

The effect of head position on the distribution of topical nasal medication using the Mucosal Atomization Device: a cadaver study

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Background: The Mucosal Atomization Device (MAD) distributes medication throughout the paranasal sinuses for patients with chronic rhinosinusitis (CRS). Determining the optimal head position is important to ensure maximal delivery of medication to the sinus cavities. The objective of this work was to determine the effect of the lying-head-back (LHB) and head-down and forward (HDF) position, on the distribution of topical nasal medication via MAD in cadaver specimens.

Methods: Twenty specimens having received complete functional endoscopic sinus dissection were chosen. The MAD was used to administer 2 mL of fluorescein-impregnated saline solution through the nose in both the LHB and HDF positions. Fluorescein was identified on 11 predetermined anatomical areas using a blue light filter. Three blinded investigators assessed endoscopic images to determine the presence of fluorescein.

Results: A total of 440 anatomical locations ($n = 20$ cadavers) received administration of the fluorescein nasal spray in the LHB or HDF position. LHB position had significantly greater total distribution to all pertinent anatomical sites

than the HDF position (76% vs 41%; $p < 0.001$; 95% confidence interval [CI], 0.26–0.44). The proportion of staining was significantly greater for the ethmoid ($p = 0.11$; 95% CI, 0.05–0.66), frontal ($p < 0.01$; 95% CI, 0.20–0.80), and sphenoid sinuses ($p = 0.03$; 95% CI, 0.07–0.73) when compared to the HDF position.

Conclusion: A greater distribution of medication to the sinonasal cavities was observed in the LHB position compared to the HDF position. These areas are of particular clinical relevance in postsurgical patients with refractory CRS. © 2013 ARS-AAOA, LLC.

Key Words:

endoscopic sinus surgery; paranasal sinuses; sinusitis; topical therapy; chronic rhinosinusitis; medical therapy

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Topical medications administered by nebulizers are frequently used for patients suffering from chronic rhinosinusitis (CRS). This technique is most useful for widespread inflammation of the olfactory cleft, ethmoid, sphenoid, and frontal sinuses where increased inflammation may obstruct drainage pathways.¹ Obstructed sinus ostia may prevent mucosal clearance, impair ciliary function, and

subsequently contribute to infection. Topical medication, such as steroid therapy, is an effective method to locally reduce inflammation and is associated with few systemic side effects.^{1,2} The success of atomized nasal medications is dependent on multiple factors such as gravity, obstructing anatomical structures, and delivery methods.^{3,4} Several delivery methods and head positions for topical nasal therapies have previously been evaluated to determine the optimal position.^{1–7} Presently there is no preferred method to administer atomized steroids to the paranasal sinuses.^{8,9} Merkus et al.⁹ assessed the effect of 3 different patient positions to determine the best method to deposit atomized nasal medication to the middle meatus. Although no statically significant difference was found between the 3 head positions, the head-down and forward (HDF) position showed improved deposition in areas superior to the middle meatus and olfactory region.⁹

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Current practice at the St. Paul's Sinus Centre (SPSC), a tertiary rhinology center, is to administer topical medication via the Mucosal Atomization Device (MAD; Wolfe-Tory Medical, Salt Lake City, UT).¹⁰ This device is advantageous as it produces a fine mist, increasing the potential contact surface area within the nasal cavity and paranasal sinuses. Clinician experience has found that patients administering medication in the lying-head-back position (LHB) can effectively treat the edematous mucosa of the ethmoid roof and frontal sinus recess. Patients are routinely instructed to lie supine and hang their heads over the edge of their bed to best simulate this position. Our objective was to determine if the LHB position increased medication dispersal within sinonasal cavities compared to the HDF position in a human cadaver model.

Materials and methods

Cadaver specimens were gathered from 2 advanced sinus surgery courses taking place in July and August 2012. Ethics approval was obtained from the University of British Columbia Research Ethics Board prior to the start of this study. Subjects included were cadaver specimens without previous sinus surgery, nasal polyposis, significant septal deviations, septal perforations, or facial trauma. All specimens received complete endoscopic dissection, which included bilateral uncinectomy, maxillary sinus antrostomy, ethmoidectomy, sphenoidotomy, and frontal sinusotomy (Draf Type IIa).

Postdissection, 2 ml of fluorescein (Fluorescite Injection, Alcon Inc., Fort Worth, TX) was mixed in a sterile emesis basin with 90 mL of sterile saline to produce a 0.20 mg/mL solution. This solution was then drawn into a 3-cc (3-mL) Luer-Lock syringe affixed to a MAD to distribute 1 mL of solution to the right and left nasal valves. Cadaver specimens received treatment in either the LHB or HDF position. The LHB position was defined as the chin being at the highest point of the head,⁹ 60 degrees below the horizontal plane. This angle was selected to simulate the position of a patient as their head hangs over the edge of their bed (Fig. 1). The HDF position was defined as the forehead close to the knees⁹ at an angle of 40 degrees below the horizontal plane with the nostrils facing upwards (Fig. 2).⁹ An analog protractor accurate to the nearest degree was used to confirm and standardize each orientation. Once positioned, three-quarters of the MAD tip was inserted at a 45-degree angle into the nasal aperture and then directed to the ipsilateral orbit. One milliliter (1 mL) of fluorescein solution was atomized through the right or left nostril (depending on study arm) and the specimen remained in position for 30 seconds prior to endoscopy. Rigid nasal endoscopy was performed with a 0-degree and 30-degree pediatric endoscope with a blue-light filter attached to the light source (Karl Storz). Images of the paranasal sinuses (maxillary, ethmoid, sphenoid, frontal) and other clinically relevant locations (inferior turbinate, anterior septum, middle turbinate, olfactory cleft, frontal recess, sphenoid recess, and nasopharynx) were captured. The right paranasal sinuses were first to receive the fluorescein spray for all specimens included. Once the procedure was completed on the right side, the head was reoriented to the alternative head position and the left paranasal sinuses received the fluorescein nasal spray. To prevent retrograde regurgitation of the dye, the sinus cavities were vigorously rinsed with normal saline and excess dye was removed from the endoscope with an alcohol swab, prior to spraying the opposite paranasal sinuses. Sinus cavities were visualized to confirm the dye was removed. These procedures were standardized for all specimens. Blinded evaluation of all captured images was conducted independently by 3 rhinologists (A.R.J., E.C.G., and A.V.T.) to determine the

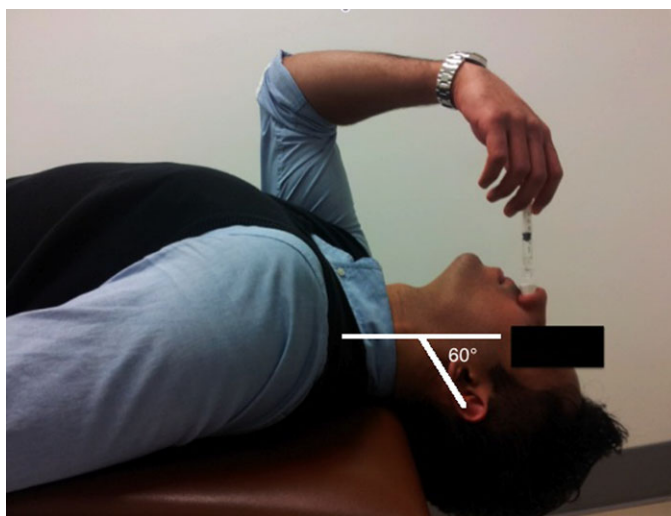


FIGURE 1. LHB position angled approximately 60 degrees below the horizontal plane. LHB = lying head back.



FIGURE 2. HDF position angled to approximately 40 degrees below the horizontal plane. HDF = head-down and forward.

noethmoid recess, and nasopharynx) were captured. The right paranasal sinuses were first to receive the fluorescein spray for all specimens included. Once the procedure was completed on the right side, the head was reoriented to the alternative head position and the left paranasal sinuses received the fluorescein nasal spray. To prevent retrograde regurgitation of the dye, the sinus cavities were vigorously rinsed with normal saline and excess dye was removed from the endoscope with an alcohol swab, prior to spraying the opposite paranasal sinuses. Sinus cavities were visualized to confirm the dye was removed. These procedures were standardized for all specimens. Blinded evaluation of all captured images was conducted independently by 3 rhinologists (A.R.J., E.C.G., and A.V.T.) to determine the

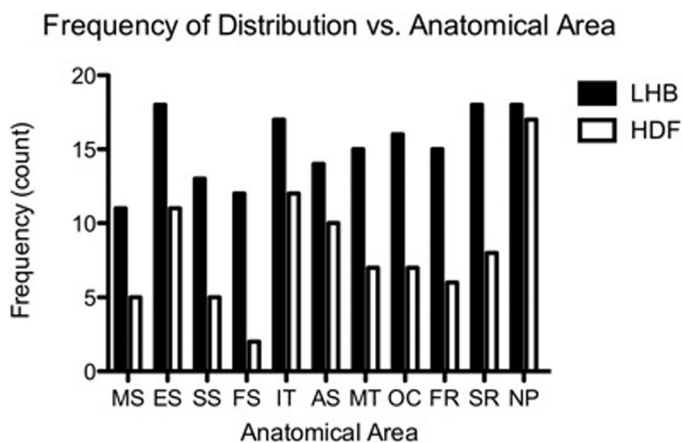


FIGURE 3. Comparison of distribution frequency for anatomical areas evaluated by head position. AS = anterior septum; ES = ethmoid sinus; FR = frontal recess; FS = frontal sinus; IT = inferior turbinate; MS = maxillary sinus; MT = middle turbinate; NP = nasopharynx; OC = olfactory cleft; SR = sphenoethmoid recess; SS = sphenoid sinus.

distribution of fluorescein. Validating the presence or absence of fluorescein required agreement by 2 of 3 blinded investigators for each anatomical location.

The presence of fluorescein was collected as a binary outcome. For statistical analysis, a *p* value greater than type I error of 5% ($\alpha = 0.05$) was used to determine statistical significance. When expected cell count assumptions were met, the chi-square parametric test was completed to calculate an odds ratio (OR) for overall staining. The right and left sides were identified as independent cavities in this study as the surgeon performing the dissection was not consistent for each specimen.

Results

Twenty cadaver specimens ($n = 40$, including right and left sinonasal cavities) were included in this study. No specimens presented with severe facial trauma or sinonasal abnormalities. A total of 440 anatomical areas were evaluated, 220 for each position respectively, which included the paranasal sinuses and other clinically relevant locations as defined above in the Methods.

Of the 220 areas evaluated for each orientation, fluorescein was identified at a count of 167 (76%) in the LHB and 90 (41%) in the HDF position. Independent 2-sample proportion analysis showed that the LHB position had a significantly greater proportion of total fluorescein stains when compared to HDF ($p < 0.001$; 95% confidence interval [CI], 0.26–0.44). The chi-square test examining the relationship between fluorescein distribution and head position indicated that this relationship was statistically significant ($p < 0.001$; OR = 4.6; 95% CI, 3.0–6.9). A greater proportion of staining for each area evaluated was found in the LHB position (Fig. 3). Individual comparisons indicated that the fluorescein reached the paranasal sinuses and other clinically relevant anatomical areas more in the LHB than the HDF position (Fig. 3). These findings were statistically

TABLE 1. Two-proportion test results comparing LHB and HDF positions

Location	LHB stain frequency	HDF stain frequency	<i>p</i>	95% CI
Total ($n = 220$)	167	90	<0.001	0.26 to 0.44
MS	11	5	0.11	–0.01 to 0.64
ES	18	11	0.03	0.05 to 0.66
SS	13	5	0.03	0.07 to 0.73
FS	12	2	<0.01	0.20 to 0.80
IT	17	12	0.16	–0.07 to 0.57
AS	14	10	0.33	–0.15 to 0.55
MT	15	7	0.03	0.07 to 0.73
OC	16	7	0.01	0.13 to 0.77
FR	15	6	0.01	0.12 to 0.78
SR	18	8	<0.01	0.20 to 0.80
NP	18	17	1.0	–0.20 to 0.30

AS = anterior septum; CI = confidence interval; ES = ethmoid sinus; FR = frontal recess; FS = frontal sinus; HDF, head-down and forward; IT = inferior turbinate; LHB, lateral-head-back; MS = maxillary sinus; MT = middle turbinate; NP = nasopharynx; OC = olfactory cleft; SR = sphenoethmoid recess; SS = sphenoid sinus.

significant for the ethmoid ($p = 0.03$), frontal ($p < 0.01$), and sphenoid ($p = 0.03$) sinuses ($p < 0.01$). Similarly, staining was found more frequently on the middle turbinate, olfactory cleft, frontal recess, and sphenoethmoid recess in the LHB position. These findings were statistically significant (Table 1).

Discussion

Postoperative nasal irrigation and pharmacotherapy is an important aspect of outcomes management following functional endoscopic sinus surgery (FESS). Depending on the institution, the standard of care may dictate that medications be administered via impregnated nasal irrigation, or that separate devices be used to irrigate the nose and apply topical medications. Common nasal irrigators include the 240-mL PowerRinse bottle (Honeydoc Inc, Vancouver, Canada), the 240-mL NeilMed Sinus Rinse bottle (NeilMed Pharmaceuticals, Inc., Santa Rosa, CA), the 240-mL NetiPot (NeilMed Pharmaceuticals), and Nasal-Care Rinse bottle (TechWorld Corp Inc., Las Vegas, NV). Medications delivered via nasal irrigation tend to get diluted and are therefore less effective. The atomization device allows for a more concentrated dose to be delivered to the area in need. There are a number of atomization devices on the market and they can be divided into 3 different types: squeeze, pump, and mechanical. The MAD is considered a pump atomization device.

The clinical literature on the efficacy of the MAD is scarce. The only clinical study in otolaryngology assessing

the efficacy of the MAD showed that topical budesonide via MAD may reduce the need for systemic prednisone and improve both physician and patient global assessment scores in postsurgical CRS patients.¹ To our knowledge, there are currently no published data in the literature on the effects of different head positions on the distribution of topical medication in the sinuses using the MAD. This is the first study to assess the optimal head position for CRS patients using the MAD. This study shows that specimens oriented in the LHB position have greater dispersal of medication throughout the sinonasal cavities than specimens oriented in the HDF position. The odds of overall staining in the LHB position are 3.2, whereas the odds of overall staining in the HDF position are 0.7. This can also be interpreted as; the odds of overall staining in LHB is 4.5 times greater than the odds in the HDF position. This knowledge is vital to providing optimal care to postsurgical patients. Senior et al.¹¹ showed that adequately treating mucosal inflammation after surgery either medically or with debridement nearly eliminates chance of revision surgery. Moreover, recurrent frontal sinusitis is a common cause for revision surgery.¹² Based on the results of our study, the LHB position should be the recommended position for administration of topical intranasal medication. We hypothesize that increased spatial distribution of medication due to the LHB position may reduce global and frontal sinus-specific mucosal inflammation. However, this hypothesis must be evaluated in subsequent human trials accounting for variations in angle of the head, sinonasal anatomy, and force of plunger depression.

The degree of dissection to open sinus cavities can also impact distribution. The degree of opening into the maxillary sinus can be controversial. Grobler et al.¹³ determined that an ostia larger than 3.95 mm resulted in reliable sinus penetration. However, Singhal et al.⁸ defined the critical ostia size to be 4.7 mm, because greater ostia size resulted in increased sinus penetration. This was further supported by Hyo et al.¹⁴ Sphenoid sinuses, on the other hand, do not have a maximal ostial size and the penetration into the sphenoid sinus is correlated with size.⁸ However, in our experience, it is prudent to limit the sphenoidotomy to 5 to 10 mm, because patients complain of headaches from inspiring cold air when the majority of their sphenoid face has been removed. Much like the sphenoid sinus, increased penetration into the frontal sinus occurs with further dissection.⁸


The optimal size of aerosolized particles has also been investigated and remains a controversial topic. Study by Negely et al.¹⁵ showed that large particles, 20 to 30 μm , deposit into the maxillary and frontal sinus, and Hwang et al.⁶ concluded that the optimal size was just larger than 12 μm . On the other hand, studies have also shown that the optimal particle size for sinonasal penetration is

<5 μm .^{16,17} The manufacturer of the MAD cites a particle size in the range of 30 to 100 μm , which is considered a large particle. Our study supports the studies done by Negely et al.¹⁵ that larger particles can penetrate sinus cavities.

The strength of this study lies within its methodology. The use of fluorescein is well validated for determining distribution within the sinonasal cavity.¹⁸ Moreover, blinded evaluation of the fluorescein distribution removed assessment bias. Last, the cadaver dissections allow for better assessment of the distribution of the particles compared to live patients. Unfortunately, certain elements of the cadaver model can confound extrapolation of these results to CRS patients. The postsurgical FESS patient may have blood clots, mucus, or polyps that could impact the distribution which cannot be appreciated in a cadaver model; in addition, cadavers do not have the moist ciliated mucosa that may help with distribution seen in live humans. A limitation of this study is that we used a dichotomous outcome variable to assess the presence or absence of fluorescein-impregnated nasal spray, rather than a continuous numerical scale. Also, several surgeons performed the cadaveric dissections, which could not be controlled. However, the specimens were used for study purposes after the first day of instruction, before extensive intracranial and orbital dissection had occurred.

This is the first study to determine the distribution of aerosolized particles using the MAD with 2 commonly used positions. We have found that the LHB appears to be the optimal position for distribution of medication using the MAD. The next step is to perform a similar trial in human subjects to determine if these results are valid and if mobile cilia carry medication to or away from relevant areas over time. This may provide further evidence on the impact of patient position on the distribution of nasal medication.

Conclusion

This study evaluated the effect of patient position on the distribution of nasal medication using the MAD. The LHB position was found to be superior in global distribution of fluorescein-impregnated saline solution and for the ethmoid, frontal, and sphenoid sinuses. These areas are of particular clinical relevance to reduce mucosal edema in postsurgical patients with refractory CRS. 

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