HOSPITAL AIRBORNE MICROBIAL POLLUTION IN
A DESERT COUNTRY

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The level of airborne microbes in hospitals is unknown in the United Arab Emirates (UAE). An investigation of the quantity and quality of airborne microbes in Al-Ain hospital, UAE, was carried out to establish standards for future reference. Using a bacteria mechanical air sampler, microbiological samples were collected from different hospital units. The bacterial and fungal isolates were enumerated and identified. The variables were coded, entered, and processed by the Statistical Packages for Social Sciences (SPSS) with $p < 0.05$ considered the cutoff point. Ten groups of microorganisms isolated were either human or environmental bacteria and fungi. Environmental agents predominated and were not identified. Some units were significantly bacteriologically more contaminated than others but fungi were close in most wards. There were small numbers and quantities of potential pathogens. There were five genera of fungi isolated with a predominance of Aspergillus species but these were low. The intensive care unit (ICU) and operating theatre (OT) had low counts and significantly more human related than environmental microorganisms. The quantity and quality of the microbial population seem to be reasonable in this observation and will serve as references for future studies. Copyright ©1997 Elsevier Science Ltd

INTRODUCTION

Atmospheric pollution is one of the most pressing problems of our age. This pollution has now reached a level that poses a potential threat to the health and well-being of the population (Gammage and Kaye 1985; Langmuir 1980; Raza et al. 1989). Indoor biological pollution has only recently begun to receive the attention afforded outdoor or even indoor chemical pollution (Yunginger et al. 1976). The apparent lack of interest is tied to the difficulties of sampling biological aerosols and evaluating of their variable health effects.

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The indoor environment can potentially place human occupants at greater risk than the outside environment, because enclosed spaces can confine aerosols and allow them to build up to infectious doses (Samet and Spengler 1991). Ventilation systems can pick up contaminated air and distribute infectious microorganisms to other parts of the building (Huddleson and Munger 1940). Ventilation system components can become contaminated with pathogenic microorganisms such as Legionella pneumophila which are subsequently transmitted to the building’s occupants (Glick 1978).

The extent of health problems caused by microorganisms in the indoor environment is difficult to
estimate. This is partly due to the broad array of microorganisms that may evoke human response and to the broad range of environmental variations in residential, commercial, and public buildings where exposure occurs. Despite uncertainty about the magnitude of the health effect caused by such exposure, the impact of some microorganisms can be significant (Gammage and Kaye 1985).

There is no single method of choice for sampling airborne microbial loads. Each method has strong and weak points, and in general more than one is necessary to accurately assess most situations. The air in a single clean room may contain numerous kinds of biological particles but technology does not exist to easily quantify or qualify all of them. The majority of bioaerosols are non-pathogenic and cause disease only in sensitized or grossly immuno-compromised individuals. It is, however, well documented that the hospital environment is a source of acquired infections (Gammage and Kaye 1985). For this reason, knowledge of the incidence of micro flora in hospitals is important for the understanding of the possible types of infections and allergies that may accrue from them. Furthermore, controlling the microbes in these hospital environments may play a role in the prevention of cross infection.

Hospital indoor air contains a diverse range of microbial population. The significance of these microbes is debatable in some quarters, whereas elsewhere it may be considered significant. The importance of the estimation of the quantity and types of airborne microorganisms is that these values can be used as an index for the cleanliness of the environment and source of hospital-acquired infections (Spendlove and Fannin 1983). The airborne spread of nosocomial bacterial or viral infection is known to occur, but is probably uncommon. Therefore, air sampling is carried out less frequently. Perhaps the most common and recent indications for environmental air sampling have been *Legionella* and *Aspergillus* infections. It is also considered important to monitor the operating rooms and other sensitive hospital units in the control of hospital-acquired infections.

The sources and spread of organisms inside the hospital are important issues. Human related organisms or the body normal flora, also found in clothing, are spread through shedding during human activities. The organisms which particularly spread this way include: *Staphylococcus aureus*, coagulase negative staphylococci (CNS), *Micrococcus species*, alpha haemolytic streptococci, *Diphtheroids species*, and Gram negative rods. Environmental organisms such as *Bacillus species*, *Streptomyces species*, and various bacteria of no medical importance, coming from other sources such as air dust, soil, and water add to this collection. These can be distributed in large areas of the hospital by the central air conditioning. This may be an important factor in the Gulf states where air conditioning is operational most of the time due to the hot desert climate.

A quantitative study of different hospital units is important. The total count of bacteria is influenced by many factors including the number of visitors and the amount of materials brought in from the outside. These include carpets, flowers, fruits, and many other items well recognized as sources of hospital contamination. Although there are no established standards for viable or nonviable particulate matter in the operating room, or in any other hospital area (Gammage and Kaye 1985), the number of microorganisms in some hospital areas, such as the operating theatre (OT) and intensive care unit (ICU) is usually extremely low. This is due to the high sanitary standards as compared to other hospital areas.

The fungal population, dissemination and the atmospheric movement are important factors (Williams et al. 1956). The common genera of fungi frequently isolated from hospital air include *A. niger*, *Chaetomium species*, and an *Alternaria species*. In air-conditioned homes, there are usually fewer fungal isolates, but significantly greater numbers of *Aspergillus species* are present in comparison to the outdoor air (Moustafa and Kamel 1976).

Geographical or regional levels of indoor microorganisms have not been extensively studied. The present study was conducted to gain knowledge of the quantity and quality of airborne microbes in a desert located hospital in the United Arab Emirates (UAE), to set standards for levels of acceptable microbial population.

**MATERIALS AND METHOD**

This project was carried out in Al-Ain city which is located in the eastern province of Abu Dhabi in the UAE. Al Ain has three hospitals serving a population of about 350 000. Al-Ain hospital, which was selected for the study, is a 14 year old institution with 511 beds and 23 wards covering all types of inpatient care and several outpatient facilities. The hospital serves both the national and expatriate resident population and is located near the center of the city.
Table 1. Hospital air microorganisms isolated from five wards (figures are means of 5 rooms).

<table>
<thead>
<tr>
<th>Types of organisms</th>
<th>MMW</th>
<th>MSW</th>
<th>FMW</th>
<th>FSW</th>
<th>PAED</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus aureus</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>27</td>
<td>33</td>
<td>73</td>
</tr>
<tr>
<td>Staphylococci (CNS)</td>
<td>1087</td>
<td>627</td>
<td>1947</td>
<td>1307</td>
<td>1953</td>
<td>6921</td>
</tr>
<tr>
<td>Micrococcus species</td>
<td>53</td>
<td>153</td>
<td>453</td>
<td>373</td>
<td>927</td>
<td>1959</td>
</tr>
<tr>
<td>Streptococci (alpha haemolytic)</td>
<td>33</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>27</td>
<td>73</td>
</tr>
<tr>
<td>Diphtheroid bacilli</td>
<td>87</td>
<td>100</td>
<td>273</td>
<td>393</td>
<td>347</td>
<td>1200</td>
</tr>
<tr>
<td>Gram negative bacilli</td>
<td>13</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>60</td>
<td>86</td>
</tr>
<tr>
<td>Bacillus species</td>
<td>367</td>
<td>253</td>
<td>1040</td>
<td>1013</td>
<td>1440</td>
<td>4113</td>
</tr>
<tr>
<td>Streptomyces species</td>
<td>0</td>
<td>33</td>
<td>220</td>
<td>73</td>
<td>133</td>
<td>479</td>
</tr>
<tr>
<td>Unidentified bacteria</td>
<td>1673</td>
<td>873</td>
<td>2887</td>
<td>1453</td>
<td>2200</td>
<td>9086</td>
</tr>
<tr>
<td>Fungi</td>
<td>153</td>
<td>153</td>
<td>180</td>
<td>167</td>
<td>73</td>
<td>706</td>
</tr>
<tr>
<td>Total</td>
<td>3479</td>
<td>2205</td>
<td>7013</td>
<td>4806</td>
<td>7193</td>
<td>24696</td>
</tr>
</tbody>
</table>

Key: MMW = male medical ward; MSW = male surgical ward; FMW = female medical ward; FSW = female surgical ward; PAED = pediatric ward.

Table 2. Intensive care unit and operating theatre microorganisms.

<table>
<thead>
<tr>
<th>Types of organisms</th>
<th>ICU</th>
<th>OT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus (CNS)</td>
<td>520</td>
<td>80</td>
</tr>
<tr>
<td>Micrococcus species</td>
<td>80</td>
<td>200</td>
</tr>
<tr>
<td>Streptococci (alpha haemolytic)</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Diphtheroid bacilli</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Bacillus species</td>
<td>53</td>
<td>93</td>
</tr>
<tr>
<td>Streptomyces species</td>
<td>7</td>
<td>47</td>
</tr>
<tr>
<td>Unidentified bacteria</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Fungi</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>687</td>
<td>473</td>
</tr>
</tbody>
</table>

Key: ICU = intensive care unit; OT = operating theatre.

Air sampling

A bacterial air sampler, one stage culture plate impactor MK2 (Casella London), was used. The sampler was set at a predetermined optimum time of 5 min which represents 0.15 m$^3$ of air per sample. The sampler was located in the center of the room away from open windows and doors, and the sampling position was 1 m above the floor. The microbiological samples were collected from the following hospital units: male surgical and medical wards (MSW and MMW), female surgical and medical wards (FSW and FMW), pediatrics ward (PAED), OT, and the ICU. Each ward was represented by five large sized rooms. Each room was usually divided into four bed partitions separated by curtains. The ICU consisted of three rooms of equal size, each with three patients capacity. During the sampling procedure, all the curtains were opened so that the whole room could be sampled as a unit. The OT consisted of a total of five rooms: three operation rooms, a pre-operative preparation room, and a post-recovery room. Sampling was done in all the operation rooms when there were no surgical procedures taking place.

Culture media and microbial identification techniques

Blood agar, Sabouraud agar, Sucrose mineral agar, Mannitol salt agar, MacConkey agar, and Mueller Hinton agar were used for isolation and differentiation. The bacterial culture plates were incubated at 37°C for 48 h while fungal cultures were incubated for up to 7 d at 25°C. The total number of colony forming units (CFU) was enumerated and converted to organisms per cubic meter air. Bacterial colonies were initially characterized by morphology and microscopic appearance and identified further by biochemical tests. These tests included: 1) oxidase, catalase, coagulase according to Cowan and Steels manual for the identification of medical bacteria; 2) identification methods in applied and environmental microbiology using other methods such as API 20 STAPH, API 20 E, and API 20 NE. Fungi were identified according to the manual of soil fungi.
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Based mainly on gross colonial appearance, microscopic examination of the spore, and hyphal characteristics of lactophenol cotton blue preparations, scotch tape mounts and slide culture where the tape mounts were inconclusive.

**Data processing, statistical methods, and analysis**

The data were processed by the Statistical Packages for Social Sciences (SPSS) (Norusis 1992). Frequency distributions, one and two way tabulations were obtained. To test significant differences between two independent groups, the Student’s t-test was carried out. The Mann-Whitney test was used to ascertain the significant differences between mean values of two independent groups for nonparameter distribution. Chi-square analysis was performed to test for differences in proportions of categorical variables between two or more groups. In 2 x 2 statistical tables, the Fisher exact test (two-tailed) was used instead of Chi-square, in particular when the sample size was small. Kraskal-Wallis one way analysis of variance was employed for comparison of several group means and to determine the presence of a significant difference between two means. The level p<0.05 was considered the cutoff point.

**RESULTS**

The types of microorganisms isolated from the air of the three different types of houses were classified into 10 groups as follows: *Staphylococcus aureus*, Coagulase Negative Staphylococci; *Micrococcus species*; *Streptococcus species*; Diphtheroid; *Bacillus species*; *Streptomyces species*; Gram negative bacilli, Unidentified bacteria and fungi.

Table 1 shows hospital microorganisms isolated from the five different wards studied. The results reflect the mean of five rooms in each ward. All ten groups of organisms described above were present. The nine bacterial groups were divided into two categories: human related microorganisms represented by the first six, and the environmental and soil microorganisms represented by the remaining other three groups.

Table 1 shows hospital microorganisms isolated from the five different wards studied. The results reflect the mean of five rooms in each ward. All ten groups of organisms described above were present. The nine bacterial groups were divided into two categories: human related microorganisms represented by the first six, and the environmental and soil microorganisms represented by the remaining other three groups.

The largest quantities of isolated microorganisms were unidentified bacteria. This group included numerous different types of bacteria which are not recognized as medically important bacteria, and were difficult to identify by diagnostic clinical laboratory techniques. The second most common organism in all units was CNS, followed by *Bacillus species* and *Micrococcus species*. All other microorganisms were detected in small numbers or not detected at all in some areas. The pediatric and female medical wards had the highest bacterial count while the surgical wards had the lowest. The male wards had less bacterial count than the female wards. Fungal colony counts were close in most wards but the lowest count was in the pediatric ward.

*Staphylococcus aureus* and the family of Enterobacteriaceae were rarely isolated, but *S. aureus* was more common in the pediatric and female surgical wards in comparison to other wards. The Gram-negative rods which were isolated from the pediatric, male medical, and female surgical wards included several genera and species such as *Pseudomonas species*, *Enterobacter species*, *Aeromonas species*, and *Escherichia vulneris*.

Table 2 shows the result of isolates from the generally recognized clean areas in the hospital, the ICU and the OR. The ICU had a mean of 687 CFU/m³ per room recorded and most of them were CNS. In the OR, a mean of 473 CFU/m³ per room was recorded, and nearly half of these were *Micrococcus species*. The ICU and OR had significantly more human related than environmental microorganisms in the air and surfaces (p<0.005).

Table 3 shows the quantity and types of fungi in hospital air. There were five genera of fungi isolated with a predominance of *Aspergillus species*. There were six *Aspergillus species* isolated, with *A. fumigatus* and *A. niger* occurring most commonly. There was no significant difference in the total number of isolates from different hospital units.

**DISCUSSION**

The unidentified bacteria were the most common group of bacteria isolated. These microorganisms were of no medical importance and thus difficult to identify by the standard medical bacteriological techniques. As dust is common in the desert environment, this group was considered to be dust-borne. These organisms have also been found to be dominant in the dust of three types of dwellings in India (Raza et al. 1989).

Quantitative study of different hospital units showed that the pediatric ward and female medical wards had the highest total count of bacteria. These findings could be explained by many factors including the number of visitors in pediatric and female medical wards which exceeded visitors in other hospital areas. At one time during the sampling process in a pediatric unit, there were seven children and three women, and in one
female medical ward room there were five female visitors in only one partition. However, in the male wards, visitors never exceeded three during the sampling process. It was also noted that the amount of materials brought from outside, such as carpets, flowers, and fruits, were more common in pediatric and female wards. These are recognized sources of hospital contamination.

The number of potentially pathogenic organisms in the hospital air was low. Pathogenic organisms represented less than 1% of the total count of bacteria isolated. In a European study, using an Andersen air sampler, pathogenic bacteria accounted for 3% of all isolates (Williams et al. 1956), but it included Streptomyces species as human pathogens. In the present study, Streptomyces species was considered an environmental microorganism, since the types of Streptomyces species isolated were unlike those that cause actinomycetoma in the region.

The low concentration of pathogenic organisms in hospital air could possibly be due to the fact that there was no strong air current to distribute the bacteria from the reservoirs (patients). Pathogenic organisms associated with wound infections would be expected in high concentration in certain hospital areas. They did not seem to be airborne and therefore their mode of transmission is most likely via direct physical contact of staff and patients. In airborne infections, such as throat and respiratory infections, the causative agents are usually isolated in a small number whereas non pathogenic Streptococcus species such as Viridans group are often isolated in large quantities.

Although there are no established standards for viable or nonviable particulate in the operating room, or in any other hospital area (Gammage and Kaye 1985), the number of microorganisms in the OT and the ICU was extremely low. This was anticipated due to the high sanitary standards in these areas, as compared to other hospital areas. The study of airborne fungal spores is important to understand the dissemination, spread, and movement of the microbes, particularly the pathogenic ones in the atmosphere (Moustafa and Kamel 1976). The common genera of fungi frequently isolated from the hospital air, A. niger, Chaetomium species, and an Alternaria species have been reported. In air-conditioned homes, there are usually fewer fungal isolates, but a significantly greater number of Aspergillus species are present in comparison to the outdoor air (Kodama and McGee 1986).

Some information is now available on the level of airborne microbes in hospital indoor air previously unknown in the United Arab Emirates. The ten groups of microorganisms isolated were either human or environmental bacteria and fungi. Environmental agents predominated but were not identified. The quantity and quality of microbial population seems to be within reasonable and acceptable limits, suggesting clean air in this hospital.
REFERENCES


