Baby shampoo nasal irrigations for the symptomatic post–functional endoscopic sinus surgery patient

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ABSTRACT

Background: *Symptoms of postnasal drainage and thickened mucus are commonly seen in patients with chronic rhinosinusitis (CRS) recalcitrant to sinus surgery and conventional medical therapies. Chemical surfactants can act as a mucolytic by reducing water surface tension and have the potential to serve as an antimicrobial agent. Baby shampoo is an inexpensive, commercially available solution containing multiple chemical surfactants. This is an* in vitro *study of its antimicrobial effects on* Pseudomonas *biofilms with translation to a clinical study for use as an adjuvant nasal wash in patients with CRS who remain symptomatic despite adequate sinus surgery and conventional medical therapies.*

Methods: In vitro *testing was performed to determine the optimal concentration of baby shampoo that disrupted preformed bacterial biofilms and inhibited biofilm formation. This concentration was then used in a prospective study of symptomatic post–functional endoscopic sinus surgery (FESS) patients who irrigated twice a day for 4 weeks. Validated outcome forms and objective smell testing was performed before and after therapy.*

Results: *One percent baby shampoo in normal saline was the optimal concentration for inhibition of* Pseudomonas *biofilm formation. Baby shampoo had no effect on the eradication of preformed* Pseudomonas *biofilms. Eighteen patients with CRS with an average of 2.8 surgeries were studied after irrigating with 1% baby shampoo solution. Two patients discontinued use because of minor nasal and skin irritations; 46.6% of patients experienced an overall improvement in their subjective symptoms, and 60% of patients noted improvement in specific symptoms of thickened mucus and postnasal drainage.*

Conclusion: *Baby shampoo nasal irrigation has promise as an inexpensive, tolerable adjuvant to conventional medical therapies for symptomatic patients after FESS. Its greatest benefit may be in improving symptoms of thickened nasal discharge and postnasal drainage.*
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Key words: Adjunctive therapy, biofilm, FESS, irrigation, mucoactive treatment, rhinosinusitis, shampoo, surfactant, topical

Current literature on chronic rhinosinusitis (CRS) is centered around a multifactorial etiology, with the importance of fungus, bacterial superantigens, allergic rhinitis, aspirin sensitivity, and organistic biofilms all being recognized. A common clinical sign of each of these is increased mucus production resulting in symptoms of postnasal drainage and thickened nasal discharge. These symptoms are especially heightened in those patients who remain symptomatic despite technically proficient endoscopic sinus surgery, in which pooling of mucin within open ethmoid and maxillary cavities often accompanies mucosal inflammation.

A mucoactive medication is the general term for an agent meant to affect mucus properties and promote secretion clearance.[1] Mucoactive medications work either to increase the ability to expectorate sputum or to decrease mucus hypersecretion. A common clinical example is guaifenesin. Although it may stimulate the cholinergic pathway and increase mucus secretion from the airway submucosal glands, guaifenesin has little efficacy in treating the thick mucin encountered in CRS.

Surfactants, both biological and chemical, are amphipathic molecules that accumulate at interfaces to impact the way other molecules behave at interfaces and in solution.[2] Having amphipathic properties allows surfactant to be solvent in both water and organic substrates. Pulmonary surfactant is a well-known biological surfactant that works as an expectorant by decreasing the ability of sputum to adhere to the epithelial layer and increasing the efficiency of energy transfer from the cilia to the mucus layer, thus improving mucociliary clearance.[1] By working to decrease sputum adhesivity and altering the microbial–surface interface, surfactant in the form of a topical lavage, may be effective in clearing thick mucin from the cavities of previously operated patients, thus improving patient symptomatology of postnasal drainage and thickened secretions.

Chemical surfactants have antimicrobial potential by causing cell membrane disruption, increasing cell membrane permeability causing metabolite leakage or by interfering with membrane functions such as energy generation and transport.[2] The use of chemical surfactants as a therapeutic detergent to break up and assist in the eradication of bacterial biofilms has been established in the orthopedic literature. Surfactant irrigation of complex infected orthopedic wounds can eradicate bacteria more efficiently than saline and antibiotic irrigation in animal models.[3] Therefore, therapeutic use of topical chemical surfactant for chronic sinusitis may have two benefits: one as a mucoactive agent and the second as a biocide with potential action against bacterial biofilms.

Baby shampoo is a cost-efficient, well-tolerated, readily available solution intended for use as a wetting agent to wash

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away grease from hair. Within the active ingredients of baby shampoo are three different chemical surfactants, PEG-80 sorbitan laurate, cocamidopropyl betaine, and sodium trideceth sulfate. We hypothesize that a nasal irrigation containing baby shampoo may be beneficial as an adjuvant therapy to conventional medications in those patients who are symptomatic despite previous sinus surgery.

METHODS

This is a prospective, Institutional Review Board–approved, nonrandomized study of CRS patients who remain symptomatic despite a previous history of sinus surgery and conventional medical therapy, including oral and topical steroids, antibiotics, oral and topical antihistamines, and saline irrigations. Many of these patients also had received previous trials of "nonconventional" therapies, including topical antibiotic irrigations, systemic and topical antifungals, and nebulized antibiotics. Symptoms before and after treatment with baby shampoo irrigations were recorded using a validated quality-of-life form, the 22-item Sino-Nasal Outcome Test (SNOT-22).[4] Objective assessment of olfactory function using the University of Pennsylvania Smell Identification Test (UPSIT)[5] was performed before and after therapy. Side effects and reasons for discontinuation were recorded in a patient diary, and the patients were seen 4 weeks after starting the baby shampoo irrigations.

The concentration of baby shampoo used for the clinical study was determined through *in vitro* testing on planktonic *Pseudomonas aeruginosa* and preformed *P. aeruginosa* biofilms. Bacterial and biofilm growth inhibition was determined using the plate-based assay described in Moskowitz *et al.*[6] Briefly, PAO1 *P. aeruginosa* bacterial strains were grown overnight. The following morning the culture was diluted to an optical density of 600 nm (OD_{600}) = 0.1 with Luria-Bertani (LB) broth and the sample was diluted again in 1:100 LB broth. For determination of biofilm formation inhibition and growth inhibition, 100 μL of diluted bacteria was added to 25 μL of a 5× concentrations of Johnson's Baby Shampoo (diluted in LB), placed in 96-well flat-bottom plates (catalog number 269787; Nalgene Nunc International, Rochester, NY) in quadruplicate. A negative control of 25 μL of PBS added to 100 μL of medium was used and showed no effect on biofilm formation or inhibition. A modified polystyrene microtiter lid with 96 pegs (catalog number 445497, Nunc TSP system; Nalgene Nunc International) was placed into the bacterial isolate growth plate. The covered 96-well plates were incubated for 20 hours at 37°C. At the completion of the incubation the lid containing the pegs was removed and processed for biofilm detection while the 96-well plate was analyzed for bacterial growth by determination of absorbance at 600 nm. After incubation, the peg lid was rinsed three times in sterile water and the lid was placed in 2% crystal violet solution (Remel, Inc., Lenexa, KS) for 30 minutes to stain the biofilms adherent to the pegs. Then, the peg lid was rinsed again three times in sterile water and dried for 1 hour. Next, the peg lid was inserted into a 96-well microtiter plate containing a 100% ethanol solution for 15 minutes. The peg lid was then discarded and the eluted crystal violate was read on a microtiter plate reader (Microplate Reader 680; Bio-Rad Laboratories, Inc., Hercules, CA) at OD_{595}. For determination of biofilm eradication, biofilms were generated on the peg as described previously with the exception of omitting addition of the shampoo. Twenty hours later the lid was washed three times in sterile water and immersed in a 96-well plate that contained prediluted baby shampoo in LB broth. Quantification of residual biofilms was performed as described previously. Once the optimal concentration of baby shampoo was determined, patients were instructed to mix the solution in normal saline and irrigate with 60 cc on each side, twice a day for 4 weeks.

RESULTS

In vitro testing showed that baby shampoo was unable to eradicate preformed *Pseudomonas* biofilms at any concentration but at 1 and 10% concentration was effective in eradicating planktonic *Pseudomonas* ($p < 0.05$). Testing also showed that baby shampoo at 1% diluted in normal saline significantly ($p < 0.05$) inhibited the formation of biofilms compared with normal saline (Fig. 1). At 10% concentration, there was an increase in biofilm formation, thus making 1% solution the determined concentration used for the clinical study.

Eighteen patients with CRS were prospectively followed as they irrigated with baby shampoo for 4 weeks. The average number of prior surgeries was 2.8 (range, 1–6). Fifteen patients (83%) had asthma and each patient (100%) was using a topical nasal steroid spray and normal saline nasal irrigation before study initiation.

Three patients were excluded from the final study analysis. One was lost to follow-up and 2 of the 18 (11%) withdrew from the study, 1 patient because of nasal irritation from the shampoo and 1 patient after complaining of hives that eventually resolved with the discontinuation of the irrigation.

Fifteen patients completed a 4-week course of baby shampoo irrigations. Each patient continued their use of topical nasal steroid sprays during the study. Ten patients also received a concomitant 2-week course of antibiotics, and two patients were on a course of oral prednisone at the time of study. The average pretreatment SNOT-22 score was 31.6 (range, 6–73). Overall, subjective improvement after treatment was seen in seven (46.6%) patients with an average decrease

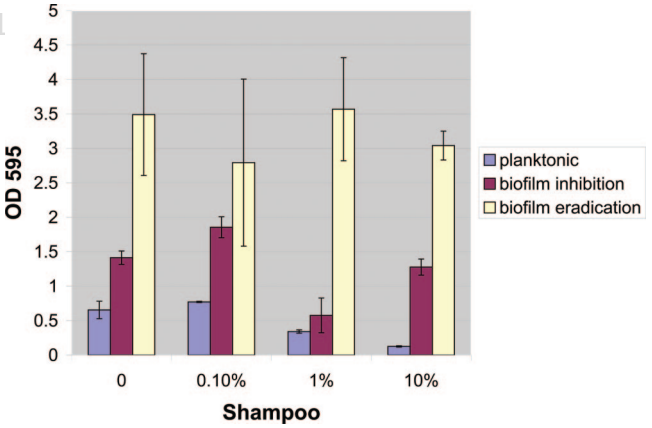

Figure 1. *Bacterial growth of* Pseudomonas *(PAO1) treated with normal saline, 0.1, 1, and 10% baby shampoo in normal saline. None of the solutions were able to eradicate preformed biofilms. One and 10% solutions eradicated planktonic bacteria ($p < 0.05$) and the 1% solution was effective in inhibiting biofilm formation ($p < 0.05$).*

of 11.1 in their SNOT-22. None of the seven patients who improved on shampoo irrigation received a concomitant course of oral prednisone, whereas four of the seven patients had received a course of antibiotics along with their baby shampoo irrigation.

Looking at specific subdivisions within the SNOT-22, the areas of greatest improvement were seen in response to postnasal drainage and thickened mucus. Of the 15 patients in the study, 9 (60%) reported an improvement in the thickness of their discharge and 8 (53.3%) reported a decrease in postnasal drainage.

Objective pre- and posttreatment smell testing was performed in 11 of the patients who completed the study. Seven of the 11 (63.6%) patients had an improvement in their UPSIT scores.

DISCUSSION

Baby shampoo is a commercially available product widely known for its wetting and grease removing effects, easy tolerability, and low cost. Baby shampoo contains the surfactant agents PEG-80 sorbitan laurate, cocamidopropyl betaine, and sodium trideceth sulfate that can act as a detergent to decrease the viscosity and surface tension of airway mucus. Chemical surfactants also have been shown to have antimicrobial activity. The use of chemical surfactants as a therapeutic detergent to break up and assist in the eradication of bacterial biofilms has been established in animal orthopedic wound models.[3] Our goal in this study was to determine the *in vitro* effects of baby shampoo on bacterial *Pseudomonas* biofilms and to translate this data to a challenging population of CRS patients that remained symptomatic despite technically adequate endoscopic sinus surgery and conventional medical therapy, including oral and topical steroids, antibiotics, and nasal saline irrigations.

Shampoo surfactants reduce the surface tension between water and grease, thereby causing the grease to be suspended in the water phase and preventing adsorption into the hair. This is achieved by the binding of grease at the center of a micelle structure with the hydrophilic portion of the surfactant pointing outward. Then, these micelles are washed away from the surface of the hair, resulting in the intended cleansing effect. The cleansing ability of a shampoo is dependent on the type and amount of surfactants used. Surfactants are classified according to hydrophilic polar group as anionic, cationic, zwitterionic, and nonionic. In most products, a shampoo base consists of anionic and zwitterionic surfactants, such as the cocamidopropyl betaine (zwitterionic) and sodium trideceth sulfate (anionic) found in Johnson's baby shampoo. These agents are effective cleansers and are noncaustic to skin and mucus membranes. Cationic agents often are used in conditioners for their antistatic properties but are poor cleansers and do not lather well. They are also strong irritants and, thus, are used only with less irritating surfactants in shampoos designed for dry hair.[7]

In vitro testing showed that baby shampoo was unable to eradicate preformed *Pseudomonas* biofilms. This may be because of the mild nature of the surfactants within the baby shampoo that are unable to break the bonds of the glycocalyx surrounding the biofilms. Another explanation is the surfactants that comprise the shampoo. Studies of chemical surfactants have shown that charge has an impact on microbial toxicity. Cationic surfactants are the most toxic and have been used as antimicrobials, whereas anionics are less toxic and more active against Gram-positives than Gram-negatives.[2] Because baby shampoo is largely made up of anionic and zwitterionic surfactants, their biocidal effects on the Gram-negative *Pseudomonas* may be limited. Although largely ineffective against preformed biofilms in this study, baby shampoo at a 1% concentration was effective in inhibiting the formation of biofilms *in vitro* as well as eradicating planktonic *Pseudomonas*. This is not entirely surprising, because surfactants adsorbing onto solid surfaces can alter the physical and metabolic state of microorganisms in a biofilm microenvironment and may disrupt microbial binding to cell surface receptors.[8] An interesting future study would be to determine if routine post—functional endoscopic sinus surgery baby shampoo irrigations may prevent future biofilm rhinosinusitis.

The 1% baby shampoo solution was fairly well tolerated in the clinical trial. One patient in the study discontinued its use because of nasal burning and discomfort with the bubbles and a second patient had a rash that resolved with the discontinuation of the irrigation. There have been reports of contact dermatitis secondary to cocamidopropyl betaine and the surfactant can serve as an allergen to some patients.[9] Patients are now screened for previous skin reactions to shampoo before intranasal use. Despite this one occurrence, the baby shampoo was well tolerated and side effects were reversible with discontinued use.

In a difficult-to-treat patient population, in which over 80% of patients were asthmatic and the average number of surgeries was nearly three, adjuvant baby shampoo nasal irrigations provided subjective overall improvement in symptoms to nearly 50% of the patients studied, with the greatest benefit to those patients with chief complaints of thick mucus discharge and postnasal drainage. Although the biocide capability of baby shampoo was not established in the *in vitro* trials, the use of surfactant as a nasal wash was supported in its moderate amount of success in an extremely difficult-to-treat patient population. The clinical portion of this study was limited by its small numbers and the lack of *in vivo* determination of shampoo's effects on mucosal biofilms. Future clinical trials with a larger number of subjects are needed to determine statistical significance and the optimal clinical concentration to use as well as the optimal dosing regimen and the effects of long-term use. In addition, future studies looking at mucosal biopsy specimens, culture data, and mucosal inflammatory mediators, before and after shampoo treatment, may shed additional light on the true *in vivo* biocidal capability of this novel therapy.

There are other obvious limitations of this study, including the frequent concomitant use of antibiotics in this population, the lack of a control group, the difficulty in measuring objective variables in CRS patients after surgery, and the small patient sample size. Despite these flaws, baby shampoo nasal irrigations as an adjuvant therapy to conventional medical therapy holds promise as a well-tolerated, inexpensive agent useful against the thick mucin often seen in the recalcitrant patient population. Additional work, looking at other types of surfactants, may help elucidate the ideal agent that will act as an effective mucoactive agent and a well-tolerated biocide.

CONCLUSION

One percent baby shampoo nasal irrigations led to improvement in SNOT-22 scores for nearly 50% of patients that remained symptomatic despite surgical and conventional medical management. Greatest improvements were in symptoms of thickened nasal secretions and postnasal drainage. Chemical surfactants within baby shampoo may have a preventative role against bacterial biofilm formation *via* biocidal and/or mucolytic mechanisms of action. Additional research is warranted into the clinical application of this novel, well-tolerated therapy.

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