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Radiographic Comparison of Three Methods for Nasal Saline Irrigation

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Objective: **To compare intranasal distribution of saline solution delivered by three popular methods for nasal saline irrigation.** ***Study Design:*** **Prospective, controlled comparison.** ***Methods:*** **Eight healthy adult volunteers received nasal irrigation with 40 mL of isotonic, nonionic contrast material immediately before having coronal computed tomography to visualize distribution of solution in the paranasal sinuses. For each study subject, three methods of irrigation were used: irrigation using positive-pressure irrigation, irrigation using negative-pressure irrigation, and irrigation using a nebulizer. For each subject, three-dimensional computer reconstructions of the irrigated paranasal sinus airspaces were used to compare contrast solution volume and distribution achieved by the three methods.** ***Results:*** **Of the three methods used, two methods, positive-pressure and negative-pressure irrigation, distributed contrast solution widely to ethmoid and maxillary sinuses, but distribution of contrast solution was more uniform using positive-pressure irrigation than using negative-pressure irrigation. The nebulization method distributed contrast solution poorly and resulted in a significantly lower volume of retained contrast solution (*P* <.05).** ***Conclusion:*** **Judged solely on the basis of solution distribution in the nasal sinuses, nasal irrigation is effective when either positive-pressure or negative-pressure irrigation is used but is ineffective when a nebulizer is used.** ***Key Words:*** **Equipment design, irrigation, nasal, isotonic solutions, paranasal sinuses, rhinitis, sinusitis.**

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INTRODUCTION

The nasal saline rinse has long been a mainstay of treatment for sinonasal disease because of its economy, safety, and apparent efficacy. Hypertonic and isotonic saline rinses have proved to be effective therapy against chronic sinusitis[1–3] and chronic rhinitis.[4] The weight of evidence is sufficient for the international consensus report of the Allergy Foundation to recommend routine use of these rinses in rhinitis.[5] Formulation of saline rinses varies widely from study to study: Concentrations range from physiological (0.9%) to hypertonic (various concentrations as high as 7%). Regardless of formulation, a growing consensus holds that the mechanism by which the saline acts is to increase the efficiency of the mucociliary transport system by decreasing the viscosity of the mucociliary blanket, decreasing edema, or both.[6,7] Common to all theories is the premise that the saline must be in direct contact with the target tissue to be effective.

There are numerous techniques available to deliver nasal saline rinses. These techniques range from simple inhalation into the nasal cavity to delivery by sophisticated devices that aerosolize saline under pressure. Despite this diversity, few studies have examined distribution of saline irrigation in the nasal cavity and paranasal sinuses,[8,9] and no published study has compared distribution by different methods.

Radiographic techniques have been employed in past studies using a radiopaque marker in place of the saline.[1,2] However, given the anatomic complexity of the nasal cavity and paranasal sinuses, traditional techniques such as technetium-99m imaging[9] have shown little more than a rough qualitative picture of the distribution of tracer material. At present, with three-dimensional computed tomography (CT) imaging, the shape and volume of complex structures such as the sinonasal system can be delineated.[10,11] Therefore, a combination of radiocontrast imaging and three-dimensional CT reconstruction can be used to accurately measure the spaces in the paranasal cavity as well as the distribution of contrast material on the mucosa.

In the present study, we compared three widely used methods for nasal irrigation by using three-dimensional CT imaging as well as qualitative and quantitative outcome measures to elucidate the optimal technique based on the distribution of rinse solution.

SUBJECTS AND METHODS

The Kaiser Permanente Northern California Institutional Review Board approved the study protocol, and participant consent was obtained. Eight healthy adult volunteers (five men and three women) with no history of acute or chronic paranasal sinus disease, symptomatic septal deviation, seasonal allergies, aller-

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gies to contrast, or nasal polyps were enrolled in the study. Ages of the study subjects ranged from 19 to 42 years.

Forty milliliters of an isotonic, nonionic, iodine-based contrast solution (Omnipaque, Amersham Health, Princeton, NJ) at an ionic strength of 140 mgI/mL was used for irrigation. The contrast solution was heated to 37°C, which gave it a viscosity of 1.5 mPa, approximately 1.5 times the viscosity of isotonic saline. Before irrigation, each subject was given phenylephrine spray decongestant to eliminate the effect of the nasal cycle and to reduce mucosal irregularities. The subject then performed irrigation with the solution, and an immediate coronal paranasal CT scanning was obtained with the patient in the prone position using a GE LightSpeed helical CT scanner (GE Medical Systems, Fairfield, CT). Scans were obtained at 2.5-mm intervals; reconstructions were created at equal intervals between scan slices. This protocol was repeated for each of three nasal irrigation methods with an interval of 24 hours or more between scans to allow complete clearing of contrast material by the mucociliary mechanism in each study subject.

The nasal irrigation methods were selected to represent fundamentally different approaches. In the first method, negative-pressure irrigation, contrast material is poured into the palm of the hand and is inhaled, or "sniffed," through both nares until 40 mL of material is used. The second method uses externally generated, positive-pressure irrigation and is represented in the present study by a commercially available squeeze bottle, the Sinus Rinse (NeilMed, Inc., Santa Rosa, CA) (Fig. 1), which delivers a gentle stream of saline to the nasal cavity. Using this method, each naris was irrigated with 20 mL of contrast solution. The third method, the RinoFlow (Respironics HealthScan, Inc., Cedar Grove, NJ) (Fig. 1) is a nebulizing device that delivers droplet particles in the 20- to 30-μm range in a controlled flow. There are two flow settings on the device: low flow (to "loosen" nasal debris) and high flow (to achieve maximal penetration into sinus cavities). The nebulizer chamber was filled with 10 mL of fluid, placed in the low-flow position, and held to the naris while the subject breathed normally through the nose until the chamber was emptied. This procedure was repeated in the opposite naris. The device was then placed in the high-flow position, and the nebulization was repeated with both nares to deliver a total of 20 mL per naris. Because the contrast material is slightly more viscous than saline, the device was tested before the study began to ensure that the contrast agent would be a reasonable proxy for isotonic saline. The RinoFlow yields a "plume" of aerosol that is easily visualized when lit against a dark background. When the height and width of the plumes using both isotonic saline and isotonic contrast material were compared, they were similar, as were the emptying times for a given volume in the nebulizing chamber (Table I). Thus, the flow rate and strength were assumed to be comparable between isotonic saline and the contrast agent.

Fig. 1. (**A**) Sinus Rinse nasal irrigation applicator (shown by permission of NeilMed Products, Inc.) and (**B**) RinoFlow nebulizer.

Coronal CT scan results were first analyzed to determine qualitative extent of distribution. For this purpose, the sinonasal cavity was divided into five anatomic subunits: nasal cavity, ethmoid sinuses, maxillary sinuses, frontal sinuses, and sphenoid sinuses. Any evidence of contrast material within a subunit was noted. Quantitative measurements were made by using a three-dimensional software program (Voxtool, version 3.0.3, General Electric Corp., Fairfield, CT), which reconstructed the volume of airspace in the nasal cavity as well as the volume of contrast material distributed into the nasal cavity. To create the reconstruction, CT source images were first manipulated in the Voxtool program to eliminate the images of high-density bone and teeth surrounding the sinonasal cavities. The sinus airspaces were rendered with a three-dimensional surface model, which confined the measured image to Hounsfield values ranging from −1024 to −400 H. The volume of contrast solution distributed was measured in a separate surface-rendering model, which confined the measured image to threshold Hounsfield values ranging from 1500 to 3000 H. Figure 2 shows a source image and a resulting three-dimensional reconstruction. Measurements of contrast volume were analyzed using the Statistix software package (version 7, Analytical Software, Tallahassee, FL). Given the small sample size and the heterogeneity of data between individual subjects, analysis required use of a nonparametric test, which was blocked by subject. Because Wilcoxon's ranked sum test fulfilled these criteria, it was chosen for analysis of continuous volumetric data. Categorical presence–absence data were analyzed with the sign test, a nonparametric test appropriate for analysis of blocked categorical data. The alpha value was set at 0.05.

RESULTS

The data are shown in Figures 3 and 4 and are described in this section for each irrigation method. In all subjects, each method of nasal irrigation distributed contrast material to the nasal cavity, but the sphenoid and frontal sinuses were poorly irrigated, regardless of method used (Fig. 3): Contrast solution reached the sphenoid sinuses in only one of eight subjects when negative- or positive-pressure irrigation was used, and contrast solution did not reach the sphenoid sinus in any subject when the nebulizer was used. Similarly, frontal sinuses were irrigated in two of eight subjects when negative- or positive-pressure irrigation was used but not when the nebulizer was used.

Differences between the three methods became evident when results for maxillary and ethmoid sinuses were compared. Of eight study subjects, negative-pressure irrigation reached the ethmoid sinuses in seven subjects, and positive-pressure irrigation reached the ethmoid sinuses in six subjects. The nebulizer irrigated the ethmoid si-

TABLE I.
Flow Rate and Plume Height Achieved by RinoFlow Nasal Irrigation Method Using Each of Two Irrigation Solutions.

	Plume Height (cm)	Emptying Time (min:sec)
Isotonic saline solution	35.4	2:46
Isotonic contrast solution	36.2	2:59

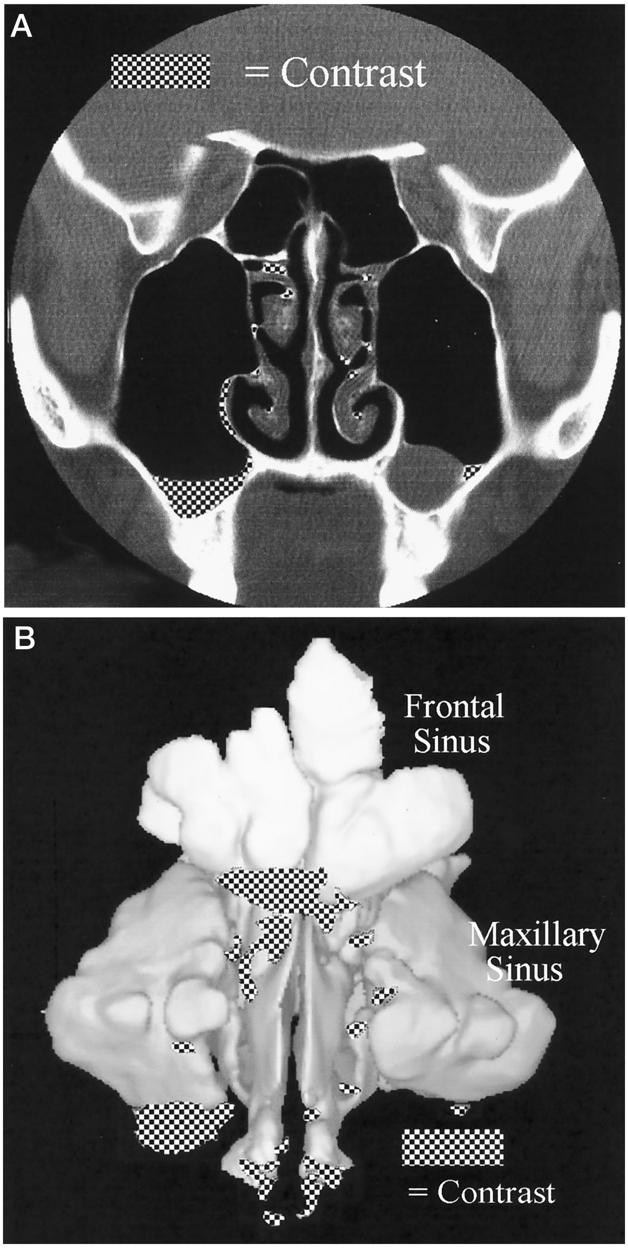

Fig. 2. (**A**) A computed tomography source image and (**B**) the image as reconstructed in three dimensions by computer.

nuses in two of eight subjects, significantly fewer than with either negative-pressure or positive-pressure irrigation ($P < .05$). Distribution of contrast solution to maxillary sinuses differed most between methods: The maxillary sinuses were irrigated by negative-pressure irrigation in five subjects (bilaterally in one subject), by positive-pressure irrigation in seven subjects (bilaterally in five subjects), and by the nebulizer in two subjects (bilaterally in no subjects). The nebulizer was significantly less effective than positive-pressure irrigation for distributing contrast solution to the maxillary sinuses.

The volume of contrast solution retained in the nasal sinuses varied widely between study subjects (Fig. 4). The highest mean volume (1.1 mL [range, 0.1–4.9 mL]) was distributed by positive-pressure irrigation. Negative-pressure irrigation distributed a mean volume of solution (0.7 mL) that was lower than but not significantly different from the volume delivered by positive-pressure irrigation. The nebulizer distributed the lowest mean volume, and even the highest volume distributed by the nebulizer (0.6 mL) was lower than the mean volume distributed by either of the other two techniques. A significantly higher volume of contrast solution was retained by use of positive-pressure irrigation than by use of the nebulizer.

DISCUSSION

The three methods tested in the present study were chosen to represent fundamentally different approaches to nasal irrigation. Negative-pressure irrigation uses internally generated nasal inhalation to draw saline into the nasal cavity. Because it uses no external equipment for delivery, negative-pressure is the simplest, least expensive irrigation method and is maintenance free. However, delivery of saline is difficult to control with this method, and it has the disadvantage of preferentially irrigating the side of the nasal cavity able to generate the strongest negative pressure (i.e., the more "open" side). This factor may be why the negative-pressure irrigation technique tended to irrigate one maxillary sinus or the other, but not both.

The second method, positive-pressure irrigation, uses an external device to generate pressure and drive saline into the nasal cavity. Positive-pressure irrigation retained a larger volume of contrast solution and irrigated the sinuses more consistently than the other methods, although results were not significantly different from those of negative-pressure irrigation. Other devices within the positive-pressure category include the bulb syringe and the Grossan Nasal Irrigator Tip (Inmunotek, Madrid, Spain).

The third approach, the RinoFlow nebulizer, uses technology previously applied to oral nebulizing devices for delivery of drugs to the bronchopulmonary system. The system is comfortable and easy to use but is expensive ($159.00 per unit) and time-intensive, requiring approximately 10 minutes per treatment. Of the three methods for nasal irrigation, the nebulizer gave the poorest results: Distribution of contrast solution beyond the nasal cavity was poorest, and volume of retained contrast solution was lowest. These findings contradict results of an earlier study,[8] which showed maxillary sinus penetration by solution in two of five study subjects using the RinoFlow nebulizer. That study[8] used technetium-99m and a gamma camera, a technique with much lower spatial resolution than CT imaging.

In the present study, qualitative description of contrast distribution and quantitative measurements of retained contrast volume were used to infer the optimal technique for nasal saline rinsing. Use of radiopaque contrast material and helical CT imaging has clear advantages over other radiological techniques. Computed tomography has unmatched spatial resolution, and the source image data may be used to create three-dimensional computer reconstructions and to take precise volumetric measurements for objects of interest (i.e., sinus

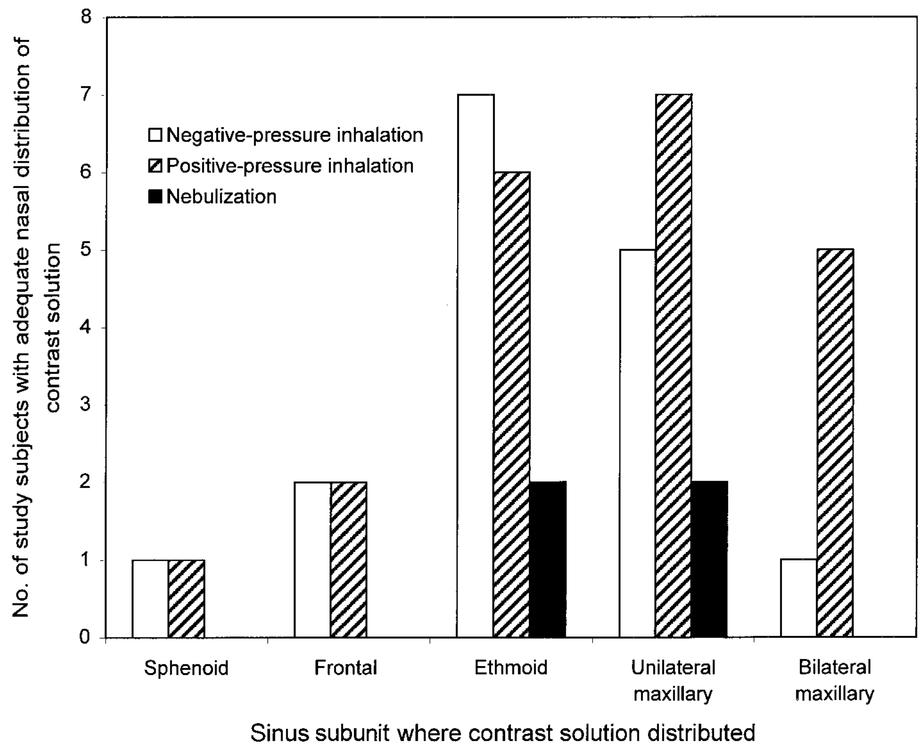

Fig. 3. Distribution of contrast solution in nasal sinuses of eight healthy volunteers who received each of three methods of nasal irrigation.

cavities and retained contrast solution). The technique has limitations as well. Isotonic Omnipaque clearly does not "coat" the mucosal surfaces perfectly with a single, low-volume rinse, but is instead distributed primarily to dependent areas. Examination of coronal CT source images showed that the contrast solution was present mainly on horizontal surfaces and in narrow spaces, where cohesive forces between mucosal walls "trap" the contrast material. Thus, contrast material shown in a given area must be assumed to represent the minimum distribution to that area; actual extent of distribution cannot be accurately delineated. However, the volume of contrast material retained dependently in the sinonasal cavity is a reasonable proxy for the extent of distribution because one can expect that some material will be trapped if it reaches the sinonasal subunit.

CONCLUSION

Eight healthy subjects had nasal irrigation using radiopaque contrast material delivered by three different methods, followed by coronal CT scanning. Three-dimensional reconstruction of scan results showed the extent to which the contrast material was distributed throughout the sinonasal cavity, and volume of retained contrast material also was measured. Of the three methods studied, both negative-pressure and positive-pressure irrigation distributed contrast material reliably to the ethmoid and maxillary sinuses, and positive-pressure irrigation was distributed to the bilateral maxillary sinuses in the majority of study subjects. The nebulizer method did not distribute contrast material reliably.

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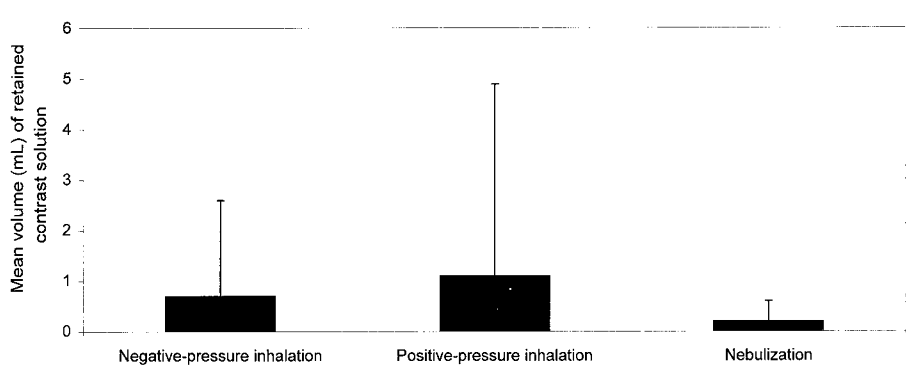

Fig. 4. Mean volume of contrast solution retained in nasal sinuses of eight healthy adult volunteers after using each of three sinus irrigation methods. Error bars indicate range.

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BIBLIOGRAPHY

1. Shoseyov D, Bibi H, Shai P, Shoseyov N, Shazberg G, Hurvitz H. Treatment with hypertonic saline versus normal saline nasal wash of pediatric chronic sinusitis. *J Allergy Clin Immunol* 1998;101:602–605.
2. Bachmann G, Hommel G, Michel O. Effect of irrigation of the nose with isotonic salt solution on adult patients with chronic paranasal sinus disease. *Eur Arch Otorhinolaryngol* 2000;257:537–541.
3. Heatley DG, McConnell KE, Kille TL, Leverson GE. Nasal irrigation for the alleviation of sinonasal symptoms. *Otolaryngol Head Neck Surg* 2001;125:44–48.
4. Nuutinen J, Holopainen E, Haahtela T, Ruoppi P, Silvasti M. Balanced physiological saline in the treatment of chronic rhinitis. *Rhinology* 1986;24:265–269.
5. International Consensus. Report on the diagnosis and management of rhinitis: International Rhinitis Management Working Group. *Allergy* 1994;49(Suppl):1–34.
6. Talbot AR, Herr TM, Parsons DS. Mucociliary clearance and buffered hypertonic saline solution. *Laryngoscope* 1997;107:500–503.
7. Homer JJ, England RJ, Wilde AD, Harwood GR, Stafford ND. The effect of pH of douching solutions on mucociliary clearance. *Clin Otolaryngol* 1999;24:312–315.
8. Negley JE, Krause H, Pawar S, Reeves-Hoche MK. RhinoFlow nasal wash and sinus system as a mechanism to deliver medications to the paranasal sinuses: results of a radiolabeled pilot study. *Ear Nose Throat J* 1999;78:550–552.
9. McLean JA, Bacon JR, Matthews KP, et al. Distribution and clearance of radioactive aerosol on the nasal mucosa. *Rhinology* 1984;22:65–75.
10. Gilani S, Norbash AM, Ringl H, Rubin GD, Napel S, Terris DJ. Virtual endoscopy of the paranasal sinuses using perspective volume rendered helical sinus computed tomography. *Laryngoscope* 1997;107:25–29.
11. Kawarai Y, Fukushima K, Ogawa T, et al. Volume quantification of healthy paranasal cavity by three-dimensional CT imaging. *Acta Otolaryngol Suppl (Stockh)* 1999;540:45–49.