Multipatient Use of Prefilled Disposable Oxygen Humidifiers For Up to 30 Days: Patient Safety and Cost Analysis

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BACKGROUND: Prefilled disposable oxygen humidification units have been shown to decrease the likelihood of contamination when compared to reusable oxygen humidification units. However, prefilled disposable humidifiers are expensive when used for single patients, especially in areas of high turnover, and it is not known whether these units need to be routinely changed before they are empty. The number of patients safely using a prefilled disposable humidifer has not been documented in previously reported work. Are patients at risk of nosocomial infections due to cross-contamination when prefilled disposable oxygen humidifiers are applied to multipatient use? What are the cost benefits of multiple patient use of prefilled disposable oxygen humidifiers? When local practice or physician preference dictates the use of humidification for low-flow oxygen, these questions need to be answered. METHODS & MATERIALS: Data were collected over two time periods to address changes due to seasonal variations and include area of use, number of patients, and quantitative cultures for aerobic microorganisms (including *Legionella*). Each disposable humidifier was monitored for a period of 1 month or until only 1 inch of water remained. Costs of using reusable humidifiers and prefilled humidifiers and therapist/nurse time to initiate therapy with both units were compared. During this period, 60 reusable humidifiers were also cultured for aerobic microorganisms and *Legionella*. RESULTS: We report results on 1,311 of the 1,315 disposable prefilled oxygen humidifiers used. We saw no significant growth in any of the prefilled disposable humidifiers for periods of up to 30 days, with > 100 humidifiers having been used by > 20 patients. CONCLUSIONS: Our results show that prefilled disposable oxygen humidifiers can be used without cross-contamination, on multiple patients, for a period of 1 month. The use of prefilled humidifiers in this way represents a substantial cost saving when compared to reusable humidifiers. (Respir Care 1993;38:343-347.)

Introduction

Although it has been suggested that humidification of low-flow oxygen (1-4 L/min) may not be necessary,[1-4] the practice is a standard procedure in our hospital, appears to be standard practice in Canadian hospitals, and persists in part because of the extremely low relative humidity encountered during cold weather. A number of studies[5-7] from the 1960s and 70s suggest that aerosols from contaminated nebulizers are likely to spread infection but that bubble humidifiers pose little threat. However, simple bubble humidifiers have been shown in a bench study to produce microaerosols capable of transmitting contagion[8] and a more recent report has implicated such devices.[9] We sought to determine the safety of prolonged multipatient use of prefilled humidifiers, to establish contamination rates of prefilled and reusable humidifiers, and to compare costs of using the two types of device.

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Methods and Materials

Areas of the hospital selected to take part in the study were the Emergency Department, Recovery Room, and four Medical Units (including a respiratory unit). Excluded were patients in respiratory or acid-fast bacillus (AFB) isolation and neutropenic and immunocompromised patients. Monitoring of the disposable humidifiers took place over two periods of time: April through August, 1990, and February through May, 1991. Reusable humidifiers were cultured during November 1991.

Prefilled Humidifiers

A monitoring sheet was attached to each humidifier as it was placed in service. The dates that the humidifier was opened and removed from service, unit and bed number, and the number of patients using the humidifer were to be noted. Personnel on nursing units were informed of the study, and in-service training was provided for the nursing staff on use of the monitoring sheet and the prefilled humidifier (Aquapak, Hudson RCI, Temecula CA). Each humidifier was kept in place for a maximum of 30 days or until only 1 inch of water remained in the humidifier. When the prefilled humidifier was removed, both the flowmeter inlet and the humidifier outlet were aseptically sealed with sterile gauze and tape and the humidifier was transported to the microbiology laboratory.

On the first Monday of each study month, humidifiers were connected to flowmeters and placed with the monitoring sheets above the patient beds. A check was made midmonth, and any humidifiers with 1 inch of water or less remaining were taken to the laboratory. At the beginning of the next month, all remaining humidifiers were removed aseptically and replaced by the same procedure.

Reusable Humidifiers

For a 1-month period, reusable oxygen humidifiers were used according to standard hospital practice as outlined. Hospital procedure dictated single-patient use, with sterile water being changed every 8 hours. However, adherence to this procedure was not monitored or enforced by our team because the purpose of this part of the study was to see whether contamination of reusable humidifiers occurred with methods currently in use. The humidifiers were collected weekly and transported to the microbiology laboratory.

Culture Procedure

Quantitative cultures were done on both prefilled disposable and reusable humidifiers for aerobic microorganisms, including *Legionella*. Residual water in the humidifiers was swirled and aseptically removed using a tuberculin syringe and a 25-gauge needle.[10] Blood agar, chocolate agar, and buffered charcoal yeast extract plates were inoculated by spreading 0.1 mL of water uniformly over the agar surface. Media were preincubated for 24 hours to exclude environmental contamination, and 70% of the samples were processed using a HEPA filtration biosafety cabinet (NuAire Biological Safety Cabinet, Model 3 NU410-400, NuAire Inc, Plymouth NM) located in the Infectious Disease Research Laboratory. All plates were incubated in 5% CO_2 at 37°C and read at 24 and 48 hours. *Legionella* plates were read at 72 hours and at 7-10 days. A record was made of the number of colony forming units per mL (cfu/mL) per plate and the different morphotypes.[11]

Results

A total of 1,315 prefilled disposable humidifiers were collected; of these, 1,311 had completed data forms and sufficient water for culturing. In the months of April through August 1990, 636 disposable humidifiers were cultured, and in the months of February through May, 1991, 675 disposable humidifiers were cultured. Sixty reusable humidifiers were cultured during November 1991. During the first monitoring period, 4/636 disposable humidifiers had from 10 to 30 cfu/mL bacterial growth. Significant growth was considered to be greater than 100 cfu/mL.[11] These four humidifiers may have been suspect due to environmental contamination of water samples during planting. A HEPA filtration biosafety cabinet was then acquired to prevent this inadvertent contamination. All of the 675 disposable humidifiers were culture negative during the second monitoring period. Of the 60 reusable

Table 1. Culture Results from Disposable and Reusable Humidifiers

Humidifier Type	Total Number	Number Contaminated
Prefilled		
Period 1	636	4 (0.6%)*
Period 2	675	0 (0%)
Reusable	60	6 (10%)

*10-30 cfu/mL, not considered clinically important.

humidifiers cultured, 6 had significant bacterial growth (Table 1). Most of this growth was coagulase-negative *Staphylococcus* or *Micrococcus* species, and therefore the contamination was thought to have been from staff handling or from poor technique during filling of reusable humidifiers as reported by Cahill and Heath.[12]

The disposable humidifiers were used from 1 to 40 days (Fig. 1), and the number of patients using a given humidifier ranged from 1 to 151 (Table 2).

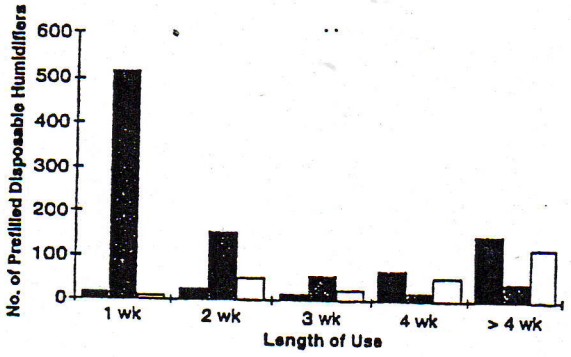

Fig. 1. Hospital area and length of use for 1,311 prefilled disposable humidifers with completed data forms. Emergency and Recovery Room data show that with high patient turnover and noncontinuous use, humidifiers can last for periods of 4 weeks or greater. The majority of the humidifiers were used on medical floors, and for 2 weeks or less because these patients were usually on continuous flows. ■ = emergency room; ■ = medical units; □ = recovery room.

The daily cost of using a prefilled disposable humidifier is outlined per liter of flowrate (Table 3). From the cost analysis figures, we can see that prefilled disposable humidifiers were economical only if used for more than one patient. In one area of high patient turnover, 1 disposable humidifier was used on 151 patients. If this humidifier had been changed for each patient, our cost would have been $314.08 instead of $2.08.

Table 2. Multipatient Use of Disposable Prefilled Humidifiers during the Study Period

Number of Patients	Number of Humidifier Units
0-5	1,067
6-20	114
21-50	77
> 50	53

*One humidifier in the recovery room was used on 151 patients.

Discussion

Although humidifiers have not been thought to play as important a role in the transmission of contagion capable of causing nosocomial pneumonias as have devices producing aerosols,[5-7] Ahlgren et al[8] in a bench study demonstrated the transmission of bacteria from inoculated humidifier reservoirs at gas flows of 5 L/min and Moiraghi et al[9] have reported association between fatal pneumonia and contaminated water in oxygen bubble humidifiers. Rhame et al[13] showed that cascade-type humidfiers can generate microaerosols capable of carrying bacteria when operated at high flowrates (10-80 L/min) but did not report on simple bubble-type humdifiers at low flowrates.

Table 3. Daily Cost of Prefilled Humidifiers Based on Estimated Duration of Use

Oxygen Flowrate	Duration of Use	Daily Cost
2 L/min	152 hours (6.3 days)	$0.33
4 L/min	80 hours (3.3 days)	$0.63

Our results,[14] like the results of others,[10,15-20] suggest that bacterial contamination of prefilled humidifiers during extended multipatient use is unlikely and support the use of prefilled humidifiers in that way.

The study of Daschner et al[21] of mechanically ventilated patients found no safety advantage for mainstream prefilled humdifiers over reusable humidifiers, but our finding of skin-flora contamination of 6/60 reusable humidifiers suggests otherwise.

When the staff time and cost for filling the reusable humidifiers and sterile water costs are taken into account, it is more cost-effective to use dispos-

able prefilled humidifiers than reusable devices (Tables 3 & 4). Guidelines for use of prefilled disposable humidifiers are sketchy and inconclusive. CDC (Centers for Disease Control)[22] addresses the issue by stating that disposable units may be safe to use for a period longer than 24 hours but "it is unknown whether these need to be routinely changed before they are empty." The Canadian Guidelines state "when used for the same patient, prefilled sterile disposable units may be left in place in accordance with the manufacturer's time limit recommendations."[23] Single-patient usage of these prefilled disposable humidifiers is very expensive[10] ($2.08 per patient, Canadian dollars), especially in areas of high patient turnover where humidifiers might be used for only a few hours. Manufacturers of disposable oxygen units label their units "single use," and the time frame for use of the unit is not addressed.

Table 4. Reusable Humidifer Cost per Patient

Hudson reusable humidifier (not included in cost analysis)	$29.00
Cleaning aide wage	$ 9.84/hour
Sterile H_2O 1,000 mL	$ 1.30
Nurse/therapist wage	$18.00/hour

Function	Time	Cost
1. Disassemble soiled humidifier, prewash, rinse, place in Cidematic $ 1.64		10 min
2. Soak in Sporicidin	10 min	$ 1.64
3. Take out of Cidematic, rinse, dry	20 min	$ 3.28
4. Reassemble, package, place on ward	10 min	$ 1.64
5. Obtain humidifier and H_2O then nurse/therapist takes to patient room to disassemble, fill with H_2O, reassemble, connect to oxygen and patient	15 min	$ 5.80
6. Take to soiled equipment room for transport to respiratory department for cleaning	10 min	$ 1.64
TOTAL	75 min	$15.64

Our hospital policy regarding reusable oxygen humidifiers states, "Only sterile distilled H_2O will be used in reusable humidifiers and will be dispensed of aseptically. After a large bottle of sterile H_2O has been opened it must be discarded in 24 hours. Reusable oxygen humidifiers should be completely emptied and refilled every 8 hours or more often if fluid gets below fill line (bottles not to be topped up)." All this was very expensive both in labor and sterile water cost. Our hospital administrative policy dictated that items labeled "Single Patient Use" not be reused. Earlier studies on multipatient use are small and include no microbiologic data regarding length of time a disposable unit may be left in place.[10,14-20] Meehan[19] showed sterility in 14 prefilled disposable humidifiers up to a period of 77 days, but this was an in-vitro study and humidifiers were never connected to patients. Seto et al[20] evaluated 46 prefilled disposables in use on patients for a period of 1 to 6 days and concluded that sterility could be maintained. Because of the small numbers and short duration, the researchers concluded that it was acceptable to leave them on wall outlets for only up to 10 days.

Conclusions

Based on our data, the practical findings are three. First, disposable prefilled humidifiers can be used safely without risk of contamination until empty, or for up to 4 weeks. Second, prefilled humidifiers can be used safely for many patients in succession. Third, using prefilled humidifiers for multiple patients will result in a substantial cost saving when compared to reusable humidifiers.

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Wielopacjentowe Stosowanie Wstępnie Napełnionych Nawilżaczy Tlenowych Do 30 Dni:

Bezpieczeństwo Pacjentów i Analiza Kosztów

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Stwierdzono, że wstępnie napełnione, jednorazowe nawilżacze tlenowe zmniejszają ryzyko zakażenia w porównaniu z wielorazowymi pojemnikami. Jednakże, wstępnie napełnione nawilżacze są droższe, kiedy stosowane są tylko u pojedynczych pacjentów, szczególnie przy częstej zmianie pacjentów. Nie wiadomo, czy pojemniki te muszą być zmieniane wcześniej, zanim są opróżnione. Liczba pacjentów, która mogłaby korzystać z tych samych pojemników nie była wcześniej zdefiniowana. Czy pacjenci są narażeni na wewnątrzszpitalne zakażenia krzyżowe, kiedy pojemniki te używane są do wielu pacjentów? Jakie są korzyści finansowe stosowania pojemników jednorazowych do wielu pacjentów? Kiedy lokalna praktyka lekarska nakazuje nawilżanie tlenu przy niskim przepływie, te pytania wymagają odpowiedzi.

Wstępnie napełnione nawilżacze

Karta monitorująca była dołączona do każdego nawilżacza. Notowano daty, kiedy nawilżacz był otwarty i kiedy wycofany z użycia, nazwę oddziału i łóżka a także liczbę pacjentów, u których stosowano nawilżacz. Personel został poinformowany o badaniu oraz przeszkolony w zakresie wypełniania kart monitorujących i nawilżaczy (**Aquapak, Hudson RCI**, Temecula CA).

Każdy nawilżacz był wykorzystywany maksymalnie do 30 dni lub gdy, zostało tylko 2,5 cm wody w pojemniku. Kiedy nawilżacz był wyjmowany, zarówno wlot przepływomierza jak i wylot nawilżacza były aseptycznie uszczelniane sterylną gazą i taśmą a pojemnik był transportowany do laboratorium mikrobiologicznego.

Wyniki

Zastosowano filtry HEPA w komorze bezpieczeństwa biologicznego, aby uniknąć przypadkowego zakażenia.

U wszystkich spośród 675 stosowanych jednorazowych nawilżaczy posiewy były negatywne.

Spośród 60 wielorazowych nawilżaczy, w 6 stwierdzono znaczny wzrost bakterii. W większości były to bakterie ze szczepów koagulazo-ujemnych Staphylococcus i Micrococcus.

Uważa się, że zakażenia pochodziły od rąk personelu oraz techniki napełniania wodą wielorazowych nawilżaczy zgodnie z doniesieniami Cahill i Heath.

Jednorazowe pojemniki były stosowane od 1 do 40 dni ora liczba pacjentów korzystających z danego nawilżacza wahała się od 1 do 151.

Analiza kosztów finansowych wskazywała, stosowanie jednorazowych pojemników było tylko ekonomicznie uzasadnione, kiedy były one stosowane u wielu pacjentów.

W obszarze częstej zmiany pacjentów (sala wybudzeń) 1 pojemnik zastosowano u 151 pacjentów.

Gdyby pojemnik był zmieniany po każdym pacjencie całkowity koszt wynosiłby 314,08 USD zamiast 2,08 USD.

Dyskusja

Nasze wyniki, podobnie jak innych autorów sugerują, że zakażenia bakteryjne wstępnie wypełnionych nawilżaczy podczas wielopacjentowego, przedłużonego stosowania są mało prawdopodobne wspierają ich użycie w ten sposób.

Kiedy bierzemy pod uwagę czas pracy personelu i koszt napełniania sterylną wodą wielorazowych pojemników, stosowanie wstępnie wypełnionych jednorazowych pojemników jest uzasadnione ekonomicznie.

Wnioski

Opierając się na naszych danych wysuwamy trzy praktyczne wnioski.

Po pierwsze, jednorazowe, wstępnie napełnione nawilżacze mogą być bezpiecznie używane bez ryzyka zakażenia do 4 tygodni.

Po drugie, wstępnie napełnione nawilżacze mogą być bezpiecznie używane u wielu, kolejnych pacjentów.

Po trzecie, korzystanie z tych pojemników u wielu pacjentów prowadzi do znacznej redukcji kosztów w porównaniu z wielorazowymi nawilżaczami.