Effects of buffered saline solution on nasal mucociliary clearance and nasal airway patency

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OBJECTIVE: To compare the effects of buffered hypertonic and buffered normal saline nasal spray on mucociliary clearance and nasal airway patency.

STUDY DESIGN AND SETTING: Double-blind trial with subjects acting as their own controls. Tertiary care academic medical center.

RESULTS: Buffered hypertonic saline and buffered normal saline both improved saccharine clearance times ($P < 0.0001$ for buffered hypertonic and $P = 0.002$ for buffered normal saline). Buffered hypertonic saline improved saccharine clearance times more than buffered normal saline (39.6% vs 24.1%, $P = 0.007$). Neither buffered hypertonic nor buffered normal saline significantly affected nasal airway patency.

CONCLUSIONS: Both buffered hypertonic and buffered normal saline nasal sprays significantly improved saccharine clearance times without affecting nasal airway patency. Buffered hypertonic saline affected saccharine clearance times to a greater degree than buffered normal saline.

CLINICAL SIGNIFICANCE: Buffered hypertonic and buffered normal saline sprays both improve mucociliary clearance and should therefore be beneficial in conditions such as rhinitis and sinusitis, which are associated with disruption of mucociliary clearance. However, these sprays do not appear to affect the nasal airway. Patients may therefore benefit from other treatments for “nasal congestion.”


For many years, topical saline solutions have been used after nasal surgery and in the treatment of rhinitis and sinusitis. Nasal irrigation with saline helps clear nasal secretions and infective debris and minimizes crusting, which may obstruct normal sinonasal drainage. Saline also appears to improve the mucociliary transport function of the nasal mucosa. Available evidence suggests that buffered hypertonic saline is superior for this purpose when compared to buffered normal saline. For example, Talbot et al showed a 17% decrease in mucociliary clearance times in normal healthy subjects after the instillation of a 3% buffered hypertonic saline solution.1 The relative superiority of buffered hypertonic saline is far from settled, however, as buffered hypertonic saline may cause significant burning, limiting its use in some patients. And, although there is little evidence to support this assertion, it has been suggested that buffered hypertonic saline solutions may act to decongest the nasal mucosa, thereby improving nasal breathing1 or providing added benefits to patients with inflamed nasal mucosa.

The purpose of this study was to compare the effect of buffered hypertonic and buffered normal saline sprays on mucociliary clearance (as assessed by the saccharine clearance method) and to use acoustic rhinometry to examine changes in nasal cavity dimensions after the instillation of these sprays. Acoustic rhinometry is a quick, noninvasive, and reliable method of measuring nasal patency. By using sound pulses and analyzing the reflections, acoustic rhinometry can objectively measure nasal cavity cross-sectional area as a function of distance from the nose. The reliability of such measurements has been confirmed using correlation studies with computed tomography and magnetic resonance imaging.2-5

MATERIALS AND METHODS

Twenty-two healthy volunteers participated in the study. Informed consent was obtained from all subjects, and this study was approved by the UTMB Institutional Review Board for research involving human subjects. Subjects taking nasal medication or who disclosed a history of significant allergies, smoking, rhinitis, or an upper respiratory tract infection within three weeks prior to the study were excluded.

Nasal patency was measured with an acoustic rhinometer from Rhinometrics (Interacoustics, Assens, Denmark), using the Rhinoscan software system. The rhinometer was calibrated before each use. Three separate measurements were recorded to ensure reproducibility, and the average was calculated. Data was re-
ported as MCA1, the minimum cross-sectional area detected in the distance between 0 and 22 mm, and MCA2, the minimum cross-sectional area between 22 and 54 mm (Fig 1).

Mucociliary clearance was measured by using the saccharine clearance test method. Subjects sat with their heads upright, and a small piece of saccharine was placed on the medial aspect of their inferior turbinate 1 to 1.5 cm behind the nasal vestibule using an ear curette. After saccharine placement, subjects were asked to avoid sniffing or sneezing. The clearance time was then noted as the time elapsed at the subjects’ first perception of a sweet taste.

Data collection was conducted on two separate days, using 3% hypertonic saline one day and 0.9% normal saline (both buffered to pH 7.6 with bicarbonate) the other. Both investigator and subject were blinded to the content of the solution used each day. On the first day, subjects were randomly assigned a saline solution; on their subsequent visit, subjects would receive the alternate saline solution.

On each day, a baseline acoustic rhinometry measurement was followed by a control saccharine clearance time. Then, subjects were given 10 sprays to one side of the nose using an atomizing sprayer of either a 3% buffered hypertonic saline solution or a 0.9% buffered normal saline solution. After 10 minutes, a second saccharine clearance time and acoustic rhinometry measurement were obtained. The same procedure was then repeated on a different day with the alternate saline solution.

Paired data obtained before and after intervention for the same day and same nasal cavity were compared, providing a control for physiological variances such as the nasal cycle or other daily variations which might have affected the mucociliary clearance patterns of the nose. Wilcoxon’s signed rank test was used to analyze changes in mucociliary clearance time and nasal cavity cross-sectional area.

RESULTS

Changes in saccharine clearance time are shown in Figure 2 and compare the percentage difference in saccharine clearance times. The saccharine clearance data was not normally distributed. There was no significant difference in control values between the solutions ($P = 0.709$), with mean control times of 13.3 minutes for buffered hypertonic saline and 13.0 minutes for buffered normal saline.

In 3% buffered hypertonic saline trials, mucociliary clearance times decreased from baseline by 39.6% (mean improvement of 349 seconds [5.8 min.] with SD = 266.9, $P < 0.0001$). In buffered normal saline trials, mucociliary clearance times decreased by 24.1% (mean improvement of 267 seconds [4.5 min.] with SD = 368.8, $P = 0.002$). Buffered hypertonic saline improved mucociliary clearance times 15.5% more than buffered normal saline (absolute difference, $P = 0.007$).

Instillation of buffered hypertonic saline increased, on average, MCA1 by 0.03 cm$^2$ (SD = 0.165; $P = 0.580$) and MCA2 by 0.07 cm$^2$ (SD = 0.221; $P = 0.903$). Buffered normal saline increased MCA1 by 0.03 cm$^2$ (SD = 0.095; $P = 0.927$) and MCA2 by 0.02 cm$^2$ (SD = 0.243; $P = 0.676$). In buffered hypertonic saline trials, MCA1 increased from baseline 7.1% ($P = 0.687$) and MCA2 increased 10.1% ($P = 0.856$). In buffered normal saline trials, MCA1 increased from baseline 6.8% ($P = 0.938$) and MCA2 increased 4.9% ($P = 0.720$). The difference was not statistically sig-
significant between buffered hypertonic saline and buffered normal saline, with $P = 0.395$ for MCA1 and $P = 0.676$ for MCA2. The results for nasal patency are shown in Figure 3.

The data did not show a correlation between improved mucociliary clearance times with buffered hypertonic saline instillation and changed nasal patency. Additionally, the acoustic rhinometry results demonstrated a decrease in MCA1 and MCA2 values (decreased airway dimensions) in 7 out of 22 subjects in buffered hypertonic saline trials and 6 out of 22 subjects in buffered normal saline trials.

DISCUSSION

Topical saline solutions are commonly used in the treatment of rhinitis and sinusitis, and the beneficial effects of this treatment may be related to improved mucociliary clearance. Nasal mucociliary clearance may be impaired by several factors: decreased ciliary beat frequency, increased viscosity of the mucus layer, outflow obstruction, crusting, mucosal contact, and altered ventilation. Impaired mucociliary function is associated with upper respiratory tract infections, allergic rhinitis, and rhinosinusitis.9,10 This study compared the effects of buffered hypertonic or buffered normal saline nasal spray on saccharine clearance times and nasal airway dimensions in normal volunteers. Despite the rational basis for using saline solutions and the widespread use of these solutions for the management of rhinosinusitis, uncertainty persists regarding what is the ideal solution for topical intranasal application.

The saccharine clearance test has been shown to be a reliable method of assessing mucociliary clearance times and is closely correlated to the clearance rates with tagged insoluble particles, which have been considered the most accurate technique.11 This test, in both the research and clinical setting, has become a useful tool because it is inexpensive and easily performed.

The results of this study corroborate the findings of Talbot et al,7 reinforcing the fact that buffered hypertonic saline improves mucociliary clearance. Additionally, the results from this study show that buffered normal saline significantly improves mucociliary clearance. With buffered hypertonic saline, clearance times decreased in 21 out of 22 subjects (95%). Unlike the results of Talbot et al, this study showed that buffered normal saline decreased mucociliary clearance times in 17 out of 22 subjects (77%). But overall, buffered hypertonic saline decreased mucociliary clearance times more than buffered normal saline in 15 out of 22 subjects (68%). Therefore, while both solutions improve mucociliary clearance, the effects of buffered hypertonic saline are more profound. Whether buffered hypertonic saline should be used in lieu of buffered normal saline is still an unanswered question, however.

An additional goal of this study was to assess objectively the effects of buffered saline solutions on nasal patency. Talbot and others have noted that in patients with congestive rhinitis there are some subjective improvements in nasal patency with topical nasal saline irrigation; however, there is little objective data to support this finding.1,12-14

In this study, buffered saline solutions had a minimal effect on nasal cross-sectional area and nasal patency. Using acoustic rhinometry, it was found that 3% buffered hypertonic saline led to decreased MCA1 and MCA2 values in 7 out of 22 subjects (32%). Similarly, buffered normal saline decreased nasal cavity cross-sectional area in 6 out of 22 subjects (27%). These changes, however, were small in aggregate and of uncertain clinical significance. A study by Baraniuk et al found that hypertonic nasal irrigation reduced nasal airspace volume and caused irritation.15 They suggested that hypertonic saline increased nasal secretion production, causing negligible changes in nasal airspace volume while producing a significant increase in the perception of rhinorrhea and nasal blockage.15

Potential sources of error in this study could come from saccharine clearance times and acoustic rhinometry measurements. Saccharine clearance times are dependent upon the investigator’s appropriate placement of the saccharine within the subject’s nose and the subject’s adherence to instructions and perception of a sweet taste. This study minimized potential bias and variability by having only one investigator perform experiments on all subjects, blinding both the investigator and subjects to the content of the solutions, and observing the subjects until completion of the clearance trial. Soane et al found the nasal cycle to have marked effects on the mucociliary clearance patterns of the

Fig 3. Average minimal cross-sectional area (MCA) before and after administration of buffered hypertonic and buffered normal saline solutions.
nose. The clearance times determined in their study showed a statistically significant difference between the two nasal passages during the morning peak of the nasal cycle, with the decongested side clearing more rapidly than the congested side. These variances could affect controlled studies on mucociliary clearance. In order to compensate for the nasal cycle and other physiological variances, a subject’s measurements were only compared after saline irrigation with his or her own control measurements for that day and same nasal cavity side.

Several factors limit the accuracy of acoustic rhinometry measurements. The most widely recognized problem with acoustic-pulse analysis is the inability to measure accurately beyond narrow apertures. Furthermore, sound loss between the nostril and the acoustic probe and to the paranasal sinuses could negatively affect the accuracy of acoustic rhinometry measurements of more distal segments. Sound loss was minimized by using a thin layer of gel as an acoustic seal and closely fitting the probe to the nostril; measurements were repeated so that the results were reproducible.

A final limitation of this study is that the effects of buffered saline solutions were examined in asymptomatic patients. For this reason, subjective data on perceived nasal obstruction could not be obtained. Future studies could include symptomatic patients and a subjective component. In a symptomatic population, the changes in nasal patency and mucociliary clearance may be more pronounced, allowing for better discrimination of results. The significance of changes in nasal airway dimension could then be correlated with changes in perceived nasal obstruction.

CONCLUSIONS

In this study of asymptomatic subjects, both buffered hypertonic and buffered normal saline nasal spray significantly improved saccharine clearance times without affecting nasal airway patency. Buffered hypertonic saline affected saccharine clearance times to a greater degree than buffered normal saline. Further study in symptomatic patients is necessary before a specific concentration of saline may be considered superior to another.

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REFERENCES