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Prevalence of Air Contamination in the Operating Theatre of Port Bouët, Abidjan

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Abstract

Introduction: Today, the challenge of combating surgical site infections has led to the adoption of a range of measures, of which the prevention of aerobiocontamination remains a determining factor. This is what justifies the scope of the present study, either to determine the level of particulate concentration of the ambient air in the operating theatre compared with the admissible threshold of the ISO 14644-1 normative standards. **Objective**: To assess the level of aerobiocontamination in operating theatres and identify the associated germs. **Methods**: The prospective study consisted of particulate air sampling using a biocollector, followed by conventional culture and particle counting, giving rise to one colony per cubic metre (**C.F.U./m³**). The samples taken covered the pre-operative, intraoperative and post-operative phases in the presence of various classes of surgery (clean, contaminated and dirty). **Results**: The results revealed a higher level of contamination during surgical activities of **410 ± 145 C.F.U./m³** followed by post-operative sampling **352 ± 131 C.F.U./m³** and finally pre-operative sampling **290 ± 135 C.F.U./m³**. In general, aerobiocontamination was high compared with the permissible contamination threshold of **293 C.F.U./m³**. **Conclusion:** Our study provides evidence that the risk of aerobiocontamination is increased by activity. The expression of this risk is essentially a function of the time factor and the nature of the surgery. However, preoperative precautions and compliance with decontamination kinetics between procedures, which are necessary for particle sedimentation, remain sound safety principles to be observed.

Keywords

Aerobiocontamination, Operating Theatre, Airborne Germs

1. Introduction

The fight against hospital-acquired infections (HAI) is a fundamental component of the policy to improve health and the quality of care in hospitals. Among these nosocomial infections, surgical site infections (SSI) are the most common post-surgical complication: their rate has been measured in certain studies to be between 2 and 5% [1]. The lethality of SSI0s is of the order of (5 to 20)%, but after certain surgeries it can be as high as 30% [2]. Some of these infections can have devastating functional consequences. They are accompanied by an average increase in length of stay of 7 to 10 days, which can reach 20 to 30 days for serious infections [3]. Given this picture, it is only logical to look at the risk factors for SSI. Among these, the role of air in the occurrence of SSIs is not negligible [4]. Indeed, given the combined effect of the susceptibility of surgical wounds to microbial contamination and the fragility of patients, air undeniably appears to be a major factor in the risk of post-operative infections [5].

As a result, prophylaxis against particulate and microbial contamination of the air in operating theatres is fundamental to improving the safety and quality of care in hospitals [6]. Health establishments are responsible for preventing the "avoidable" part of iatrogenic risks, which means instituting regular microbiological checks on the quality of ambient air in operating theatres [7]. In 2014, the US healthcare-associated infection surveillance programmes (SENIC project) showed that SSI was the number one preventable healthcare-associated infection [8]. A 19% to 41% reduction in the rate of SSI over 6 years was also observed after the implementation of a policy to combat nosocomial infection in hospitals participating in these programmes [9].

It is in this context that the present study focuses on the prevalence of aerobiocontamination in the operating theatre and the identification of germs isolated at Port Bouët General Hospital. It proposes a method for assessing and determining the bacteriological and epidemiological characteristics of bacteria, in order to put in place, the necessary means to protect patients from post-operative infections.

2. Materials and Methods

- **Ethical considerations**

Confidentiality and anonymity were respected during the study, thanks to the use of a single survey form in which patients' identities were replaced by codes. In addition, samples were taken with the written and informed consent of the parents of eligible patients. This study also required the authorisation of the Director of Port Bouët General Hospital.

- **Study framework**
  - **Collection site: operating theatres at the Port Bouët General Hospital (HGPB)**

The samples were taken in the HGPB operating theatre in the Abidjan Sud health district. The hospital had three (03) operating theatres grouped together in one building. These rooms were used for all types of surgery, regardless of whether the operation was scheduled or urgent. Architecturally, the walls were covered in resin (oil) paint. The floor covering was smooth and dust-free, with a well-expanded skirting board. All the blocks were equipped with two (02) double doors always leading to an airlock. The doors to the patient movement circuit were fitted with an aluminium plate to cushion the impact of stretchers. Each unit was equipped with split air conditioning. The temperature in the blocks varied between 20 and 22˚C, in accordance with the recent recommendations of the clinical excellence commission health New South Wales of Australia [10].

- **Place of microbiological analysis: National Public Health Laboratory (LNSP)**

Samples taken in the various operating theatres at the HGPB were sent directly to the LNSP for analysis.

- **Sampling**
  - **Air sampling**
    - **A moment to reflect**

Air samples were taken in three stages around the operating field: before, during and after surgery.

- Before surgery: after cleaning, a pre-operative sample was taken to measure the level of residual microbial load and decontamination kinetics.
- During surgery: in the presence of the surgical team and the patient, a per-operative sample was taken to assess the impact of the patient's presence on the microbiological quality of the air.
- At the end of the operation, a post-operative sample was taken to assess the impact of the type of surgery on the microbiological flora in the air.

- **Definition of sampling points**

The determination of the number of sampling points in a cleanroom was proportional to the area of the cleanroom as defined in the equation below in **ISO 14644-1**. In addition, these sampling points should be uniformly distributed throughout the room [11]. The cleanrooms selected for our study had an average area (A) of 80 m^2. In application of the principle relating to the determination of the number of sampling points in cleanrooms**,** the following equation was applied: $N_L = \sqrt{A} = \sqrt{80} = 8.94$. The minimum number of sampling points per room was therefore **9**. However, for the purposes of the study, the number of samples per room was of the order of **14**.

- N_L was the minimum number of sampling points (rounded up to the nearest whole number).
- A was the area of the cleanroom or clean zone to be controlled, in square metres.

- **Measured characteristics**

○ **Determining the permissible particulate concentration in cleanrooms**

The particulate cleanliness of the air was designated by a classification number **N** in accordance with ISO **14644-1:**1 [11]. The maximum permissible concentration ***Cn***, for each particle of size **D** *taken into* account, was given by the equation:

$$Cn = 10^{N} \times \left(\frac{0,1}{D}\right)^{2,08}$$

- ***Cn*** is the maximum permissible concentration (in particles per cubic metre of air) of suspended particles whose diameter was equal to or greater than size ***D***. ***Cn*** was rounded to the nearest whole number, limited to 2 significant digits.
- **N** was the ISO classification number; it must be less than or equal to 9.
- ***D*** was the size considered in micrometres.
- **0.1** was a constant expressed in micrometres.

In the case of operating theatres, the particle cleanliness class chosen was **6** [11]. In the present study, the diameter of the particles measured was 5 µm [12].

In practice, the permissible particulate concentration was:

$$Cn = 10^{6} \times \left(\frac{0,1}{5}\right)^{2,08}$$

$$Cn = 293 \text{ C.F.U./m}^3 \text{ of air}$$

○ **Definition of the elementary volume of the sample per sampling point** [11] [13]

The elemental volume of the sample expressed the sufficient volume of air to be sampled at each point so that, at the limit of the specified ISO class (**Table 1**), at least 20 particles would be detected. The elementary volume (**Vs**) per sampling point is given by the following equation:

$$Vs = \frac{20}{Cn.m} \times 1000 = \frac{20}{293} \times 1000$$

$$Vs = 68 \text{ litres}$$

- **Vs** was the minimum elementary volume, in litres, taken at each point.
- ***Cn.m*** was the class limit (in number of particles per cubic metre) for the largest particle size taken into account in the target classification (see **Table 1**).
- **20** was the number of particles that could be counted if the particle concentration was that of the class limit.

Table 1. Maximum permissible particle concentrations in (particles/m³ of air) [11] [13].

Number of classification	Maximum permissible concentrations (particles/m³ of air) of particulate matter of a size equal to or greater than that shown below					
ISO (N)	**0.1 µm**	**0.2 µm**	**0.3 µm**	**0.5 µm**	1 µm	**5 µm**
ISO Class 1	10	2				
ISO Class 2	100	24	10	4		

Continued

ISO Class 3	1.000	237	102	35	8	
ISO Class 4	10.000	2.370	1.020	352	83	
ISO Class 5	100.000	23.700	10.200	3.520	832	29
ISO Class 6	1.000.000	237.000	102.000	35.200	8.320	293
ISO Class 7				352.000	83,200	29,300
ISO Class 8				3.520.000	832.000	29.300
ISO Class 9				35.200.000	8.320.000	293,000

NB: Because of the uncertainties involved in measurement, concentrations are given to no more than 3 significant figures.

In this study, the sampling device had a suction capacity of around **60** litres per **20** seconds, either **180** litres per minute.

- **Expression of results** [14]

The sampling results were expressed as Colony-Forming Units per cubic metre (C.F.U./m^3). The number of C.F.U./m^3 was determined from the sampling time and the flow rate of the device, which was 180 litres of air per minute (corresponding to 0.18 m^3 of air/min).

$$\text{Number of } C.F.U./\text{m}^3 = \frac{\text{Number of colonies}}{\text{Sampling time} \times 0{,}18}$$

- **Statistical analysis**

The statistical analysis was carried out using Epi/ Info 6.2 (CDC) software to compare the independence of the means of the qualitative variables using the chi-square test (χ^2). Fisher's exact probability test was also used with this software to test the independence of the quantitative variables studied.

3. Results

The prospective study of particulate contamination of ambient air recorded 135 samples taken, with an average of 44 samples taken in each operating theatre and 03 in the recovery and intensive care units. At each sampling point, based on the elementary volume (0.18 m^3) sampled, the result obtained was defined as the number of particles giving rise to a colony per cubic metre (C.F.U./m^3). The results were reported as the mean and standard deviation per block.

- **Level of contamination as a function of operating phases**

Table 2. Average concentration of particles in the different operating phases in the operating theatre.

Sampling point for 03 blocks	Pre-operative (C.F.U/m^3)	Per-operative (C.F.U/m^3)	Post-operative (C.F.U/m^3)
Average	**290**	**410**	**352**
Standard deviation	**135**	**145**	**132**

These results indicated a level of contamination in the ambient air well in excess of the permissible threshold of 293 (C.F.U./m³) of the ISO 14644-1 [11] (Table 2). In addition, most of the particulate concentrations obtained at each sampling point were above the tolerable microbial concentration of 32 **C.F.U./m³** (no activity) or **180 C.F.U./m³** (human presence) [15].

- **Impact of residual flora on intra-operative activity**

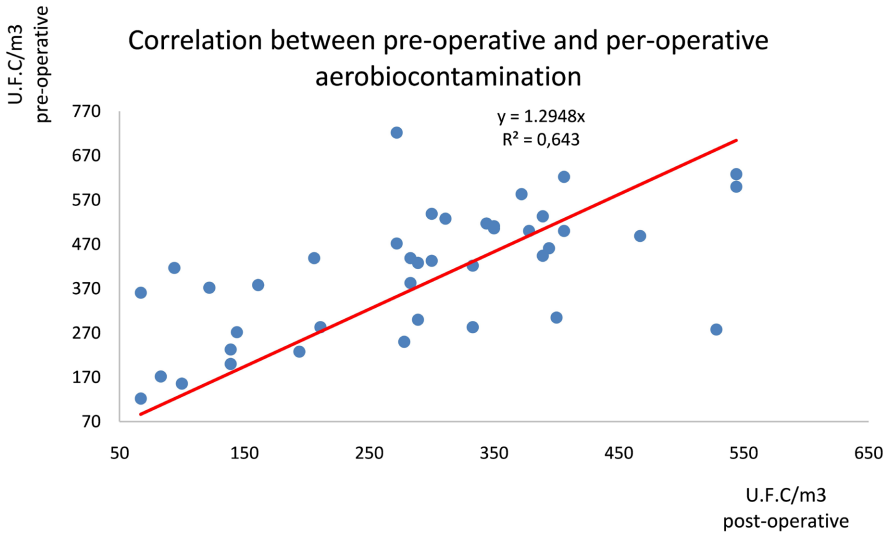

Figure 1. Correlation between preoperative and intraoperative aerobiocontamination.

With a correlation coefficient r = 0.6 and $p < 0.05$, the results indicated that the pre-operative residual flora had a direct influence on the generation of intra-operative aerobiocontamination (Figure 1).

- **Impact of surgical activity on aerobiocontamination**

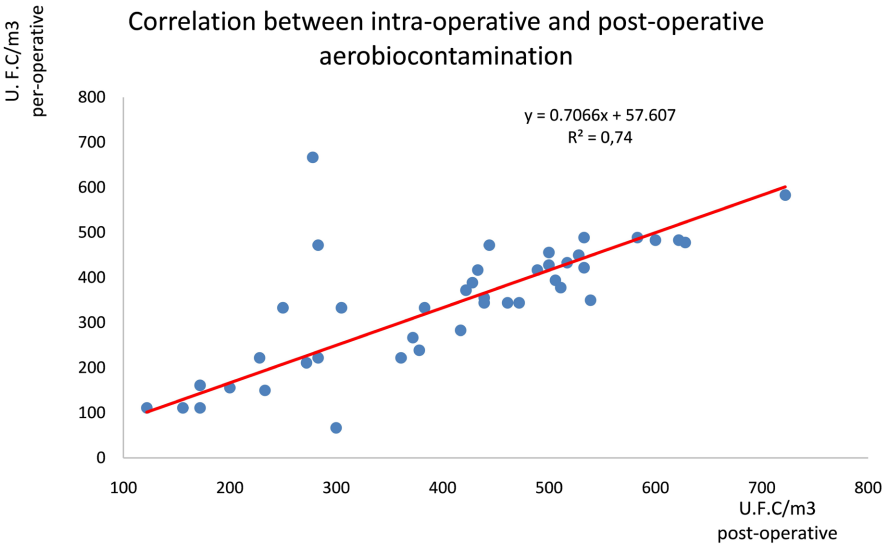

Figure 2. Study of the correlation between intra-operative and post-operative aerobiocontamination.

The interest here in counting particulate matter at the end of each procedure was guided by the need to assess the real impact of the said procedure on the quality of the ambient air in the operating theatre. Thus, with a correlation coefficient $r = 0.74$ and $p < 0.05$, we could conclude that the extent of aerobiocontamination at the end of each operation was a direct consequence of the surgical procedure (Figure 2).

- **Decontamination kinetics**

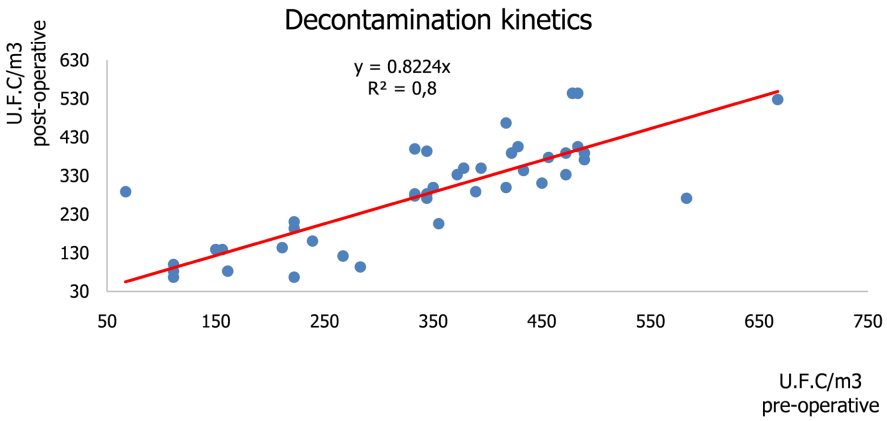

Figure 3. Evolution of decontamination kinetics.

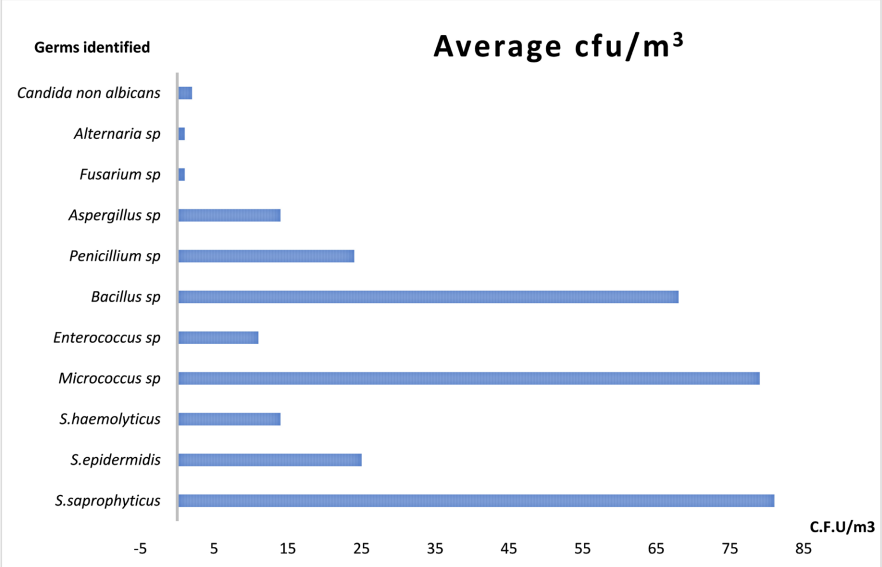

Figure 4. Nature and frequency of micro-organisms identified in the operating theatre.

The study of the correlation of microbial flora between the post-operative and pre-operative phases was a response to the need to respect decontamination kinetics between different surgical procedures. In theory, decontamination kinetics is the time required to eliminate 90% of particles 0.5 µm in diameter or larger [16]. In other words, this time is referred to as the resting time of the rooms. In view of the results of the statistical analysis of the present study, $r = 0.8$ and $p < 0.05$, the

decontamination kinetics were not satisfactory between interventions. On the other hand, decontamination kinetics were interesting for translating the dynamics of a room's behaviour (**Figure 3**).

✓ **Germs identified**

Microbiological analysis of air samples from the three operating theatres revealed six (06) saprophytic bacterial strains (85%), namely: *Staphylococcus saprophyticus*, *Staphylococcus epidermidis*, *Staphylococcus haemolyticus*, *Entérococcus sp*, *Micrococcus sp and Bacillus sp* and five (05) fungal strains (15%): *Penicillium sp*, *Aspergillus sp*, *Fusarium sp*, *Candida non albicans* and *Alternaria sp.* The most frequent species were *Staphylococcus saprophyticcus*, *Micrococcus sp and Bacillus sp*, accounting for 72% of the germs identified, with an estimated bacterial load of 283 C.F.U./m^3 and a fungal load of 56 C.F.U./m^3. Unlike various previous studies (**Figure 4**).

4. Discussion

Air control in the operating theatre is one of the essential measures for preventing the risk of infection in surgery [17]. Because of its mobility, air is a real vector in the occurrence of surgical site infections (SSI), hence the need for regular control and monitoring of ambient air quality in operating theatres [18]. The results obtained from monitoring the quality of ambient air in the HGPB operating theatre were very high. Generally speaking, the average particulate concentrations obtained pre-operatively, per-operatively and post-operatively were 290 ± 135 C.F.U/m^3, 410 ± 145 C.F.U./m^3 and 352 ± 132 C.F.U./m^3 respectively. The particulate concentrations obtained at each sampling point were regularly well above the permissible microbial concentration of 32 C.F.U./m^3 (no activity) or 180 C.F.U./m^3 (human presence). As an indication, after several years of investigation into air quality in several conventionally ventilated operating theatres, Pasquarella *et al.* proposed an alert level of 180 C.F.U./m^3 for operating theatres and 32 C.F.U./m^3 for non-operating theatres (using an active method measurement) [15]. In addition**,** in relation to the ISO 14644-1 standard, the results of the present study indicated a level of contamination of the ambient air well above the admissible threshold of 293 (C.F.U./m^3) in the operating theatre [19]. The importance of aerobiocontamination in the intra-operative phase compared with the other phases observed here was also confirmed by the statistical analysis carried out ($r = 0.74$ and $p < 0.05$) establishing a correlation between the occurrence of aerobiocontamination and the particulate load in the intra-operative phase. Far from being an isolated study, several previous similar studies looking at the question of the correlation between particulate concentration and microbiological air quality had led to various results [20]. Among them, some studies by Landrin *et al.* in 2005, Scaltriti *et al.* in 2007 and Cristina *et al.* in 2012 concluded that there was no correlation between particle count and microbiological contamination [21]-[23]. However, other studies by Stocks *et al.* in 2010 and by Wan *et al.* in 2011 have confirmed the existence of a correlation [24] [25]. This increase in aerobiocon-

tamination could be explained in part by the surgical activity mobilising the surgical team [22] [23]. Previous experimental studies have shown that humans emit a considerable number of particles into their immediate environment, either around one million per minute for an average activity. These were skin flakes, more or less carrying bacteria. They were suspended in the air despite their large size (10 to 15 μm) thanks to convection currents generated by the temperature gradient between the body and its environment, known as the "human heat island" [26]. Our results were also in line with those of Clarke *et al.* who, in the course of 40 hip replacement operations using PCR and conventional culture, showed that the percentage of positive samples was significantly higher at the end of the operation than at the beginning [27]. Looking at the consequences of aerobiocontamination, talon *et al.* in 2006 established that the patient's skin was the source of only 2% of contamination, while particles in the air accounted for the remaining 98% through direct contamination of the site [28]. Similarly, Pasquarella *et al.* in 2003 maintained that the risk of contamination of the surgical site by airborne particles was attributable in 30% of cases to the direct deposition of particles on the wound and in 70% of cases to their deposition on the surgeon's instruments and hands, followed by transfer to the wound [14]. This argument confirms that of Knobben *et al.* in 2006 and other studies which also explained that particle sedimentation would lead to contamination of instruments (up to more than 30% of positive samples), hence the need to respect the postoperative decontamination kinetics as recommended by the experts of the French Hospital Hygiene Society [29]. However, in the present study, the statistical analysis ($r = 0.8$ and $p < 0.05$) of the data relating to the decontamination kinetics indicated that the rest time of the rooms was satisfactory. In fact, rest periods between different surgical procedures were rarely observed during the survey. In view of the negative impact of non-compliance with decontamination kinetics on the increase in particulate contamination during the operating phase, both cleaning staff and surgeons need to be made aware of the need to comply with environmental and hygiene requirements in operating theatres.

Therefore, far from concluding that there are no infectious risks preoperatively (inappropriate antibiotic prophylaxis, lack of hygiene, significant residual flora) and postoperatively (irregularity of postoperative care), according to the results of several studies Munckhof *et al.* in 2005 or Crader *et al.* in 2022, the risk remains at all levels to varying degrees [30] [31]. In addition to the obvious risk of aerobiocontamination for SSI, other risk factors coexist, such as the duration of the operation, the ASA score, the nature of the operation and the Altemeir classification of operations, which should not be underestimated [32].

Finally, the microbiological identification of the samples taken at the end of the operations revealed the existence of eleven micro-organisms, including six (06) saprophytic bacterial strains (85%), namely: *Staphylococcus saprophyticus*, *Staphylococcus epidermidis*, *Staphylococcus haemolyticus*, *Entérococcus sp*, *Micrococcus sp and Bacillus sp* and five (05) fungal strains (15%): *Penicillium sp*, *Aspergillus sp*

Fusarium sp, *Candida non albicans* and *Alternaria sp*. The most frequent species were *Staphylococcus saprophyticcus*, *Micrococcus sp and Bacillus sp*, accounting for 72% of the germs identified, with an estimated bacterial load of 283 C.F.U./m^3 and a fungal load of 56 C.F.U./m^3. Following the example of several previous studies [17], most of the airborne microbes identified are saprophytic germs which may prove potentially pathogenic for patients weakened by the surgical wound. At the end of this study, a significant correlation emerged between airborne particles (5 µm) and the microbes found in operating theatres. In addition, our results are supported by those of Wang *et al.* who also concluded that there was a correlation between particles (5 µm) and aerobiocontamination in the operating theatre due to the fragility of the patients operated on [33]. However, in contrast to our results, several studies similar to ours have directly demonstrated pathogenic *S. aureus* species which are even multi-resistant to meticillin and ampicillin [17] [34].

5. Limits

Although this experimental study has the advantage of reflecting the natural microbial flora of the operating theatre, it has a number of limitations. Due to limited resources (human and financial), we were unable to follow patients with surgical site infections during the study period to determine the susceptibility or responsibility of airborne germs. Nor did the small sample size allow for a more optimal interpretation of the prevalence of airborne contamination. Thus, with the current implementation of sampling procedures and techniques, we encourage the use of larger sample sizes and improved SSI data.

6. Conclusion

Today, the aggressive nature of surgical site infections means that health establishments need to adopt more preventive measures in addition to traditional biocleaning and maintenance methods. Among these measures, control of the microbiological quality of the air is strongly recommended. In addition, the high levels of aerobiocontamination in the blocks: 290 ± 135 C.F.U./m^3, 410 ± 145 C.F.U./m^3 and 352 ± 132 C.F.U./m^3 compared with the admissible threshold of 293 C.F.U./m^3 in our work demonstrate the need for regular monitoring, including the associated risk factors. Finally, these results call on the health authorities to fulfil their duty to prevent the avoidable proportion of surgical site infections and improve management of the unavoidable proportion.

What Is Known about This Subject?

Given the combined effect of the sensitivity of surgical wounds to microbial contamination and the fragility of patients, air undeniably appears to be a major factor in the risk of post-operative infections.

Prophylaxis against particulate and microbial contamination of the air in operating theatres is therefore fundamental to improving the safety and quality of care in hospitals [6]. Health establishments are responsible for preventing the "avoid-

able" part of iatrogenic risks, which means instituting regular microbiological checks on the quality of ambient air in operating theatres.

What's New in This Study

Unlike previous similar studies using passive sampling approaches, this study adopted an active sampling mode using a portable S.A.S. air bio-collector. The study also established sampling protocols for future studies and defined the characteristics to be measured in operating theatre air contamination studies.

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Conflicts of Interest

The authors declare no conflict of interest

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