A randomized controlled study comparing the efficacy of nasal saline irrigation devices in children with acute rhinosinusitis

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Abstract

Objective: To evaluate the efficacy of positive-pressure nasal irrigation devices in children with acute sinusitis, in addition to bacterial colonization of the irrigation device.

Method: We performed a randomized, prospective, controlled study of 80 children with acute sinusitis, aged between 3 and 15 years. Participants were randomly separated into two groups, where one group was treated using a squeezable bottle and the other group treated using a syringe. All patients were instructed to use a 1.25% buffered hypertonic solution for nasal irrigation twice daily for 2 weeks, in addition to amoxicillin-clavulanic acid. During this period, all participants recorded a 5S score, satisfaction score, any side effects and use of antihistamines. Parents were instructed to clean the device with soap after each use. After this period, the nasal irrigation devices were sent to a microbiological laboratory for bacterial identification.

Results: At the 2-week follow-up, improvement in both 5S and satisfaction scores were observed in both groups compared to baseline, which were significantly higher in the group treated with the squeezable bottle compared to the syringe. Few complaints were reported, and side effects were equal in both groups. The overall rate of bacterial contamination for both treatments was approximately 80%, but this did not translate into higher rates of infection amongst patients.

Conclusions: The use of a squeezable bottle for nasal irrigation in children with acute sinusitis was associated with further improvements in 5S and satisfaction scores compared to syringe use, and there were no significant differences in bacterial contamination between methods.

Keywords: Acute sinusitis; Pediatric sinusitis; Buffered hypertonic saline nasal irrigation; Nasal irrigation device; Contamination of nasal irrigation device

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Introduction

Sinusitis is a common problem in pediatric primary care practice. The average child has six to eight colds per year, and it has been estimated that 0.5-10% of colds progress to acute sinusitis.[1,2] The symptoms of pediatric sinusitis often present as persistent or worsening of upper respiratory tract infection symptoms (most commonly cough, purulent nasal discharge, nasal congestion, fever and halitosis).[3-5] If inadequately treated, acute sinusitis can interfere with quality of life and cause serious morbidities. Antibiotics play a major role in medical treatment,[3,4,6] and adjunctive treatment with nasal irrigation and decongestants may also be helpful.[3,4,7]

Nasal irrigation can facilitate the removal of nasal discharge, pathogens, crusts, allergens and irritant-containing mucus. It can also improve the mucociliary transport function of the nasal mucosa and nasal patency by decreasing mucosal edema. Several studies in the literature have reported benefits of nasal irrigation as adjunctive treatment of sinonasal diseases, including acute rhinosinusitis.[8-13] It has been suggested that

hypertonic saline is superior to normal saline for reducing symptomatic rhinonasal symptoms,[8,9,14,17,18] and also improves quality of life.[8,9] Furthermore, buffered solutions are superior to non-buffered solutions, as they have minimal adverse effects.[17,18] Three small clinical trials in children have demonstrated benefits from the use of saline nasal irrigation as an adjunctive treatment for acute sinusitis.[10-12] However, there is currently no evidence to support the use of hypertonic buffered solution as adjunctive therapy for children with acute bacterial rhinosinusitis.

There are a wide variety of nasal irrigation devices available, including nasal drop with suction, nebulizer or nasal sprays, and positive-pressure devices, either using a syringe, pot or squeezable bottle. Previous studies have shown that nasal irrigation with positive-pressure devices are more effective than nebulization or nasal spray,[19-26] however, only few studies have compared the effectiveness of different positive-pressure devices. Heatley et al. reported that both bulb syringes and nasal irrigation pots were equally effective for patients with sinonasal disease,[27] whereas Krayenbuhl et al. reported that squeezable plastic bottles were more effective in patients following endonasal surgery compared to normal saline nose drops.[28]

Regarding the potential for bacterial contamination, previous studies have reported increased bacterial colonization after use of a nasal irrigation device over 1 week. The most common colonizing organisms were found to be *Staphylococcus aureus*, coagulase-negative *Staphylococcus*, *Acinetobacter*, *Pseudomonas aeruginosa* and other gram-negative bacilli.[29-32] Most of these studies were conducted in adults or in patients following sinunasal surgery.

Until now, there have been no controlled trials comparing the effectiveness of different positive-pressure devices for nasal saline irrigation in children with sinusitis, and no information regarding bacterial colonization of nasal saline irrigation devices in this population. Therefore, the aim of this study was to evaluate the effectiveness of squeezable bottles and syringes as nasal saline irrigation devices in a pediatric population with acute sinusitis. Moreover, we determined the incidence of bacterial colonization in these devices after 2 weeks of use.

Methods
Participants
A randomized, controlled, prospective study was conducted. Eighty children with acute sinusitis, aged between 3 and 15 years, were recruited from a pediatric outpatient department and pediatric allergy clinic at Thammasat Hospital between March 2013 and May 2014. Approval for the study was granted by the ethics committee of Thammasat University, and informed consent was obtained from all parents before beginning the study. The inclusion criteria were as follows: (1) aged between 3 and 15 years; (2) presumptive diagnosis of acute bacterial rhinosinusitis, the criteria of which included persistent nasal discharge or cough for more than 10 days without improvement, new onset of nasal discharge, development of a cough or fever 5-6 days following initial improvement, high fever (greater than 39°C), and purulent nasal discharge for at least 3 days.[3,4] Patients with a history of penicillin allergy, nasal anatomical defects or paranasal sinus defects, abnormal nasal ciliary function, immunodeficiency, and those that had experienced

prior complications from sinusitis were excluded. In addition, patients with a compliance rate estimated at below 80% were also excluded.

Study design
All patients were asked to complete a case record form (CRF), in addition to providing both a 5S score[33] and satisfactory score using a visual analogue scale (scored from 1-7). A physical examination was performed on all patients at their first visit. Block randomization was used to randomly divide patients into two treatment groups, according to a computer-generated list. Thirty-nine patients were randomized to receive a squeezable bottle, and 41 to receive a disposable 20 ml-syringe as the nasal irrigation device. An investigator dispensed either the squeezable bottle or syringe for nasal irrigation according to the computer-generated list. All patients were instructed to irrigate their nasal cavities using 1.25% buffered hypertonic solution, and patients were trained by an experienced nurse, who briefly demonstrated the nasal irrigation technique. After each nasal irrigation, patients were asked to report any burning sensations, nasal congestion, or any other side effects resulting from use of the irrigation device, in addition to reporting a satisfaction score for nasal irrigation using a 7-point Likert scale. The investigator prescribed either amoxicillin-clavulanic (40-50 mg/kg/day) for patients who had no risk of antibiotic resistance, or amoxicillin-clavulanic acid (80-90 mg/kg/day; 4 g/day maximum) for patients at higher risk. Adjunctive medications, such as antihistamines and decongestants were permitted, and patients were allowed to continue all previous medications. Each group was suggested to irrigate their nostrils until no further nasal discharge remained, or until the maximum amount of irrigated solution (240 ml) had been used twice daily for a period of 2 weeks. Parents were instructed to clean the device with soap after each use. All participants and parents recorded their daily symptoms on a diary card, and were followed-up after 2 weeks. The 5S score, 7-point Likert scale for nasal irrigation satisfaction, frequency of adjunctive medications and adverse events were assessed by both the participants and subjectively by the parent (for young children). At the 2-week follow-up, the nasal irrigation device was sent to the microbiological laboratory for bacterial identification. Patients were removed from the study if they were found to have used nasal irrigation < 80% of the total period.

5S score
The 5S score is a validated symptom score developed specifically to evaluate sinus symptoms in pediatric patients, including nasal obstruction, daytime cough, nighttime cough, headache or facial pain, and colored nasal discharge.[33] All symptoms were graded on a 4-point scale: 0 = absent, 1 = mild symptoms (symptoms that are present but not particularly bothersome), 2 = moderate symptoms (symptoms that are bothersome but do not interfere with daily activities), 3 = severe symptoms (symptoms that are bothersome and interfere with daily activities or disturb sleep). The presence of colored nasal discharge was assigned a score of 3, and its absence was scored as 0. The symptom scores were summed to give the mean 5S score. The score was determined by the physician at the initial visit, then by the parent/caregiver at home each day

throughout the course of treatment. Caregivers completed the questionnaire in a daily diary card after consulting the child. The mean 5S score was determined at the first visit, and after 1 and 2 weeks of treatment.

Evaluation of nasal irrigation satisfaction using a 7-point Likert scale

Parents were asked to score the child's health status on a 7-point Likert scale at the beginning of the trial and at the 2-week follow-up visit.[34,35] Responses were recorded on a scale from 1 (unsatisfactory) to 7 (excellent).

Daily diary of nasal symptom score, side effects and daily medication use

Patients and their parents were instructed to record the daily nasal symptoms, side effects and medication use (antihistamines and decongestants) on a diary card in the evening after performing the nasal irrigation, in addition to determining the 5S score. Five nasal symptoms were recorded daily by patients. In younger children, parents were allowed to record the symptoms. The side effects from nasal irrigation and medications used were also recorded each day.

Colonization of nasal irrigation devices

The nasal irrigation devices used by patients in each group were sent to the microbiological laboratory for bacterial identification. Each bottle and syringe was filled with 10 ml sterile distilled water to cover the inner surfaces. A 100 μl sample of the water was collected from each irrigation bottle or syringe, and used for bacterial culture on 5% sheep blood agar (LAB015, England) and MacConkey agar (LAB045-A, England) plates, which were incubated at 37ºC for 24 hours. The isolated colonies were classified as being either gram-positive or gram-negative by Gram staining. The isolated colonies were grown on 5% sheep blood agar, then cultured in selective agar for *Staphylococcus aureus* (Staphylococcus Medium no. 110; Oxoid, UK) and incubated at 37ºC for 24 hours. The colonies grown were counted as *Staphylococcus aureus*-positive.

Statistical analysis

The mean 5S scores and 7-point Likert scale scores (for satisfaction with nasal irrigation use) between the two groups were compared using an independent samples t-test. The amount of antihistamine or pseudoephedine taken, compliance, side effects and bacterial colonization were compared using a chi-square test or Fisher's exact test adjusting for multiple comparisons. Statistical significance was considered to be P ≤ 0.05 for all comparisons.

Results

Eighty children with acute sinusitis participated in the study, including 50 boys and 30 girls, with an average age of 6.8 years (range 2.9-14 years). Patients were randomly separated into two groups, one of which received a squeezable bottle nasal irrigation device (22 boys and 17 girls, average age of 6.8 years) while the other group received a disposable 20 ml-syringe (28 boys and 23 girls, average age of 6.8 years). At the 2-week follow-up visit, 74 participants were assessed (92.5%). Six participants did not complete the saline irrigations during the

treatment period due to an improvement in nasal symptom score, including one patient from the squeezable bottle group and five patients from disposable syringe group. At baseline, there were no significant differences in patient demographic data, 5S scores or type of sinusitis (**Table 1**). All parameters assessed by the 5S score and the mean 5S score had improved in both treatment groups after 2 weeks (P < 0.05). However, patients treated with the squeezable bottle had significantly greater improvement in their 5S score compared to those treated with the syringe (P = 0.03), especially for nasal congestion and nasal discharge (**Table 2**). **Figure 1** shows the improved 5S score at 2 weeks compared to the baseline score.

Table 1. Demographic data, 5S-score, bacterial culture between two groups

Parameter	Squeezable bottle (N=38)	syringe (N=36)	P-value	95% CI
Age[a] (years)	6.9±2.7	7.1±2.7	0.8	-1.1-1.4
Male[b]	22	25	0.31	
Type of sinusitis[b]				
Progressive	31	27		
Acute severe	6	3		
Double sickening	0	2	0.96	
Previous sinusitis[b]	18	16	0.80	
Previous antibiotic use[b]	16	18	0.49	
Daycare[b]	5	1	0.11	
History of AR[b]	29	33	0.07	
History of asthma[b]	12	10	0.72	
Intranasal steroid use[b]	25	27	0.20	
Antihistamine use[b]	22	20	0.94	
1st use nasal irrigation[b]	10	11	0.69	
5-s score[a]	6.9±2.5	6.6±2.3	0.5	-1.5-0.8

[a] Data are reported as mean ±SD.
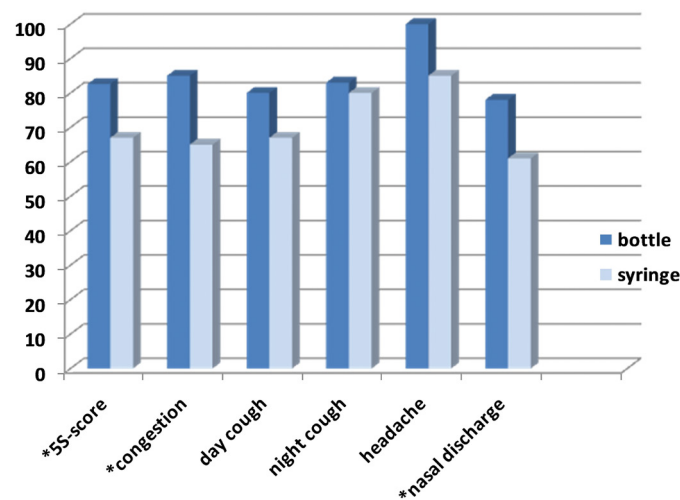[b] Data are reported as number (percent) of patients.

Figure 1. The improving rate of 5S-score at week 2 compare to baseline.

* : P<0.05(compare between group in the same period)

Table 2. Effectiveness of treatment between two groups at 1, 2 weeks

Parameter	First visit (baseline)		Phone call (1 week)		2nd visit (2 weeks)	
	bottle (N=38)	syringe (N=36)	bottle (N=38)	syringe (N=36)	bottle (N=38)	syringe (N=36)
5S-score[a]	6.9±2.5	6.6±2.4	2.0±1.6+	2.8±2.5+	1.2±1.5*#	2.2±2.0#
- congestion	2.0±0.7	1.7±0.9	0.6±0.7+	0.7±0.8+	0.3±0.6*#	0.6±0.7#
- day cough	1.0±0.9	1.2±0.8	0.4±0.6+	0.6±0.8+	0.2±0.5#	0.4±0.6#
- night cough	1.2±1.0	1.0±1.1	0.3±0.5+	0.7±0.1+	0.2±0.4#	0.2±0.4#
- headache	0.3±0.8	0.4±0.7	0.03±0.2+	0.1±0.4+	0.00±0.00#	0.06±0.3#
- nasal discharge	2.26±0.9	2.3±0.7	0.7±0.6*+	1.1±0.9+	0.5±0.6*#	0.9±0.9#
Satisfaction score[a]	5.97±1.3	5.11±1.2	6.4±0.8+	5.7±0.8+	6.6±0.6*#	6.1±0.8#
Decrease antihistamine use[b]			16(42%)	12(33%)	23(60%)	18(50%)
Episode of URI[b]					1(2.6%)	4(11%)
Side effect[b]	3(8%)	8(22%)	5(13%)*	14(39%)	6(16%)	6(17%)

[a] data are reported as mean ± SD
[b] data are reported as number (percent) of patients.

* p < 0.05 compare between group in the same period
+ p < 0.05 in the same group (compare first and second visit)
# p < 0.05 in the same group (compare first and third visit)

Table 3. bacterial contamination in nasal irrigation devices

		Squeezable bottles (N=38)	syringe (N=30)	P-value
Bacterial culture (%)	No growth	5(13.2)	7(23.3)	0.39
	Gram +	6(15.8)	4(13.3)	
	Gram -	2(5.3)	1(3.3)	
	Mixed growth	25(65.8)	18(60.0)	

Table 4. Identification of pathogenic *Staphylococcus aureus* in gram positive contamination devices

Gram positive contamination	Pathogenic *S. aureus* contamination (%)		No growth (%)
	Squeezable bottles	Syringes	
53 cases	18 (33.9)	11 (20.7)	24 (45.3)

Satisfaction with nasal irrigation was determined by a 7-point Likert scale at the beginning of the treatment period (0 weeks), 1 and 2 weeks following initiation of treatment. The mean scores represented a status of between satisfactory and good, and patients treated with the squeezable bottle had a statistically greater improvement in mean satisfaction score compared to those treated with the syringe (P = 0.004, P = 0.001 and P = 0.009 at 0, 1 and 2 weeks, respectively). Details are presented in **Table 2**.

We also assessed the efficacy of each device for controlling nasal symptoms in pediatric sinusitis patients by comparing their use of antihistamines and decongestants. For both groups, reduced use of antihistamines was observed 1 and 2 weeks after initiation of treatment, but there was no statistically significant difference between the groups (**Table 2**). Five patients developed upper respiratory infections during the 2-week treatment period (one patient in the squeezable bottle group and four patients in the syringe group). These five patients had gradual improvement in nasal symptoms within 1 week of follow up. None of these five patients required further antibiotic treatment.

To assess the safety and tolerability of each device, patients were asked about their sensations and feelings after application of the nasal wash. At the first visit, 11 of 74 patients (14.8%) reported side effects including nasal irritation (two patients in the squeezable bottle group and six in the syringe group), nasal congestion (one patient in the squeezable bottle group and one in the syringe group) and tinnitus (one patient in the

syringe group). One week later, 19 patients reported side effects including nasal irritation (one patient in the squeezable bottle group and 10 in the syringe group), nasal congestion (three patients in the squeezable bottle group and two in the syringe group) and tinnitus (one patient in the squeezable bottle group and two in the syringe group). At the last visit, 12 patients reported side effects including nasal irritation (one patient in the squeezable bottle group and four in the syringe group), nasal congestion (four patients in the squeezable bottle group and one in the syringe group) and tinnitus (one patient in the squeezable bottle group and one in the syringe group). However, these unexpected symptoms were not serious enough to warrant discontinuation of nasal irrigation. The results are summarized in **Table 2**.

Data were collected from the devices used by 68 patients to evaluate bacterial contamination. Among 38 samples from squeezable bottles, bacteria were identified in 86%, six of which were positive for gram-positive bacteria, two for gram-negative bacteria and 25 for a mixture of both gram-positive and gram-negative bacteria, with five bottles negative for bacterial growth. In 30 samples from syringes, bacteria were identified in 76%, four of which were positive for gram-positive bacteria, one for gram-negative bacteria and 18 for both gram-negative and gram-positive bacteria, with seven syringes negative for bacterial growth (**Table 3**). To identify pathogenic bacteria in the gram-positive and mixed organism-positive devices (53 cases), *Staphylococcus aureus* was selected as a representative pathogen in nasal mucosa. The results showed that colonization

by pathogenic *Staphylococcus aureus* was found in 18 squeezable bottles and 11 syringes, and 24 devices were not colonized with pathogenic *Staphylococcus aureus* (**Table 4**).

Discussion

Nasal irrigation is widely used as an adjunctive treatment for sinusitis. It is effective for decreasing sinonasal symptoms and improving mucociliary clearance.[8-15] Although there are commonly minor side effects, the beneficial effects of nasal irrigation appear to outweigh these problems for the majority of patients.[11,18] Various different devices have been studied for nasal irrigation. Previous studies have reported that nasal irrigation with positive-pressure devices are more effective than nebulization or nasal sprays.[29-32] Until now, there have been no randomized controlled studies to compare positive-pressure nasal irrigation devices in children with sinusitis.[29-31,36] To our knowledge, this is the first randomized controlled trial to show greater efficacy and greater satisfaction from a squeezable bottle versus a disposable syringe for providing short-term (2 weeks) relief of sinonasal symptoms in pediatric sinusitis. The mechanism for this greater efficacy is unclear. It has been suggested that squeezable bottles can more effectively release the volume of solution into the nasal cavity, as the tip of the bottle fits into each nostril resulting in minimal leaking of the irrigated solution, which more effectively clears mucus from the nasal cavity, thereby allowing the sinus ostium to open and drain secretions or pus from the sinus. The squeezable bottle can also easily be used with one hand, allowing the other hand to hold the child's head in a good position. Finally, older children can use nasal irrigation by themselves, and can adjust the volume of the irrigated solution by controlling the pressure to squeeze.

Regarding the safety of nasal irrigation devices, we found that both devices were well-tolerated by the patients and showed similar minor side effects, none of which were serious enough to discontinue nasal irrigation. However, six participants (one in the squeezable bottle group and five in the syringe group) dropped out of the study due to an improvement in nasal symptoms within the first week of treatment. It is not possible to conclude whether this was due to better tolerance of the squeezable bottle compared to the syringe.

Previous studies have only provided limited information regarding bacterial contamination of nasal irrigation devices, most of which have focused on patients who used nasal irrigation following endoscopic surgery or patients with chronic rhinosinusitis. The rate of bacterial contamination has been reported to range between 45-97%, with a higher rate of contamination observed when devices were used for longer than 1 week.[29-32] However, no cross-contamination between devices and patients has previously been identified.[36] Our study is the first to report the rate of bacterial contamination in nasal irrigation devices used by children. Our results are in line with previous reports,[29-32,36] as the overall rate of contamination was found to be 80%, which was similar for both the bottle and syringe. The most prevalent bacteria cultured were *Staphylococcus aureus*, in addition to other non-pathogenic gram-positive and unidentified gram-negative bacteria. Consistent with previous studies, no cross-contamination between devices and patients was identified. Although device contamination did not translate into a higher rate of infection in our patients, it is important to emphasize that regular cleaning of the irrigation device is required to minimize bacterial contamination. Previous studies have attempted to minimize bacterial contamination, including the design of a one-way valve or pulsed nasal irrigation to minimize backwash,[31,37] in addition to the use of improved methods of cleaning nasal irrigation devices,[29-31] however, none have been found to be effective. Keen et al.[34] found that Milton's solution (1% NaOCl and 19% NaCl), combined with subsequence microwave of the bottle, was effective at reducing the contamination of irrigation bottles. The development of effective cleaning techniques for nasal irrigation devices warrants further investigation.

In conclusion, this study supports the regular use of nasal irrigation with a positive-pressure device, particularly a squeezable bottle, as an effective adjunctive treatment for pediatric sinusitis. It is effective for reducing sinonasal symptoms and can be used by patients with good compliance and minimal side effects. Bacterial contamination of nasal irrigation devices was found to be similar to that previously reported by other studies, with a high rate of contamination observed. However, in this study, none of the patients that used a contaminated irrigation device had persistent or recurrent symptoms. Future studies should focus on developing an effective technique for cleaning nasal irrigation devices.

Acknowledgments

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