Short communication

Bacterial distribution analysis of the atmosphere of two hospitals in Ibb, Yemen

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تحليل التوزُّع الجرثومي في جَوِّ مستشفَيَيْن في مدينة إبّ، باليمن

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الخلاصة: تم إجراء تحليل جرثومي للهواء في ثمانية مواقع في كل من المستشفيَيْن العامّين الموجودين في مدينة إبّ، وذلك خلال الفترة من شباط/فبراير حتى حزيران/يونيو 2002. وقد أعطت ثلاثة مواقع فقط في المستشفيَيْن، قِيَماً يُعْتَدُّ بها إحصائياً، لتوزُّع الجراثيم في الهواء الجوي، وهي صالة الاستقبال، وردهات المستشفى، والعيادة الخارجية. وكان متوسط قِيَم عدد المستعمرات الكلي والجراثيم المخمِّرة للاَّكتوز، والجراثيم الحالّة للكريات الحمراء، والجراثيم غير المخمِّرة للاَّكتوز في هذه الأماكن، هو 478.6 وحدة مكونة للمستعمرات (و م م)/م^3، و24.9 و م م/م^3، و6.5 و م م/م^3، و4.8 و م م/م^3 على التوالي. وكان أعلى تعداد جرثومي في صالة الاستقبال، تَلَتْها ردهات المستشفى والعيادة الخارجية. وكان أعلى تعداد جرثومي عند الساعة الثامنة صباحاً، ثم عند الساعة الثانية ظهراً ثم الساعة السادسة مساءً.

ABSTRACT A bacteriological distribution analysis of the air was carried out at 8 sites in each of 2 general hospitals in Ibb during the period February–June 2002. Only 3 sites, reception hall, hospital passages and outpatient clinic, gave meaningful values for the distribution of bacteria in the atmospheric air. In these locations, mean values for total plate count, lactose fermenting bacteria, haemolytic bacteria and non-lactose fermenting bacteria were 478.6 colony forming units (cfu)/m^3, 24.9 cfu/m^3, 6.5 cfu/m^3, and 4.8 cfu/m^3 respectively. The reception hall had the highest bacterial count, followed by hospital passages and the outpatient clinic. The highest bacterial count was for 08.00, followed by 14.00 and 18.00.

Analyse de la distribution bactérienne dans l'air ambiant de deux hôpitaux à Ibb (Yémen)

RÉSUMÉ Une analyse de la distribution bactérienne dans l'air a été effectuée sur 8 sites dans chacun des 2 hôpitaux généraux à Ibb durant la période février-juin 2002. Seuls 3 sites – le hall de la réception, les couloirs de l'hôpital et le service des consultations externes – ont fourni des valeurs significatives pour la distribution des bactéries dans l'air ambiant. Dans ces lieux, les valeurs moyennes pour la numération totale sur plaque, les bactéries fermentant le lactose, les bactéries hémolytiques et les bactéries ne fermentant pas le lactose étaient de 478,6 unités formant colonies (UFC)/m^3, 24,9 UFC/m^3, 6,5 UFC/m^3 et 4,8 UFC/m^3 respectivement. Le hall de la réception avait la plus forte numération bactérienne, suivi par les couloirs de l'hôpital et le service des consultations externes. La numération bactérienne la plus élevée était 08,00, puis 14,00 et 18,00.

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Introduction

Hospitals have a notorious reputation for infection and septic infection has been well documented [*1*]. Despite dramatic developments in surgical and medical techniques, infection acquired in hospitals remains a major cause of morbidity and mortality, leading directly or indirectly to an enormous increase in the cost of hospital care and to the emergence of new health hazards for the community [*2*].

Infection may be spread by airborne transmission from the respiratory tract, from the skin by natural shedding of skin scales, during wound dressing or during bed making, and by aerosols from equipment such as respiratory apparatus and air-conditioning plants. Infectious agents may be dispersed in the air as small particles or droplets over long distances [*2*].

Quantitative and qualitative microbiological measurements are required in premises where safe working depends on the microorganism content of the air being kept at a very low level, e.g. surgical theatres and premises where certain food and pharmaceutical materials are prepared. In hospital wards in which cross-infection is possible, it may be necessary to examine the air for a particular pathogen. The type and number of microorganisms in the air at any time depend on a variety of factors, the most important of which are number of persons present, degree of body movement and amount of disturbance of their clothing [*3*].

Most of the data available in this field are concerned with fungi [*4*]; there is little or no data in the literature concerning bacterial load of hospital air. This survey is, therefore, an attempt to assess the bacterial distribution in ambient air in 2 hospitals.

Methods

Sampling sites and times

Air samples were collected weekly during the period February–June, 2002, from Al-Thawra and Al-Nasir general hospitals, the only government hospitals in Ibb City, Yemen, which is located 190 km south of the capital, Sana'a.

Al-Thawra Hospital has a mean of 233 outpatients and 75 admissions per day; the corresponding figures for Al-Nasir Hospital are 60 outpatients and 15 admissions. At both hospitals, air samples were collected from the following sites: operating theatre, male surgical ward, female internal ward, refreshment room, clinical laboratory, outpatient clinic, hospital passages and reception hall. From each site, samples were collected at 3 times, morning (08.00), afternoon (14.00) and evening (18.00). These times were chosen to correspond with patient crowdedness (which is directly proportional to the bacterial atmospheric pollution) in the hospital wards: before working hours (i.e. morning), rush hours (i.e. afternoon) and after working hours (i.e. evening). At each sampling, 3 replicate samples were collected (1 for each type of plate). The time between sample collection and receiving the sample in the laboratory never exceeded 1 hour.

Sample collection and bacteriological media

The samples were collected using a microbiological air sampler, MAS-100 (Merck, Darmstadt, Germany). The air sampler was loaded with Petri dishes that had previously been prepared under sterile condition with the following media: plate count agar (CM0325, for total aerobic bacteria); blood

agar base No 2 with horse blood, (PB0114, for haemolytic bacteria); MacConkey agar (CM0007, for lactose fermenting and non-lactose fermenting bacteria) (all media were from Oxoid, Basingstoke, UK). The height of the air sampler was 1.5 m above the ground level, in a horizontal position. The air sampler was set up to allow the passage of 1000 L (1 m^3) of air over the bacteriological media.

Sample processing and analysis

Microbiological analysis for total plate count, lactose fermenting bacteria, non-lactose fermenting bacteria and haemolytic bacteria was carried out according to the method described by Crichton [*5*]. The plates were incubated at 37 °C for 24 hours (48 hours in case of poor or no growth). After incubation, a colony counter (Gallenkamp) was used for counting the bacterial colonies which had developed.

Since the data from corresponding sites in each hospital were similar, the original data from both hospitals were combined then processed and expressed as either a mean value or as a percentage.

Results

At both Al-Thawra and Al-Nasir hospitals, only 3 sites, i.e. reception hall, hospital passages, and outpatient clinic gave values for the distribution of the bacteria in the atmospheric air of the hospital that were compatible enough to allow a reasonable analysis for the distribution of the bacteria at these sites, therefore these 3 are discussed in detail. Ambiguous (disparate) results were found for the other sites.

Plate counts are shown in Table 1. Mean bacterial counts were: total plate count 478.6 colony forming units (cfu)/m^3, lactose-

Table 1 **Total plate count and counts for lactose fermenting, non-lactose fermenting and haemolytic, bacteria in the air for 2 hospitals in Ibb**

Bacteria count	Time	Colony forming units/m^3 air				
		Reception hall	Hospital passages	Outpatient clinic	Mean	Overall mean
Total plate count	08.00	1190	640	350	726.7	478.7
	14.00	650	480	240	456.7	
	18.00	370	240	148	252. 7	
Lactose fermenters	08.00	50	34	12	32.0	22.8
	14.00	35	15	5	18.3	
	18.00	29	13	12	18.0	
Non-lactose fermenters	08.00	22	0	0	7.3	4.9
	14.00	13	0	0	4.3	
	18.00	9	0	0	3.0	
Haemolytic bacteria	08.00	5	11	1	5.7	6.6
	14.00	9	4	0	4.3	
	18.00	14	5	10	9.7	

fermenting bacteria 24.9 cfu/m^3, haemolytic bacteria (e.g. *Streptococcus pyogenes*) 6.5 cfu/m^{3}and non-lactose fermenting bacteria 4.8 cfu/m^3. The counts were generally highest in the morning (08.00) followed by afternoon and evening.

The reception hall had the highest overall count, followed by the hospital passages and the outpatient clinic.

Discussion

The highest count, for total plate count, was expected since plate count agar is known to allow the growth of a wide range of saprophytic and other bacteria.

The count for lactose-fermenting bacteria was higher than for non-lactose-fermenting bacteria. This result was also expected since a number of studies have demonstrated that lactose-fermenters are more widely distributed than non-lactose-fermenters [*6,7*].

The count for haemolytic bacteria (6.6 cfu/m^3) was fairly high, unfortunately, no data were noted in the literature for comparison with this value. Haemolytic bacteria are known to be involved in infection of the upper respiratory tract [*8*]. However, Senior reported that in studies concerned with airborne infection in man, the particles encountered are those that carry bacteria capable of growth on blood agar during aerobic incubation for 24 or 48 hours at 37 °C [*9*], incubation conditions which also applied in our study.

The highest bacterial count was in the reception hall, followed by the hospital passages and finally the outpatient clinic. The variation could be related to differences in the degree of crowding; the reception hall is usually more crowded than the other locations. Moreover, internal movement produces an increase in both humidity and temperature, which are known to be important factors affecting bacterial viability [*10*]. Ambiguous results that were found for the other sites may be because of the oscillation of the variables that affect bacterial concentration.

Table 1 also shows that counts were highest in the morning, followed by the afternoon and the evening. This observation may be related to the busy period of the day. The hospitals are usually at their busiest at 08.00, gradually becoming less busy through the afternoon and the evening.

Unlike the other bacteria examined, the distribution of haemolytic bacteria at different hospital locations and different times of the day did not show a clear pattern. Since many virulent strains belong to this bacterial group, further, more extensive, studies are required to determine distribution of these bacteria in the ambient air of hospitals.

It has been reported that most of the contaminants are harmless saprophytes and commensals, and even when carriers or infected students are present, usually less than 1%, and commonly only 0.01%–0.1%, of the airborne bacteria are pathogens [*9*]. In rooms occupied by patients with tonsillitis or infected wounds, *Streptococcus pyogenes* may be present at a level of 0.1–50 cfu/m^3 [*5*]. This level of contamination may seem small, but it must be remembered that a normal adult inhales about 15 m^3 of air/24 hours. The probability of a person becoming infected will be greater if he is exposed to a high concentration of airborne pathogens, but no level of contamination, however low, can be regarded as safe. Infection is usually initiated by the deposition of a single infected particle at a favourable site in the respiratory tract, although the probability of any one such particle initiating infection is likely to be low for common pathogens, e.g. 10^{-2} to 10^{-5} for *Staphylococcus aureus*

in the nose [*11*]. It may be high for some, e.g. for *Mycobacterium tuberculosis* in the lung [*12*].

Finally, the removal of air contaminants and the control of room temperature and humidity are necessary. Recommendations for air treatment in hospital ambient air include:

- the use of filtration, electronic cleaners, chemical treatment with activated charcoal or other sorbents;
- temperature control in the range of 20.0–24.5 °C;
- humidity control in the range of 20%–60%.

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