Microbiological Assessment of 24- and 48-h Changes and Management of Semiclosed Circuits from Ventilators in a Neonatal Intensive Care Unit

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The contamination of semiclosed disposable circuits of Healthdyne and Bourns ventilators was studied in a newborn intensive care unit over a 2-year period. A total of 379 fluid samples was obtained from inspiratory and expiratory tubing condensates and traps and from thermal humidifier columns fed with prefilled containers of sterile water. In addition, 100 tryptic soy agar plates were exposed to the exhalation mist of the circuits sampled. With 24-h changes of circuits a 2.5% contamination rate was observed (phase I). In an effort to contain costs, circuits were changed every 48 h (phase II); the concentration of potential pathogens increased to $10^5$ CFU/ml with this extension of changing time. Two long-term (15- and 9-month) infants were colonized and intermittently infected, one with Klebsiella pneumoniae and Staphylococcus aureus and the other with Pseudomonas aeruginosa. When the protocol was readjusted from 48- to 24-h circuit changes (phase II), the contamination rate decreased; for the two colonized infants (35 circuits, 123 samples) the contamination rate decreased from 19 to 6% ($P < 0.01$; chi-square test), and for seven noncolonized infants (59 circuits, 217 samples) the contamination rate decreased from 5 to 0.5% ($P < 0.001$; chi-square test). These data suggest that frequent changing of the circuits reduces colonization and cross-infection.

Improvements in technology have greatly enhanced the chances of survival for high-risk neonates, especially term and preterm low-weight newborns (14–16). Because sepsis reduces the chance for survival, its detection in neonates is very important (17). New or changed therapies, equipment and protocols should be tested for effectiveness in diverse settings (14). The methods used to detect colonization, particularly colonization with resistant organisms, and the transmission of such organisms to other high-risk individuals need periodic assessment for improvement of techniques and for safer health care delivery (7, 8, 10, 12, 16, 19, 20).

One area of investigation includes life support systems that are used in respiratory therapy. In this paper I describe the results of a study of respiratory therapy equipment. One hospital requested microbiological surveillance of a disposable closed-system ventilator circuit that was newly installed in a neonatal intensive care unit (ICU). This system, with 24-h changes of circuits, was monitored intermittently over a 6-month period (phase I of this study) to determine contamination rates. During the following year (phase II) the personnel decided to extend the use of circuits to 48 h in order to contain costs. The major objectives of this study were (i) to conduct quantitative and qualitative microbiological tests on samples obtained from disposable ventilatory circuits that were changed every 24 h (phase I) or every 48 h (phase II), (ii) to review data and the modification of the change-of-circuit protocol, if warranted, and (iii) to evaluate the significance of changes in microbial concentrations after any modifications of protocol were instituted.

(Some of the results were presented previously [Int. Cong. Microbiol. 1982, Boston, Mass., p 337, p. 108].)

MATERIALS AND METHODS

Definition of terms. The closed-system ventilator (Fig. 1) utilized a prefilled container (1,500 ml; Concha) of sterile water which fed a thermal humidifying column every 24 h. Although it was not necessary to manually open the humidifier reservoir to add sterile water periodically, the system required periodic emptying of condensate from the inspiratory and expiratory traps every 2 to 6 h. Thus, the closed-system circuit was really a semiclosed system.

The term rate of contamination was used to indicate the percentage of positive samples found among a group of samples.

The term neonate refers to infants from birth up to 27 days of life. The term infant refers to a child under the age of 2 years.

Samples of in-use equipment. Over a 2-year period, 379 samples were obtained from the disposable circuits of 23 premature infants on ventilators (20 patients on Healthdyne ventilators; 3 patients on Bourns ventilators) in a 15-bed ICU. Samples (1 ml) of fluid were pipetted from the circuits into sterile screw-cap test tubes (150 mm) on a daily or intermittent basis. These samples were either immediately transported to a microbiology laboratory or placed on ice for processing. They usually were plated and incubated within 1 to 2 h after collection depending on the number of samples collected per day. The sites of sampling from the disposable circuits (Fig. 1) included the inspiratory (Fig. 1D and E) and expiratory (Fig. 1G and H) tubing and traps and the reservoirs of the thermal humidifier columns (Concha) within the humidifying units (Fig. 1B). When the circuits and prefilled water containers were changed, the date and time were recorded by the therapist. Additionally, for each circuit tested tryptic soy agar plates were exposed for 30 s to the ventilator expiratory aerosol exhaust at the exhaust connector (Fig. 1H); 100 plates were collected.

Plating. When a direct dilution method (13) was used, 0.1-, 0.01-, and 0.001-ml samples were plated by using pipettes (0.1 ml) and calibrated loops. Tryptic soy agar and blood agar plates containing 5% defibrinated sheep blood were used. All plates were incubated aerobically at 37°C for 24 to
48 h and at 25°C for an additional 3 to 5 days for slow growers. The aerosol tryptic soy agar plates were incubated at 37 and 25°C as described above.

**Identification.** Representative colonies were counted, described, and Gram stained. Types of hemolysis and pigmentation were noted. Oxidase tests were done on gram-negative rods. Oxiferm and Enterotube systems (Roche Diagnostics, Nutley, N.J.) or the API-20E system (Analytab Products, Inc., Plainview, N.Y.) were used for identification. Tests for motility (SIM agar or wet mounts) and growth at 42°C were included when necessary. Staphylococci were grown on mannitol-salt agar slants, and resistance to novobiocin was tested. Catalase and coagulase tests were also performed, when appropriate. *The Manual of Clinical Microbiology* (11) was used as a verification reference for identification.

**Growth curves.** Cultures of *Staphylococcus aureus* and *Klebsiella pneumoniae* obtained from the circuits of one infant were grown under the following simulated clinical conditions in the laboratory. Condensates were collected from inspiratory and expiratory circuits in use for 24 to 36 h in 150-ml sterile flasks. These condensate samples were then autoclaved for 15 min at 121°C. Dilutions of each of the two organisms subcultured in nutrient broth for two or three generations were then seeded into 15-ml portions of the sterile condensate that were placed in test tubes (16 by 150 mm). Duplicate tubes of these organisms were maintained in a water bath at 27°C. Turbidity, as indicated by changes in optical density at 550 nm (Spectronic 20 colorimeter; Bausch & Lomb, Inc., Rochester, N.Y.), was recorded every 15 min for the first 12 h; thereafter, readings were taken on an hourly basis due to the apparent slowness of growth. Pour plates were prepared hourly for viable count determinations.

**Statistical analysis.** In order to investigate the significance of the increased microbial concentrations (differences between 24- and 48-h medians) for daily samples, the Wilcoxon matched-pairs signed-ranks test was used. More precisely, the following hypotheses were used: null = median of <10³ CFU/ml; alternate = median of ≥10³ CFU/ml. The chi-square test was used to show the significance of the differences in rate of contamination which occurred after modifications in the protocol of circuit changes were instituted.

**Patient population.** A total of 20 noncolonized neonates hospitalized in the ICU for 1 to 4 weeks were sampled (13 patients in phase I, 7 patients in phase II). These neonates ranged in weight from 640 to 2,500 g. In addition, three colonized infants, which were born with respiratory complications, became long-term patients on ventilators in the neonatal ICU. One intubated infant sampled in phase I was born with hypoplastic lungs and was hospitalized for 48 days. Two infants sampled in phase II were born with hyaline membrane disease and required tracheostomies. These patients were hospitalized for 15 and 9 months and were designated case 1 and case 2, respectively. Before and during this study these three infants periodically showed signs and symptoms of infectious respiratory disease; therefore, they were isolated and placed on antibiotic therapy.

**Hospital environmental control.** The disposable circuits were placed in biohazard plastic bags, secured, and discarded in closed containers. The external parts of the machinery were sprayed with an isopropanol-based aerosol disinfectant spray (Kleenaseptic; Airshields, a Healthdyne Co., Hatboro, Pa.). Contact with the spray was made for approximately 5 min, after which the machinery was dried with a clean cloth. This procedure was repeated, and then the equipment was considered available for use for another patient. Pieces of equipment, beds, and appointments in the ICU rooms were changed weekly for the noncolonized neonates and monthly for the colonized infants. Thus, patients were placed in freshly disinfected rooms on a rotating basis.

Samples (1 ml) obtained from 25 prefilled (Concha) water containers were processed as described above and served as controls for sterile water supplies.

**RESULTS**

**Phase I.** Only 1 of 39 samples (2.5%) from 14 neonates (Table 1) was positive for microbial growth. Interestingly, the positive sample was obtained from the colonized long-term (6-week) infant. When this infant was sampled on day...
In the infant period, collection of sample tubing for long-term neonates was attempted, but no Pseudomonas aeruginosa was obtained, probably because the circuits were changed every 24 h rather than every 48 h for colonized infants or for patients with respiratory infectious disease or both. Exceptional precautionary measures were urged, especially for the isolated patients. Thereafter, the case 1 circuits were negative for 8 of 11 sampling; 2 expiratory trap samples and 1 humidifier sample were positive (Fig. 2). After the directive was issued by hospital personnel to change back to a 24-h protocol, case 2 cultures were positive for one of six inspiratory samples and for four of seven expiratory samples (Fig. 3). Thus, the 123 samples from the two highly colonized infants that yielded 19% positive cultures with the 48-h changes (Table 1) yielded 6% positive cultures with the 24-h changes (P < 0.01; chi-square test). Positive endotracheal washes from these two infants occurred concomitantly with the positive ventilator samples. The infants were colonized or had intermittent active respiratory infections according to charted clinical findings. Case 1, who was subsequently transferred to an institution for children, developed infections with S. aureus and K. pneumoniae. Case 2, who expired at the age of 9 months, developed infections with P. aeruginosa.

The use of equipment was also extended to 72 h for two samples from the seven ventilated noncolonized neonates. For these seven neonates (Table 1), 5% of the 217 samples were positive when the circuits were changed every 48 h, and 0.5% were positive when circuit changes occurred every 36 h after admission, only the inspiratory tubing samples could be obtained, and they were negative; 1 week later, the inspiratory tubing sample was negative, and the expiratory tubing sample yielded >10^7 CFU of Pseudomonas aeruginosa per ml. Tracheal sample results were also positive for P. aeruginosa. No additional samples were obtained because the infant expired on day 48 of hospitalization.

**Phase II.** A total of 340 fluid samples was collected from 94 ventilator circuits of two highly colonized infants and seven noncolonized neonates (Table 1). At the beginning of the collection period, it was observed that (i) some colony counts increased greatly (to 2 × 10^9 CFU/ml) (Fig. 2 and 3) after the circuits were used for 24 h or more for the two highly colonized long-term cases and (ii) the changing of some circuits was extended to 72 h on two different sampling days (Fig. 2 and 3). The most common organisms found included Acinetobacter calcoaceticus subsp. anitratus, K. pneumoniae, P. aeruginosa, Pseudomonas maltophilia, Bacillus spp., Candida spp., Micrococcus spp., and Staphylococcus epidermidis in case 1 (Fig. 2). P. aeruginosa, S. aureus, and Bacillus spp. were encountered in case 2 (Fig. 3). During this time, P. aeruginosa was found in the humidifier column (1 × 10^5 CFU/ml) and also on one 30-s aerosol plate (>2 × 10^4 CFU per plate) at 48 h (Fig. 3).

Because there were marked increases in the concentrations of potential pathogens, an interim report was prepared for the hospital personnel. After this, the circuits were changed every 24 h rather than every 48 h for colonized infants or for patients with respiratory infectious disease or both. Exceptional precautionary measures were urged, especially for the isolated patients. Thereafter, the case 1 circuits were negative for 8 of 11 sampling; 2 expiratory trap samples and 1 humidifier sample were positive (Fig. 2). After the directive was issued by hospital personnel to change back to a 24-h protocol, case 2 cultures were positive for one of six inspiratory samples and for four of seven expiratory samples (Fig. 3). Thus, the 123 samples from the two highly colonized infants that yielded 19% positive cultures with the 48-h changes (Table 1) yielded 6% positive cultures with the 24-h changes (P < 0.01; chi-square test). Positive endotracheal washes from these two infants occurred concomitantly with the positive ventilator samples. The infants were colonized or had intermittent active respiratory infections according to charted clinical findings. Case 1, who was subsequently transferred to an institution for children, developed infections with S. aureus and K. pneumoniae. Case 2, who expired at the age of 9 months, developed infections with P. aeruginosa.

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**TABLE 1.** Percentages of positive samples from ventilator units in a 2-year neonatal ICU surveillance

<table>
<thead>
<tr>
<th>Phase</th>
<th>No. of patients</th>
<th>No. of ventilator circuits</th>
<th>No. of samples</th>
<th>48-h Changes</th>
<th>24-h Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>14a</td>
<td>19</td>
<td>39</td>
<td>NDa</td>
<td>1 (2.5)</td>
</tr>
<tr>
<td>II</td>
<td>2 (colonized)b</td>
<td>35</td>
<td>123*</td>
<td>23 (19)</td>
<td>8 (6)</td>
</tr>
<tr>
<td></td>
<td>7 (noncolonized)c</td>
<td>59</td>
<td>217*</td>
<td>10 (5)</td>
<td>1 (0.5)</td>
</tr>
</tbody>
</table>

* In phase I there were 13 short-term neonates and 1 neonate who became a long-term case (6 weeks).
* ND, Not done.
* The numbers in parentheses are percentages.
* Two respiratory system-colonized infants remained in the hospital neonatal ICU for prolonged times (15 and 9 months).
* P < 0.01 (chi-square test).
* Number of noncolonized neonates (excluding the two colonized infants).
* P < 0.001 (chi-square test).

- **FIG. 2.** Sites and distribution of microorganisms in case 1. Symbols: /, change in protocol; //, break in time; solid lines, daily changes; dashed lines, intermittent changes; , 24-h changes; , 48-h changes; , 72-h changes. ac, A. calcoaceticus subsp. anitratus; b, B. subtilis spp.; c, C. albicans spp.; d, P. maltophilia; e, humidifier column (2.6 × 10^6 CFU of K. pneumoniae per ml, attributed to backflow from t-tube); f, K. pneumoniae; g, M. luteus spp.; h, S. epidermidis; i, P. aeruginosa; j, S. aureus.
24 h (P < 0.001; chi-square test). The inspiratory circuits or expiratory circuits or both of two noncolonized neonates were contaminated with Enterobacter agglomerans (0 at 24 h; >10^3 CFU/ml at 48 h) on three different dates. The samples from these patients and two other noncolonized neonates had ≤400 CFU of either S. epidermidis, Micrococcus spp., or Bacillus spp. per ml at one or two sites. The sites contaminated with these gram-positive organisms included one expiratory trap, two inspiratory traps, and two humidifier columns. The circuits of three noncolonized neonates were negative at all sampling times. All prefilled water containers used as controls were negative.

**Statistical analysis.** The overall rate of contamination during phase II for the 340 samples (Table I) decreased from 10% for 48-h changes to 3% for 24-h changes (P < 0.001; chi-square test). When the differences between the 24- and 48-h microbial concentrations were compared, the Wilcoxon matched-pairs signed-ranks test was used to determine whether the observed increases were significant. Ten matched concentrations of microorganisms from the expiratory data were available for both 24- and 48-h consecutive observations. Because my primary interest was in the size of the increase when growth cultures were positive, two pairs showing no increase were not included in the analysis, leaving a sample size of eight. This is equivalent to discarding zeros in the Wilcoxon test, which is recommended (4, 9). The results showed Tn = 0, which (with n = 8) gave P = 0.004. Similarly, for nine matched concentrations of microorganisms from the inspiratory data, four pairs of zeros were discarded, leaving Tn = 0 (n = 5; P = 0.031).

**Comparison of contamination rates by site.** After the change in protocol from 48 to 24 h was made, a comparison of the percentages of positive samples by site showed consistent decrease (Fig. 4). For the 217 samples from the seven noncolonized neonates, the graph showed 4 to 8% decreases in the percentages at the humidifier sites and at the inspiratory and expiratory sites, respectively. However, for the 123 samples from the two colonized infants, a 5% decrease was observed at the humidifier site; 11 and 22% decreases were observed at the inspiratory and expiratory sites, respectively. When the numbers of positive and negative samples for the 48- and 24-h changes were analyzed by a chi-square analysis for the different sites, only the data for the inspiratory and expiratory sites of the 123 samples from the two colonized infants showed a significant difference (P < 0.001). In general, greater contamination rates were observed (Fig. 4) in the data from expiratory sites than in the data from inspiratory sites. One exception was found among the noncolonized short-term neonates, for whom the inspiratory contamination rate was 8% (compared with 5% at the expiratory site).

**FIG. 3.** Sites and distribution of microorganisms in case 2. Symbols: /, change in protocol; //, break in time; solid lines, daily changes; dashed lines, intermittent changes; ●, 24-h changes; ▲, 48-h changes; △, 72-h changes. a, Exhaust (30-s exposure; approximately 2 × 10^10 CFU of P. aeruginosa per plate); b, 10^3 CFU of P. aeruginosa per ml in the thermal humidifier column; c, P. aeruginosa (1 × 10^6 CFU/ml) and Bacillus spp. (3.5 × 10^8 CFU/ml); d, S. aureus (1.2 × 10^6 CFU/ml) and P. aeruginosa (6 × 10^5 CFU/ml); e, P. aeruginosa (5 × 10^6 CFU/ml) and Bacillus spp. (1 × 10^5 CFU/ml).

**FIG. 4.** Differences in percentages of positive samples by site after 48- and 24-h changes of ventilator circuits (phase II).
autoclaved in-use (24- to 36-h) inspiratory and expiratory circuit of a colonized infant in phase II are shown in Fig. 5. Laboratory conditions of two organisms obtained from *P. aeruginosa* (18-h lag phase) and *S. aureus* (20-h lag phase) grew sates maintained at 27°C. These data may be related to the actual care of ventilator circuits. In a neonatal ventilator, assuming prepackaged sterile water packs and an uncontaminated oxygen supply, the most logical place for contamination is the breathing circuit. The part of the circuit least likely to be contaminated is the heated humidifier column (if it is kept at approximately 60°C). The humidifier columns of cases 1 and 2 were contaminated with 2.6 × 10^4 CFU of *K. pneumoniae* per ml and 10^5 CFU of *P. aeruginosa* per ml, respectively. These two contaminations apparently resulted from the backflow of a t-tube during the weaning process from the ventilator in case 1 and during ordinary usage in case 2. The latter most probably occurred by raising the tubing during care of the infant or changing of circuits.

The inspiratory and expiratory tubing and traps may become contaminated during set-up at ports. However, the traps must be emptied periodically since various amounts of condensate collect in the traps because of temperature differentials. The humidified oxygen was delivered at 37°C. The approximate temperature readings were as follows: heated humidifier column, 60°C (42°C at the outlet); inspiratory trap condensate, 27°C; and distal expiratory trap condensate, 24°C. Traps may become logical microbial portals due to manipulation during frequent emptying. The factors most likely associated with contamination include oral and respiratory organisms shed from the patient, accumulation of organic debris during tracheal suctioning, and contamination from hands of personnel. Nutrients present in wet tubing and condensate traps could support microbial growth (1, 2, 5, 6). Moist conditions during prolonged use likewise could provide favorable growth conditions (2, 5). The inspiratory condensate showed increased growth from 0 to 24 h, from 24 to 48 h, and, on two occasions, from 48 to 72 h (Fig. 2 and 3). The exceptional higher contamination rate of the inspiratory condensate compared with the expiratory condensate (8 and 5%, respectively) may reflect differences in the source of contamination (predominantly gram-positive organisms), as well as differences in microbial growth patterns. The four gram-negative inspiratory and expiratory microbial counts of *E. agglomerans* reported for the seven noncolonized neonates apparently represented hand contamination during the emptying of traps. This gram-negative organism was not reported elsewhere.

Ideally, it would be expedient to determine an optimal change time of circuits that coincides with the lag phase of the microbial growth curve. The objective would be to avoid exponential multiplication of organisms. Assuming no or low contamination through air exposure at the beginning, one would expect a prolonged lag phase for growth of organisms in sterile water at room temperature. However, studies have shown that some gram-negative organisms can grow rapidly when they are transferred into sterile distilled water (1, 2, 5, 6), reaching a concentration of ≥10^6 CFU/ml in 24 h. *P. aeruginosa* and *Pseudomonas cepacia* required little or no lag time at 25 and 37°C when they were placed in sterile distilled water for 24 or more h (2, 5).

**FIG. 5.** Viable counts obtained on an hourly basis for *K. pneumoniae* (18-h lag phase) and *S. aureus* (20-h lag phase) grown in autoclaved in-use (24- to 36-h) inspiratory and expiratory condensates maintained at 27°C.

**Growth curve.** The results of experimental growth under laboratory conditions of two organisms obtained from the circuit of a colonized infant in phase II are shown in Fig. 5. The lag phase for *K. pneumoniae* at 27°C was 18 h, after which exponential multiplication occurred; the concentration reached ≥10^4 CFU/ml by 24 h. *S. aureus* also demonstrated a prolonged lag phase (20 h) and reached a concentration of ≥10^6 CFU/ml by 28 h. The generation times under these conditions were 27 and 36 min, respectively.

**DISCUSSION**

A preliminary surveillance of semiclosed disposable ventilator circuits that were changed every 24-h revealed a contamination rate of 2.5%. This rate was based on only 1 positive expiratory sample among the 39 samples obtained from the circuits of 14 neonates in phase I. Nevertheless, the nature of the contamination deserves attention. The long-term, low-birth-weight infant with respiratory complications from birth and with a compromised host defense system was at greater risk for colonization and subsequent active infection than the normal low-birth-weight neonates who were hospitalized for short times (2 to 3 weeks) (8, 15). Colonization of the infant and circuits and subsequent active infection with *P. aeruginosa* were evident in this patient, as determined by clinical and hospital laboratory reports.

Similar problems associated with high-risk and long-term infants were encountered in cases 1 and 2 of phase II. These patients were used in this study as examples to emphasize the need for watchfulness among personnel. At the beginning of the phase II study, when 48-h changes were being used, the contamination rate for the two long-term colonized infants seemed high at 19%. These infants could serve as sources of infection for one another, for other neonates, and for personnel. Cross-infection was reportedly traced to one staff member who carried *P. aeruginosa* from case 2 to case 1 via improperly washed (unscrubbed) hands. Corrective steps in handwashing and scrubbing procedures were more strictly enforced thereafter. Surveillance of the microbial populations on the hands of personnel and biotyping of organisms were not feasible during this study; however, such studies would be helpful in assaying and documenting patterns of cross-infection.

It is often difficult to determine the source of a contaminating organism. Nonetheless, reports of potential pathogens in bodily fluids or tissues, especially in the sputum or tracheal washings of long-term, high-risk infants, should alert respiratory therapy and other personnel that the possibility of cross-contamination with these pathogens is immi-
In view of this and the findings of other workers, the following points should be considered: (i) the microbial concentrations found in this study may represent minimal to gross contamination at some point in time of the use of a circuit, most likely due to instrumentation of the respiratory tract of the patient or to manipulation of ports and tubing; (ii) some pseudomonads and some coliform bacteria are capable of growing when they are placed in sterile distilled water at 25 or 37°C with little or no lag time (1, 2, 5, 6); (iii) some organisms, such as K. pneumoniae and S. aureus, in laboratory experiments simulating in-use circuitry conditions demonstrated a prolonged lag phase when they were grown in sterilized in-use inspiratory and expiratory condensates but achieved exponential growth by 24 and 28 h, respectively (Fig. 5); (iv) consecutive samplings showed microbial population increases that were statistically significant; (v) the overall rates of contamination for the 340 samples and the inspiratory and expiratory sites of the 123 samples from the two colonized infants were significantly less (as determined by chi-square analysis) in 24-h circuits than in 48-h exchanged circuits; and (vi) simply changing circuits every 24 h or less could be a safer and more cost-effective route to follow until the laboratory reports of a patient become negative. If cross-infection should occur, increased hospitalization and risk of life could defeat the purpose of the hoped-for economy of the 48-h protocol.

The changing of the ventilator machine from a highly colonized long-term infant in isolation to a noncolonized neonate merits special precaution. The two 5-min decontamination periods described above for thorough cleaning, disinfection, and cloth drying of the external parts of the ventilator before being moved to another neonate deserve consideration. Air-drying and ≥30 min of exposure to isopropyl alcohol on smooth hard surfaces are recommended according to Centers for Disease Control guidelines (3). The microbial contaminants detected in the circuits in this study confirm this recommendation since condensate can be accidently spilled on the exterior parts of a ventilator.

There is great concern that contaminated inspiratory and expiratory traps and tubing (Fig. 1D, E, G, and H) may be raised high enough to submerge the bronchial tree of a patient via backflow. Furthermore, the condensate may flow in the opposite direction to the humidifier column (Fig. 1B), which apparently occurred on two occasions in this study, or the condensate may flow to the disposable or stationary expiratory valve (Fig. 11). In the latter situation there should be concern about the use of stationary valves under these conditions. The exhaust valve deserves attention since one plate exposed to the exhaust was contaminated at 48 h with P. aeruginosa (≥2 × 10³ CFU per plate). Centers for Disease Control guidelines, recommend changes of the expiratory values with changes of circuits (18). However, this presents a problem since some ventilators house stationary valves rather than disposable valves. Additionally, the discarding of contaminated inspiratory and expiratory condensates into open trash cans rather than closed trash cans to avoid environmental splatter or into sinks where handwashing occurs needs to be examined. One recommendation is to discard (18) the condensate into a closed container to which a disinfectant, such as an iodophor, has been added (13). The choice of the most effective disinfectant and the most suitable type and size of collection container (including cost) needs further study.

A question which remains is the consequences to high-risk infants when there are notable microbial growth increases in the circuitry with extended usage (from 24 to 48 and 72 h).

From empirical judgment, the fewer potential pathogens in relationship to the patient, machinery, personnel, or environment, the less chance of cross-contamination. The high numbers of organisms observed in ventilator circuits of patients in the ICU suggest potential cross-contamination hazards from in-use respiratory therapy equipment (13, 18). The potential for colonization of one or more pathogens in significant numbers, especially in the respiratory tracts of long-term infants, is a distinct possibility and perpetuates the danger of cross-infection.

The marked decrease in contamination rates observed after the use of circuits was reduced from 48 to 24 h, particularly among the highly colonized infants, suggests that more frequent changing and careful handling of the entire circuits should reduce cross-infection and colonization. Continued study of this and related problems is warranted.

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LITERATURE CITED


