Computational fluid dynamic modeling of nose-to-ceiling head positioning for Sphenoid Sinus Irrigation

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Objectives

- Introduction
- Materials and methods
- Results
- Discussion
- Literature Review
- Conclusion
Computational fluid dynamic modeling of nose-to-ceiling head positioning for sphenoid sinus irrigation

John R. Craig, MD,1 James N. Palmer, MD2 and Kai Zhao, PhD

Background: After sinus surgery, patients are commonly instructed to irrigate with saline irrigations with their heads over a sink and noses directed inferiorly (nose-to-floor). Although irrigation can penetrate the sinuses in this head position, no study has assessed whether sphenoid sinus penetration can be improved by irrigating with the nose directed superiorly (nose-to-ceiling). The purpose of this study was to use a validated computational fluid dynamics (CFD) model of sinus irrigations to assess the difference in sphenoid sinus delivery of irrigations after irrigating in a nose-to-floor vs nose-to-ceiling head position.

Methods: Bilateral maxillary antrostomies, total ethmoidectomies, wide sphenoidotomies, and a Draf III frontal sinusotomy were performed on a single fresh cadaver head. CFD models were created from postoperative computed tomography maxillofacial scans. CFD modeling software was used to simulate a 120-ml irrigation to the left nasal cavity with the following parameters: flow rate 3 mL/second, angle of irrigation 20 degrees to the nasal floor, and either nose-to-floor or nose-to-ceiling head positioning.

Results: In the postoperative CFD models, the sphenoid sinuses were completely penetrated by the irrigation while in a nose-to-ceiling head position. However, no sphenoid sinus penetration occurred in the nose-to-floor position. Other sinuses were similarly penetrated in both head positions, although the ipsilateral maxillary sinus was less penetrated in the nose-to-ceiling position.

Conclusion: CFD modeling demonstrated that the nose-to-ceiling head position was superior to the nose-to-floor position in delivering a 120-ml irrigation to the sphenoid sinuses. © 2017 ARS-AAOA, LLC.

Key Words: topical therapy for chronic rhinosinusitis; computational fluid dynamics; endoscopic sinus surgery; chronic rhinosinusitis; sphenoid sinus irrigation


Topical delivery to the paranasal sinuses is an active area of rhinologic research, with various microscopic and macroscopic factors of topical delivery being studied.

Among macroscopic factors, optimizing the delivery and distribution of sinus irrigations has been 1 of the more heavily studied areas. Penetration of the paranasal sinuses by topical irrigations is minimal in unoperated sinuses, regardless of head position or delivery device. Prior studies have analyzed different head positions such as vertex-to-wall (nose-to-floor), vertex-to-ceiling (nose-to-wall), and vertex-to-floor, and how they affect topical sinus delivery. After sinus surgery, irrigation can be delivered to each of the sinuses in a nose-to-floor head position, provided high-volume delivery devices (≥100 mL per side) are used. Generally studies have focused on optimizing irrigation delivery to the maxillary, ethmoid, and frontal sinuses, as these sinuses are more commonly involved with recalcitrant disease. Recalcitrant sphenoid sinus disease has received little attention in the literature, and therefore has

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Introduction

- Topical delivery to the paranasal sinuses is an active area of rhinologic research.
- Optimizing the delivery and distribution of sinus irrigations has been one of the more heavily studied areas.
- Penetration of the paranasal sinuses by topical irrigations is minimal in unoperated sinuses, regardless of head position or delivery device.
- Recalcitrant sphenoid sinus disease has received little attention in the literature.
Head Positions?
Head Positions?

Mygind’s Position
Head Positions?
Head Positions?

Ragan Position
Head Positions?
Head Positions?

Moffett Position
Purpose

The purpose of this study was to use a validated computational fluid dynamics (CFD) model to compare the degree of sphenoid sinus penetration by irrigation after sinus surgery on a cadaver, in nose-to-floor vs nose-to-ceiling head positions.
Materials and methods

- One fresh cadaver head was obtained from the University of Pennsylvania morgue.
- Full house FESS and Draf III
- SinusRinse® squeeze bottle (was angled at approximately 20 degrees to the nasal floor. Irrigation of 120 mL was performed to the left nasal cavity at a volume flow rate of 30 mL/second (120 mL per side over 4 seconds)
Materials and methods

- Postoperative CFD models were then created from the postoperative cadaveric CT scans.
Materials and methods

- Irrigation penetration of each of the paranasal sinuses was graded ipsilateral and contralateral to the side of irrigation. The following grading scale was used to classify and compare the degrees of sinus penetration by the irrigation:
  - 0 = no penetration
  - 1 = minimal or slow filling
  - 2 = complete or rapid filling.
### Results

**Table 1.** Grading (0–2) and comparison of irrigation penetration into the sphenoid sinuses after surgery in the cadaver experiment and CFD model.

<table>
<thead>
<tr>
<th></th>
<th>CFD (nose-to-floor)</th>
<th>CFD (nose-to-ceiling)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sphenoid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left, ipsilateral</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Right, contralateral</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Maxillary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left, ipsilateral</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Right, contralateral</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Ethmoid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left, ipsilateral</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Right, contralateral</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Frontal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left, ipsilateral</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Right, contralateral</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Results
Discussion

- The findings from this study suggest that after sphenoidotomy, the nose-to-ceiling head position is an alternative to other classically described head positions for delivering topical irrigations to the sphenoid sinus.
- The CFD models compared in this study support the hypothesis that placing the sphenoid sinus in a gravity-dependent nose-to-ceiling position can improve topical delivery to the sphenoid sinus.
Discussion

- Singhal et al. assessed 10 cadaver heads endoscopically while delivering 120-mL irrigations in 3 different head positions.

✓ Conclude:
- even in an unoperated state the sinus was penetrated, and penetration increased after sphenoidotomy.
- There were no significant differences in sphenoid sinus penetration between the 3 head positions tested.

Discussion

- Beule et al. performed Draf IIIs and wide FESS on 19 cadaver heads, and irrigated the heads with varying volumes of irrigation (50 to 200 mL) stained with fluorescein, methylene blue, or food coloring. They assessed the mucosal area of staining of each sinus after irrigation.

✓ Conclude:
  - 20% of the sphenoid sinus was stained at all volumes of irrigations
  - maxillary, ethmoid, and frontal sinuses were each more significantly penetrated with increasing irrigation volumes to upward of 60% to 70%.

Discussion

- Chen et al. performed irrigations on 5 cadaver heads after varying degrees of surgical openings to each of the sinuses, including the sphenoid sinus. Heads were oriented with the nose facing 45 degrees downward. They compared sinus penetration between a 240-mL squeeze bottle vs a pulsating irrigator.

✓ Conclude:
  - neither device achieved heavy penetration of the sphenoid sinus

Criticism

- Only 1 cadaver
- Variable anatomy, extents of surgery, and irrigation parameters may lead to different degrees of sphenoid sinus penetration.
- Cadavers are not ideal representations of live patients
- Oropharyngeal penetration?
- Requires standing in a bath or shower
Conclusion

- Based on a CFD model of sinonasal irrigations, the nose-to-ceiling head position was more effective than the nose-to-floor position at delivering high-volume saline irrigations to the sphenoid sinuses after sphenoidotomies.
Thank You