1 mm (SD: 0.7), retraction distance away from orbital rim was 8.2 mm (SD: 0.3), corridor volume was 2,751 mm³ (SD: 736), and orbital areas at the portal entrance and greater wing of sphenoid were 127 mm² (SD: 19.2) and 210 mm² (SD: 14.0), respectively. Dry lab and cadaver testing validated the computer planning analysis.

Conclusion: A method was created and validated to determine the optimal surgical approach and pathway geometry for accessing a specific target pathology. It was robust and is applicable to many clinical scenarios. Initial evaluation in surgical cases has begun.

Background

• Current surgical planning is performed on 2 dimensional images. Even multi disciplinary, state of the art tumor board discussions do not incorporate 3 dimensional modeling.
• Surgical morbidity is decreasing, yet surgical complexity is increasing. Many surgical pathways exist that can access the same target, and there are boundary conditions for each based on individual anatomy. How to choose the best pathway?
• Objectives of our research are to create a computer model that permits (1) optimal selection of surgical pathway, (2) design of pathway geometry, (3) virtual endoscopy, and (4) the ability to create a physical model based on the virtual planning.

Methods

• The angles between potential portals, and distances to targets were computed using a computer model to access the lateral cavernous sinus. (x,y,z) coordinates from three dimensional imaging software that defined the approach vectors were used to calculate the angles and distances.
• The approach vectors with the most favorable angles relative to skull base and sagittal planes were selected.
• Virtual endoscopy was performed.
• Pathway boundaries defined: iterative design process to minimize orbital retraction along surgical pathway, yet maximize visualization and instrument range of motion at target location.
• Code was written to compute pathway volume by numerical integration.

Results

• The analysis was performed on 4 CT scans of normal skull base anatomy (2 males, 2 females, age range 23 to 59).
• The procedure was performed on three preserved lateral injected cadaver heads (6 orbits) with surgical navigation. Based on the morphometric analysis, retraction of orbital contents was limited to less than 9 mm.
• The lateral orbital rim does not need removal because this approach is retrocanthical and endoscopic. Unlike open approaches, this endoscopic approach starts by placing the surgeon at the medial floor of the middle fossa, thereby making temporalis muscle dissection and an extended temporal craniectomy unnecessary.
• Visualization was superb with direct on face view of the target location and critical surrounding structures.
• The average distance to the target locations was 6 cm compared to greater than 9.5 cm transanally.
• Removal of the bone of the lateral orbital rim is not required or beneficial; the only bone removed is that between the superior and inferior orbital fissures.
• Skeletionalization of the carotid via drilling is not required as would be in the transanathelio-endosigmoido-sphenoid endoscopic endonasal approach to the cavernous sinus.

Conclusions

• Complex operations, particularly those in the skull base, should be planned to the greatest extent possible to prevent complications and minimize unexpected intraoperative findings. This includes 3 dimensional modeling, visualization of pathway design, virtual endoscopy, and possibly even the production of a physical model.
• Computer modeling determined geometric limitations on orbital retraction and surgical access, and aided in the development of a surgical corridor that minimized collateral tissue damage.
• The greatest utility of this particular surgical approach may be for biopsy of lesions within Meckel’s cave and the lateral cavernous sinus.
• The morphometric analysis calculated cross sectional areas, quantified orbital volume retraction at 2.7 cm³, and demonstrated that less than 9 mm of retraction on the orbital contents can provide surgical access to the target location without removal of the orbital rim or a skin incision.
• The lateral retrocanthical approach offers minimal tissue disruption, adequate path volume, a short distance to the pathology, and does not necessitate manipulation of critical neurovascular structures.