Bactericidal Effect of the Air-Fluidized Bed

ROBERT J. SHARBAUGH, PH.D., THOMAS S. HARGEST, B.A.

From the Department of Surgery, Medical University of South Carolina, Charleston, South Carolina 29401

THE recent development of the air-fluidized bed has provided a valuable tool for management of postoperative patients. In addition to its use in postsurgical cases, the air bed has also been shown to be extremely valuable in the treatment of decubitus ulcers in paraplegics,[2] insomnia,[1] and in the treatment of serious thermal injuries.[5]

The introduction, however, 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. This is pointed out by Knight[3] and Riley[4] who have indicted such equipment as venous and bladder catheters, syringes, air-cooling systems and "sterile" distilled water as primary routes of nosocomial infection.

Initial tests at the Medical University of South Carolina on the first air-fluidized bed failed to reveal any bacterial or mycotic contamination associated with the air-bed system. The ceramic spheres which fill these beds have continued to remain sterile for over 2 years, even though they are often subjected to various quantities of plasma, urine or feces, all of which may enhance microbiological growth. The present study was undertaken in an effort to explain this continued sterility of the ceramic spheres contained in the air-fluidized bed.

Materials and Methods

Growth of the Organisms

The bacterial species chosen for this study met one or both of the following criteria: (a) known to cause frequent and serious complications in burn patients, (b) a member of the normal flora of the gut or skin. The bacterial representatives were *Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa. Candida albicans* was chosen as a representative mycotic agent.

The organisms were grown overnight in Trypticase Soy Broth. The resulting suspensions were washed twice in saline and resuspended in heat inactivated, pooled human plasma to a concentration of 1×10^7 organisms/ml. Subsequent studies were conducted using these suspensions as inoculum. Care was taken to avoid using any plasma possibly containing traces of antibiotics.

Effect of pH

Sterile ceramic spheres were added to pooled human plasma to give a sphere to plasma ratio of 2:1. The pH change of the plasma due to the presence of the ceramic spheres was recorded. Following the maximum change in pH, 0.2 ml. aliquots of plasma were innoculated, each receiving 0.1 ml. of a different test organism. Growth rates were followed for 8 hours and assayed using standard plate count technics.

The Effects of Chemical Toxicity

Pooled human plasma was incubated in the presence of sterile ceramic spheres for 30 minutes. Following incubation, the pH was readjusted to the level which existed prior to the addition of the spheres. Representative aliquots were inoculated as above and microbial growth followed for 8 hours.

Effect of Sequestration and Desiccation

This series of tests was conducted with the air bed in full operation. Normal running temperature was 31–33°C. A small area of the air bed was isolated and subsequently

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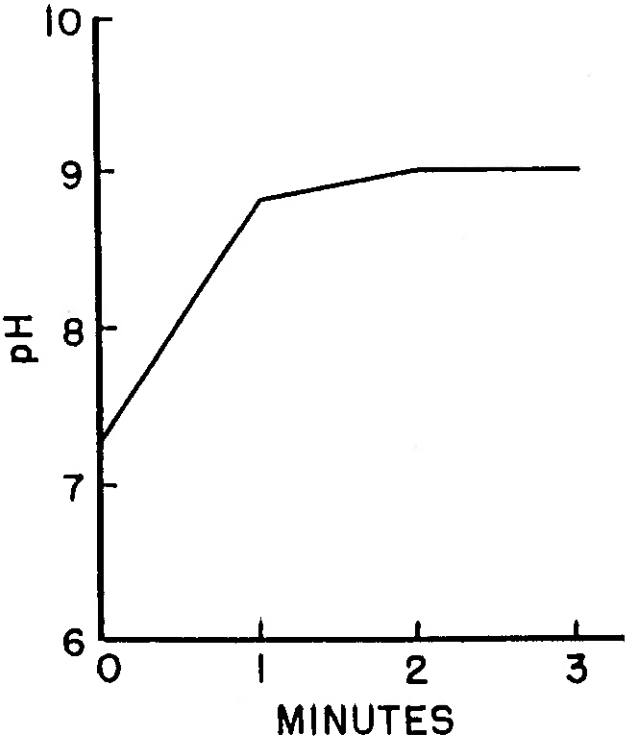

FIG. 1. The effect of ceramic spheres on the pH of pooled human plasma. Sphere to plasma ratio of 2:1.

inoculated with 0.2 ml. aliquots of the standardized microbial suspensions. This caused the bed media to aggregate into individual clusters. Following incubation, the number of viable organisms remaining in the clustered spheres was determined over varying periods of time. Results are expressed as the number of viable organisms per cluster of ceramic spheres.

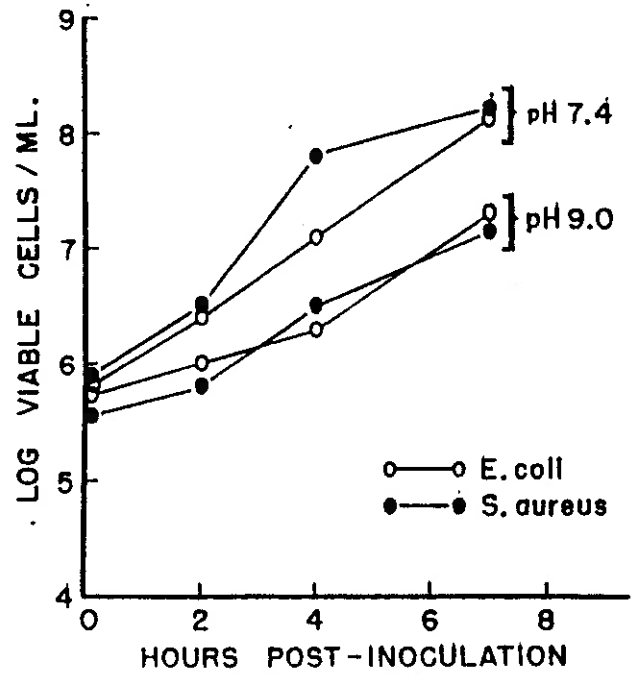

FIG. 2. The effect of high pH on the growth of *E. coli* and *S. aureus* in pooled human plasma.

Results

Initial experiments involving the bactericidal effect of ceramic spheres were designed to examine the effect of these spheres on the pH of human plasma. Using a sphere to plasma ratio of 2:1, there was a rapid rise in pH. The initial level of 7.4 rose to 9.0 in approx. 2 minutes (Fig. 1). Thereafter the pH level failed to show any further increase.

Since the chemical composition of the spheres was alkaline in nature, studies were performed on the effect of increased pH on the growth of various microorganisms. The results of these studies are depicted in Figure 2. Both *E. coli* and *S. aureus* showed significant retardation in their growth rates at the higher pH level. The growth rates of *P. aeruginosa* and *C. albicans* were similarly retarded but are not shown in an effort to avoid repetition.

Studies involving the effect of non-specific toxic factors on bacterial and mycotic growth failed to reveal any evidence to support their presence (Fig. 3). Both *S. aureus* and *P. aeruginosa* showed normal growth rates in plasma preincubated with ceramic spheres. Although not shown, *E. coli* and *C. albicans* revealed similar results.

Studies involving the bactericidal effects of desiccation were conducted utilizing an air-fluidized bed in actual operation. Under these conditions, the running temperature is 31–33°C and a constant stream of air flows over and through the ceramic spheres. Two of the three bacteria placed in this environment showed a rapid decrease in numbers (Fig. 4). The number of viable *E. coli* and *P. aeruginosa* decreased by nearly 100-fold in the first six hours. *C. albicans* showed over a 10,000-fold decrease in numbers during this same time period. In contrast, cultures of *S. aureus* failed to ex-

hibit any significant decrease in numbers over the 6-hour period. Further incubation of this organism in the air bed environment showed a 10-fold decrease in numbers after 24 hours.

Discussion

The air-fluidized bed is filled with ceramic spheres which are highly alkaline in nature. As expected, the saturation of human plasma with these spheres resulted in a rapid rise of the plasma pH, from 7.4 to 9.0. This is due to the presence of excess sodium ions on the surface of the ceramic spheres. It is evident, then, that any body fluids entering the bed charge probably undergo a rapid and significant rise in pH.

Studies designed to assess the bactericidal and fungicidal effects of this rise in pH showed significant retardation in the growth rate of various microorganisms. However, no true bactericidal effect, as evidenced by a decrease in numbers, was observed as the result of increased pH levels.

The possibility existed that additional toxic factors other than pH were inherent to the ceramic spheres. However, studies designed to examine for the presence of such factors which possessed bactericidal or fungicidal properties were uniformly negative.

The entrance of any liquid into the bed medium causes the immediate formation of clusters or clumps of the ceramic spheres. The natural formation of these clusters leaves no free wetted surfaces as spheres will continue to adhere until no wetted surface remains. Due to their increase in size and density, the clusters settle to the bottom of the bed medium. Microorganisms contained in any fluid entering the bed system are, then, sequestered into individual clumps of ceramic spheres. Viability studies on the bactericidal and fungicidal effect of such sequestration and subsequent desiccation showed all of the organisms except *S. aureus* undergo a very rapid decrease in numbers. Cultures of *S. aureus* showed only a very gradual decline in numbers, with only a 10-fold decrease being evident after 24 hours.

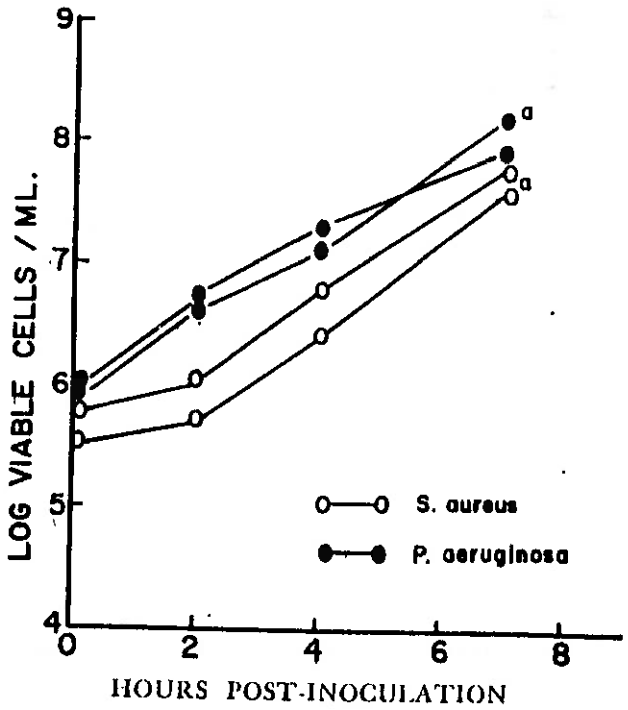

FIG. 3. The effect of non-specific toxic factors on the growth of *S. aureus* and *P. aeruginosa* in pooled human plasma.
(a) Bacterial growth in pooled human plasma preincubated in the presence of ceramic spheres; pH readjusted to 7.4 prior to inoculation.

It would appear that increased pH and additional toxic factors associated with the air bed medium do not play a major role in

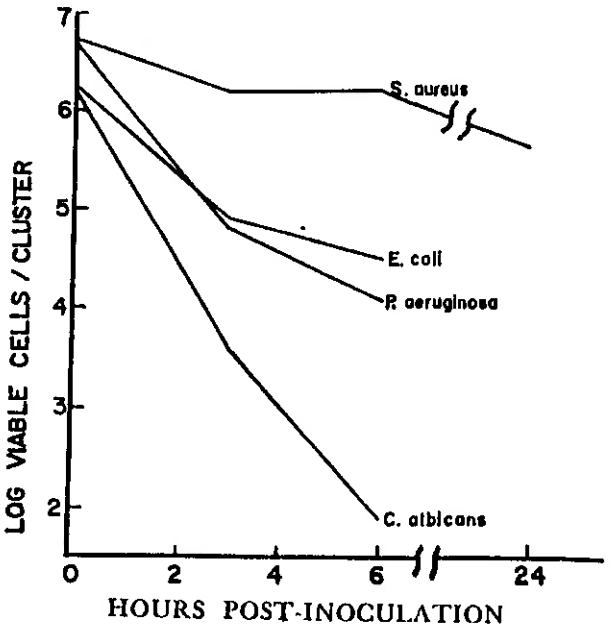

FIG. 4. The bactericidal and fungicidal effect of sequestration and desiccation in the ceramic sphere medium of the air-fluidized bed.

the continued sterility of the air-fluidized bed. In contrast, sequestration and desiccation of microorganisms within the air-bed system are the major contributors to the bed's continued sterility. The fact that *S. aureus* appears to remain viable for longer periods of time than most other contaminants may cause some alarm. However, it should be pointed out that once clusters are formed, they quickly settle to the bottom of the bed and remain there. Thus, even though staphylococci may remain viable for some time, the sequestering action of the clusters prevents any contact between the bacteria and the patient.

Summary

Under normal conditions of operation, the air-fluidized bed has failed to reveal any microbial contamination over a period of 2 years. Examination of this phenomenon showed the effects of increased pH and nonspecific toxic factors to bear little relationship to the sterility of the air-bed system. In contrast, sequestration and desiccation of microorganisms by the air-bed medium appear to be the main contributing factor toward the bactericidal and fungicidal ability of the air-fluidized bed.

References

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