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Further Studies on the Bactericidal Effect of the Air-Fluidized Bed

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THE RECENT acceptance of the air-fluidized bed as a patient care device has had many far-reaching implications. In addition to its use in the treatment of decubitus ulcers[4] and insomnia,[3] many other applications of the air bed have been reported. These have included the treatment of head and spinal injuries,[7] burns,[5] and as a means of providing patient comfort during labor.[2]

However, the introduction of any device or technic into the hospital environment must be accompanied by some assurance that it will not serve as a vehicle of microbiological contamination.[6] The air beds in operation at the Medical University of South Carolina have failed to reveal any significant level of microbiological contamination. Studies reported previously showed this to be due mainly to sequestration and desiccation of microorganisms by the ceramic spheres which comprise the medium of the air-fluidized bed.[6] We undertook this study in an effort to examine the microbiological cleanliness of the air bed filter sheet and of the air passing through the air bed itself.

Materials and Methods

The Air-Fluidized Bed. A schematic diagram of the air-fluidized bed is shown in Figure 1. Air is pumped through the bed medium consisting of crown optical soda-lime glass spheres. These spheres are coated with silicone and have an average diameter of 75-100 microns. A loose polyester filter sheet of 37 microns porosity separates the patient from the bed medium. Air entering the bed first passes through a diffuser board which serves to separate the ceramic sphere medium from the air chamber. It then passes over and through these spheres at a flow rate of 2 feet per minute. Under these conditions, the patient is buoyed and tends to float. The depth of the layer of ceramic spheres is about 12 inches and the normal penetration of the patient's body into this layer is about 4 inches. In our studies, a smaller model of the air-fluidized bed was employed. However, all dimensions of this smaller bed are proportional to those of the standard size beds. Hence, the velocity of air flow remains the same regardless of the size bed employed.

Organisms and Culture Conditions. Cultures of *Pseudomonas aeruginosa, Staphylococcus aureus* and *Escherichia coli* were grown overnight at 37° C in Trypticase Soy Broth (Difco Laboratories). The cultures were washed and resuspended in broth to a concentration of 1×10^7 organisms per ml. Using these suspensions, isolated sections of the air bed filter sheet were contaminated using cotton tipped applicators impregnated

TABLE 1. *Viable Staphylococci Recovered from Outflow Air of Air Bed*

Experiment No.	Total bacteria injected	Sample volume (liters)*		Total viable bacteria recovered	
		Inflow	Outflow	Inflow	Outflow
1	1×10^7	9	135	1.5×10^4	None
2	5×10^7	9	135	1.2×10^5	None
3	1×10^8	9	135	2.0×10^5	None
Mean	5.2×10^7	9	135	1.1×10^5	None

* Inflow samples were gathered for one minute; outflow samples for fifteen minutes.

with the different microbial suspensions. The areas so contaminated covered approximately 12 square inches. At regular time intervals thereafter, surface contamination of the sheet was measured using contact culture plates. Results are expressed as the number of viable organisms per four square inches of surface area.

Studies of the microbiological content of the air flowing both into and out of the air bed were conducted in the following manner: Using a DeVillbis atomizer, an aerosol (droplet size less than 100 microns) of viable staphylococci (1-2 × 10^7 ml.) was injected into the upstream air flow of the bed. This aerosol was injected in a volume of 5.0 ml. under a pressure of 4 inches Hg. over a time period of 60 seconds. Beginning with the moment of aerosol administration, samples of air flowing both into and out of the bed were obtained using liquid impingers.† Inflow air samples, totaling 9.0 liters, were obtained during the entire 60 seconds of aerosolization. Outflow samples, totaling 135 liters, were obtained during aerosolization and for an additional 14 minutes thereafter. All samples were collected under a pressure of 6 inches Hg. In an effort to insure adequate and accurate samples of outflow air, the air bed was covered with an air-tight, sterile plastic canopy (Fig. 2). An exit duct, identical in size to that entering the air chamber (1.0 inches I.D.), was used in obtaining outflow air samples. The plastic canopy allowed all of the air passing through the bed to be funneled through the outflow exit. As a result, representative samples of both inflow and outflow air were obtained. The air bed was maintained under normal operating conditions during the entire course of these experiments. Normal operating temperature is 30-32° C. The relative humidity was held at 30 per cent by a mechanical humidifier capable of controlling within ±5 per cent.

After the collection of inflow and outflow samples, serial tenfold dilutions of the impinger fluid were made and transferred to Trypticase Soy agar plates. After 18–24 hours incubation, colony counts were made and the total number of impinged viable bacteria determined.

† Millipore Corp., Bedford, Mass.

Results

The results of a study designed to assess the degree of cleanliness maintained by the air bed filter sheet are shown in Fig. 3. One hour following contamination of the sheet, *E. coli, S. aureus* and *P. aeruginosa* showed plate counts of 147, 154 and 152 colonies respectively. Both *E. coli* and *P. aeruginosa* then displayed a rapid decline in numbers. Six hours following contamination, the number of viable *E. coli* recovered had fallen to eight organisms per contact plate. Viable pseudomonas recovered at this time fell to three organisms per contact plate. *Staphylococcus aureus* remained viable for a significantly longer period of time. Plate counts fell to 126 colonies six hours following contamination of the sheet. At 24 hours postcontamination, an average of seven viable staphylococci remained per plate while there was none of *E. coli* or *P. aeruginosa.*

In an effort to examine the ability of the air bed to maintain an outflow of air free of microbiological contamination, viable staph-

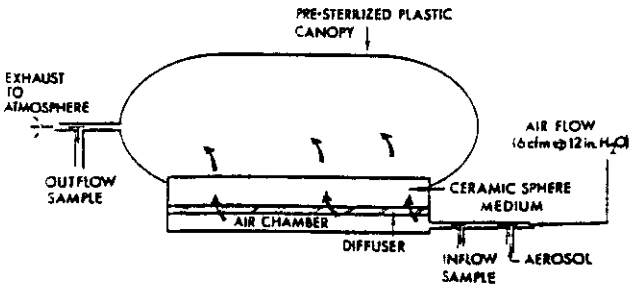

FIG. 1. Schematic diagram of an air-fluidized bed.

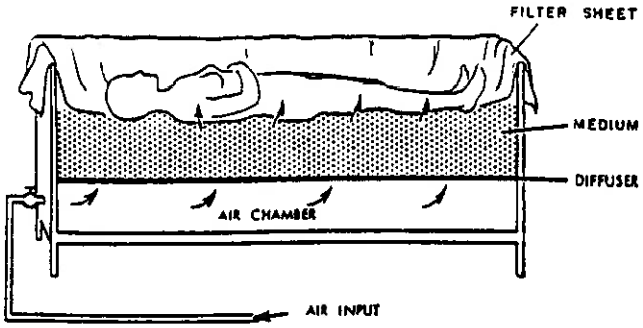

FIG. 2. Experimental design employed in examining the inflow and outflow air of an air-fluidized bed following aerosolization with *S. aureus*.

ylococci were dispersed into the inflow air of the bed. The number of viable cells passing through and out of the bed are shown in the table. Following the introduction of 1–10 × 10^7 total staphylococci into the air stream, an average of 1.1 × 10^5 viable bacteria was recovered in a volume of nine liters of air flowing into the bed. Samples of the air flowing out of the bed remained bacteria-free, even after a volume of 135 liters was sampled over a 15-minute period. Although not included in the table, an additional sampling of the outflow air totaling 1,620 liters over a 12-hour period also failed to reveal the presence of any microbiological contamination whatsoever.

Discussion

Under normal conditions of operation, no microbial contamination has been revealed in air-fluidized beds at the Medical University of South Carolina over a period of three years. Previous studies showed desiccation and sequestration of microorganisms by the ceramic sphere medium of the air bed to be the primary factors for this continued sterility of the air bed.[6] The extremely large surface area provided by the ceramic sphere medium serves to further increase the effect of desiccation. Recently, however, questions have been asked concerning the necessity for sterilization of the air bed filter sheets prior to use. These sheets are periodically changed and washed, but they are not routinely sterilized. Our studies, using three genera of bacteria commonly implicated in nosocomial infections, suggest that if a filter sheet were placed on an air bed 24 hours prior to patient use and the bed run under normal conditions, the

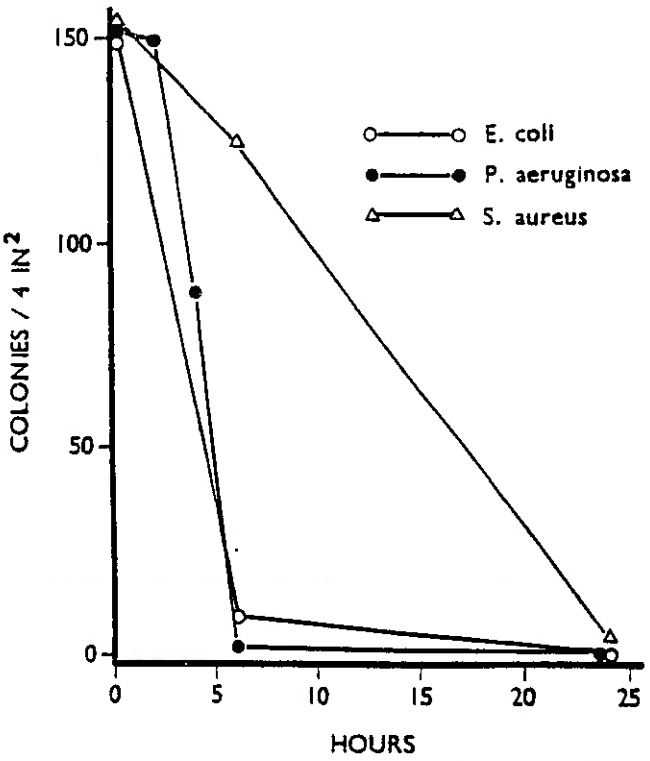

FIG. 3. Persistence of *S. aureus*, *E. coli* and *P. aeruginosa* on air bed filter sheets following direct contact contamination. Values represent the average of three experiments. Normal operating conditions of the air bed were used (30–32° C, 25–35% relative humidity).

sheet would be essentially free of all bacterial contamination. For comparison, studies conducted on cotton sheeting contaminated with *S. aureus* revealed a persistence time of six to seven days when held at 35 per cent humidity.[8]

One problem commonly occurring with use of most medical instruments and patient care devices is that of an ever-increasing degree of microbial contamination upon repeated usage. Contamination occurs especially with devices which may lie unused for periods of time between patient treatments. In an effort to maintain a stable humidity, the air-fluidized bed is normally operated on a continuous basis, regardless of whether or not it is occupied by a patient. Hence, there is no problem of microbial proliferation during periods of nonuse. In contrast, the continuous operation of the bed serves to maintain a very low level of microbial contamination.

In the treatment of open wounds such as burns and decubitus ulcers, restriction of microbiological contamination is of utmost concern. Hence, the use of the air bed in such instances requires that the air flowing

out of the bed and over the patient not be a potential source of infection. In our study, a large number of viable staphylococci was introduced into the inflow air of the air bed. The number of organisms introduced was many times that which would be found in the air circulating through a hospital environment. Samples of the air flowing out of the bed remained bacteria-free, even after a volume of 1,620 liters was sampled over a 12-hour period. This is undoubtedly due, in large part, to the trapping of microorganisms in the diffuser board which serves to separate the ceramic sphere medium from the air chamber. Also, air flowing into the air chamber often reaches a temperature of approximately 49° C, a temperature which kills most microorganisms. (The difference between the temperature of the air chamber (49° C) and that of the air bed (30–32° C) is due to thermal lag.) Thus, it would appear that patient contamination resulting from air-borne contaminants in the outflow air of the bed is quite unlikely.

The possibility that air flowing over the patient might serve as a vehicle of surface contamination from one patient to another must be considered. However, it should be pointed out that normal convection currents of air in a hospital ward approximate 5 ft./min.[1] while flow rates over the patient in an air bed are only about 2 ft./min. Thus, the chance of patient cross-contamination in a room containing an air bed is actually less than that in a room without an air bed.

Previous studies showed sequestration and desiccation by the air bed medium to be the main contributing factors toward the bactericidal and fungicidal ability of the air-fluidized bed.[6] These two properties, combined with the constant stream of warm air flowing out of the bed, maintain a filter sheet essentially free of all microbiological contamination. In addition, the possibility of air-borne contamination of the patient is all but negated by the air bed system. Unlike other beds, the air bed continues to rid itself of microbiological contamination while in use. Thus, the possibility of auto- and cross-contamination of patients upon continued use of the bed is very small. The advantages of such a patient care device in the hospital environment are obvious.

Summary

Our studies were designed to evaluate the ability of the air-fluidized bed system to maintain filter sheets and outflow air free of microbiological contamination. Experimental contamination of the filter sheet was followed by the rapid disappearance of both *E. coli* and *P. aeruginosa*. Viable cells of *S. aureus* remained for longer periods of time. However, 24 hours following contamination the filter sheets were essentially bacteria-free. Following the aerosol dispersion of viable staphylococci into the inflow air of the air bed, samples of the outflow air were monitored for microbial content. Without exception, all such samples remained completely sterile, even after as much as 1,620 liters of outflow air were sampled.

Acknowledgments

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