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OPERATING ROOM ENVIRONMENT WITH TURBULENT AIRFLOW

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ABSTRACT

Different levels of bacteriological contamination were observed in two identical operating rooms served by air-conditioning systems having the same air distribution with a definite turbulent pattern.

Both rooms had practically the same occupancy rates, but in one of them dirty wound operations were performed, whereas in the other only traumatology surgery - i.e., with clean wounds - was carried out.

The bacterial particle count readings taken over the operating table revealed, as expected, a lower contamination level in the traumatology room - never above Class 5 level as defined by the American College of Surgeons. In the operating room where dirty wound operations were performed, Class 5 level was - though not always - exceeded.

INTRODUCTION

Considerable disagreement is found in the literature as to the type of ventilating system and airflow that best suits operating rooms (ORs). Thus a study concerned, among other things, with a laminar vertical flow system at 65 ft/min, points "to the possible dangers inherent in nonturbulent patterns: the surgeon, bending over the wound site is a source equivalent to as many as 1,000 airborne particles per minute ..." (Kethley 1966).

In another paper horizontal laminar flow is favored, and it is stated that "downward flow of air will prevent transport of airborne contamination from one part of the room to another in a horizontal direction but may deposit on the wound site contamination generated by the head and arms of the surgical team ..." (U.S. Department of Health, Education and Welfare 1969). At the same time, however, the system limitations are acknowledged: "under certain conditions a relatively small change in the position of personnel and equipment can result in a large increase in airborne contamination levels."

On the other hand Corriell states: "... but for the use in the OR we favor vertical flow ..." (Corriell), whereas Nelson is a proponent of horizontal laminar flow (Nelson 1975; 1976a; 1976b; 1976c; 1977; Ritter 1977). Very low contamination levels are achieved with such a system, .11 to .84 bacteria per cubic foot (Nelson 1975) and .004 to .8 (Nelson 1976b), with personnel wearing helmet aspirator systems.

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The issue concerning the choice of the best air-handling system for ORs is discussed in the Laufman report (Laufman) on a statement by the American College of Surgeons which claims, among other things, "... there is no known conclusive evidence to support the superiority of vertical over horizontal flow, or vice versa, nor that of unidirectional over turbulent flow, or vice versa, insofar as these parameters affect infection rates." At this point it is interesting to note that the Laufman report recalls a contradictory statement by Charnley (Porter 1972), one of the prime proponents of so-called laminar airflow enclosures: "... the laminar flow is already out of date for operating theaters." In view of the contradictions exemplified above, it was deemed worthwhile investigating the type of environment established in ORs with turbulent flow. A survey was carried out at the hospital of SS. Trinità of Romano di Lombardia, Italy. Its scope was to find out how the bacteriological level of contamination varied in two ORs - of the same shape and size and equipped with air-conditioning systems having identical airflow rate and turbulent flow pattern distribution but with different surgical procedures - and rate them according to the classification of the American College of Surgeons.

AIR CLEANLINESS CLASSIFICATIONS FOR OPERATING ROOMS

The classification of the microbiologic air cleanliness defined by the American College of Surgeons (1976) is based upon viable microbiologic particle counts: "viable particles are defined as those independently airborne particles of variable size which contain or transport microorganisms which produce colonies on culture media," that is, bacteria or colony-forming units (CFU). Airborne bacteria are microorganisms residing on particles larger than 2 microns. The classification in question considers three classes having the characteristics listed in Table 1.

LAYOUT OF THE OPERATING SUITE AND ROOMS

The operating suite of the hospital of Romano di Lombardia has been in use since 1976. Its layout is shown in Figure 1.

One of the four identical operating rooms is illustrated in Figure 2. The investigation was carried out in room A (dirty wounds) and room D (clean wounds). Each operating room has a volume of 147 m^3 (5176 ft^3) and is supplied by 2700 m^3/h (1590 ft^3/min) of air at the rate of 18.4 air changes per hour. Supply air is 100% outside air in conformity with local regulations.

Rooms A and D have the same occupancy; the operating team usually has eight to ten people in both cases. It was not established, however, whether any of them were chronic staphylococcal carriers.

Air is distributed by means of two ceiling-mounted fixed-bar diffusers with manual dampers and two wall exhaust registers (one at ceiling level and the other in the vicinity of the floor). Although this arrangement meets ASHRAE specifications (1982), it does not create laminar flow but a very turbulent air distribution pattern.

All four operating rooms are pressurized by manually throttling the exhaust registers; however, no differential pressure gauge is installed across their partitions to check the pressure difference.

AIR-CONDITIONING SYSTEMS

The four operating rooms are connected to two identical and independent air-conditioning systems kept running 24 hours a day; the machinery, housed on the roof of the building 12 m (36 ft) above the operating room floor, has a common fresh air intake. The systems, each serving two ORs, can maintain the following conditions:

-- dry-bulb temperature: 24°C to 26°C (75.2 F to 78.8 F)
-- relative humidity: 45% to 65%.

Figure 3 shows the flow and control diagram of both systems, which are fitted with rolling type and pocket prefilters as well as HEPA (high efficiency particulate air) filters. Since the absolute filters (HEPA) used have efficiency of 99.99% or higher for particles of .3 microns or larger, the supply air is practically sterile.

INSTRUMENT USED FOR THE TESTS

The tests of microbiologic cleanliness of the air were performed with an air sampler applying the general principle of the surface air system method. The sampler has a flow rate of 180 L/min (6.36 ft^3/min). The air aspirated is blown onto a triptic soy agar surface of contact plates, which are incubated at 37°C (98.6 F) for 48 hours. The microorganism colonies are then visible to the naked eye and can be counted.

The instrument was operated for five minutes in each test in accordance with the requirements of the American College of Surgeons (Table 1) regarding the minimum volume of air aspirated and the air was sampled 20 to 25 cm (8 to 10 in) above the wound.

RESULTS

Twenty-four tests were carried out, each consisting of three or four counts taken before, during, and at the end of an operating session after cleaning and disinfection. The tests were numbered 1 through 12 (room A) and 13 through 24 (room D). Points corresponding to the various counts have been plotted in Figures 4, 5, 6, and 7 with the same numbers listed below together with the names of the operations performed (points 1.1 to 24.1 indicate counts at the beginning of surgical procedures; the last points indicate the counts after cleaning and disinfecting).

- test 1 : point 1.2 during cholecystectomy; 1.3 during appendectomy
- test 2 : point 2.2 during gastrectomy;
- test 3 : point 3.2 during protocolectomy;
- test 4 : point 4.2 during cholecystectomy and choledocolithotomy;
- test 5 : point 5.2 during cholecystectomy;
- test 6 : point 6.2 during surgery for a diaphragmatic hernia;
- test 7 : point 7.2 during appendectomy;
- test 8 : point 8.2 during cholecystectomy;
- test 9 : point 9.2 during hemithyroidectomy;
- test 10: point 10.2 during gastrectomy;
- test 11: point 11.2 during saphenous vein strip;
- test 12: point 12.3 at the end of appendectomy; 12.4 at the end of the operating session;
- test 13: point 13.2 during carpal tunnel release; 13.4 during removal of metal from left hand;
- test 14: point 14.2 during open reduction for talo-navicular dislocation; point 14.3 at the end of the operating session;

- test 15: point 15.2 during acetabular component replacement in total hip; point 15.3 at the end of the operating session;
- test 16: point 16.2 during external fixation for tibial shaft open fracture; 16.3 during tibial osteotomy for nonunion;
- test 17: point 17.2 during Achilles tendon surgical repair; 17.3 at the end of the operating session;
- test 18: point 18.2 during osteosynthesis of femur; 18.3 at the end of the operating session;
- test 19: point 19.2 during meniscectomy, 19.3 at the end of the operating session;
- test 20: point 20.2 during knee ligament surgical repair; 20.3 at the end of the operating session;
- test 21: point 21.2 during forefoot and foot osteosynthesis; 21.3 at the end of the operating session;
- test 22: point 22.2 during patellas circumferential wiring; 22.3 after cleaning;
- test 23: point 23.2 during osteosynthesis of intertrochanteric fracture; 23.3 at the end of the operating session;
- test 24: point 24.2 during tibial shaft plate removal; 24.3 at the end of the operating session.

Figures 4 and 5 refer to operating room A (dirty wounds), Figures 6 and 7 to room D (traumatology surgery operations, clean wounds). Both rooms start in the morning as Class 1. As expected, the contamination level in A is always higher than in D. Although room A frequently exceeds Class 5 level contamination, it never goes beyond Class 20. Room D sometimes approaches the maximum contamination level of Class 5 but does not exceed it.

It may be observed that the counts recorded for room D do not obviously compare with the contamination levels listed by Nelson (1975; 1976b) for horizontal flow clean rooms with personnel wearing isolator systems (where traumatology surgery was also performed), although sometimes they come close to them.

CONCLUSION

The findings of the present investigation reveal that in operating rooms that meet ASHRAE design criteria, the bacterial contamination did not exceed Class 20 of the American College of Surgeons classification in the case of dirty wound operations and Class 5 with clean wound procedures.

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TABLE 1
Air Cleanliness Classes

CLASS	NUMBER OF BACTERIA PARTICLES PER CUBIC FOOT		NUMBER OF BACTERIA PARTICLES PER CUBIC METER		MINIMUM SAMPLE OF AIR REQUIRED	
	MIN	MAX	MIN	MAX	CUBIC FEET	CUBIC METERS
1	0	1	0	35	30	0.849
5	MORE THAN 1	5	MORE THAN 35	175	30	0.849
20	MORE THAN 5	20	MORE THAN 175	700	10	0.283

LEGEND

① HEAD NURSE OFFICE
② ANAESTHETIC ROOM FOR OPERATING ROOMS C & D
③ ORTHOPAEDIC INSTRUMENTS
④ PLASTER ROOM
⑤ RECOVERY ROOM
⑥ ANAESTHETIC ROOM FOR OPERATING ROOMS A & B
⑦ TOILETS
⑧ SURGEONS' ROOM
⑨ INSTRUMENT ROOM
⑩ PREPARATION ROOM FOR MATERIAL TO BE GAS-STERILIZED
⑪ SCRUB ROOM FOR OPERATING ROOM C & D
⑫ SUBSTERILE ROOM FOR OPERATING ROOM C & D
⑬ SCRUB ROOM FOR OPERATING ROOM A & B
⑭ SUBSTERILE ROOM FOR OPERATING ROOM A & B
⑮ DIRTY CORRIDOR
⑯ ⑰ ⑱ CLEAN CORRIDOR
Ⓐ OPERATING ROOM
Ⓑ OPERATING ROOM
Ⓒ OPERATING ROOM
Ⓓ OPERATING ROOM

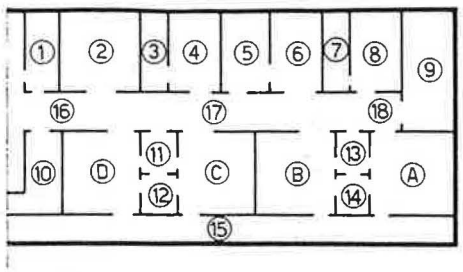

Figure 1. Layout of operating suite in hospital of Romano di Lombardia

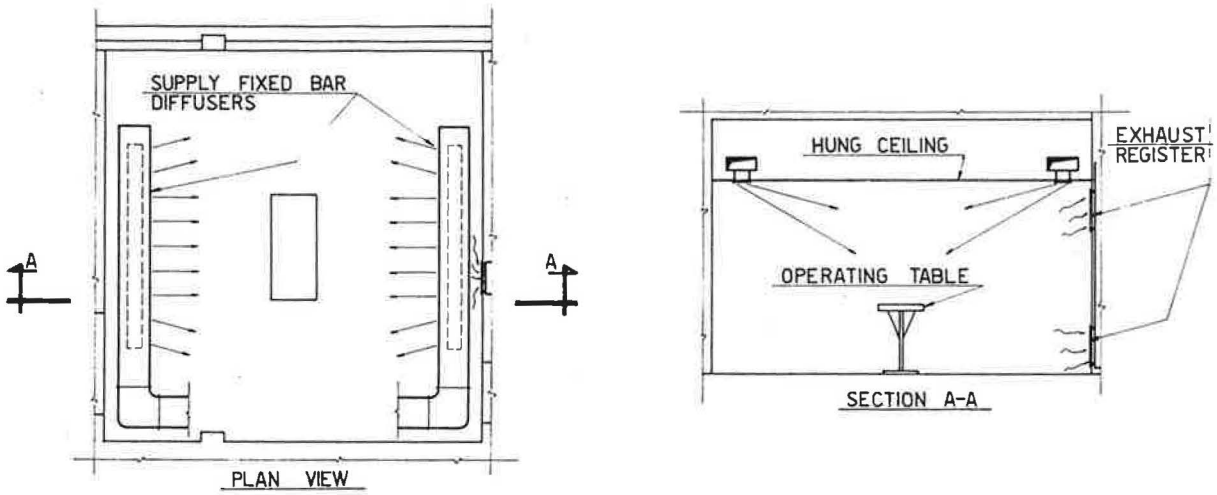

Figure 2. Layout of operating room

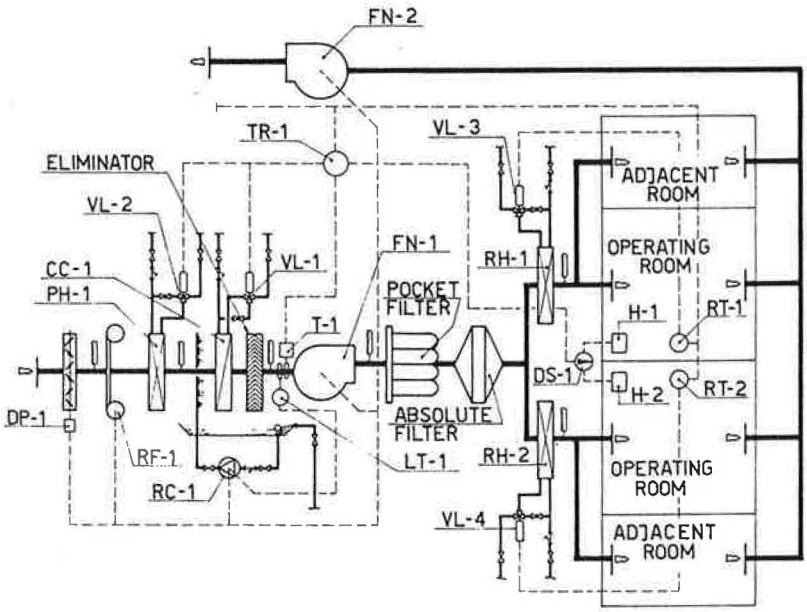

Figure 3. Flow and control diagram of air-conditioning systems

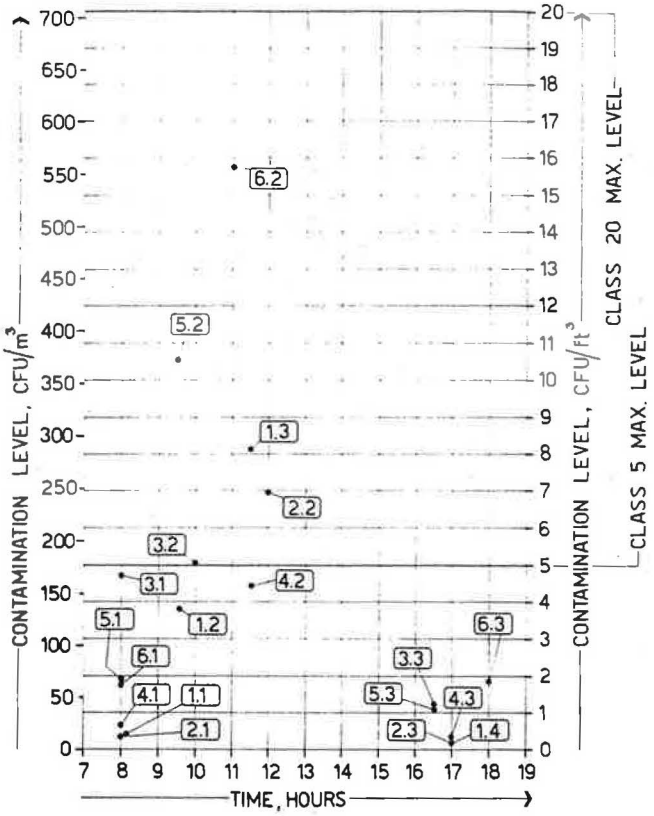

Figure 4. Test results in operating room A

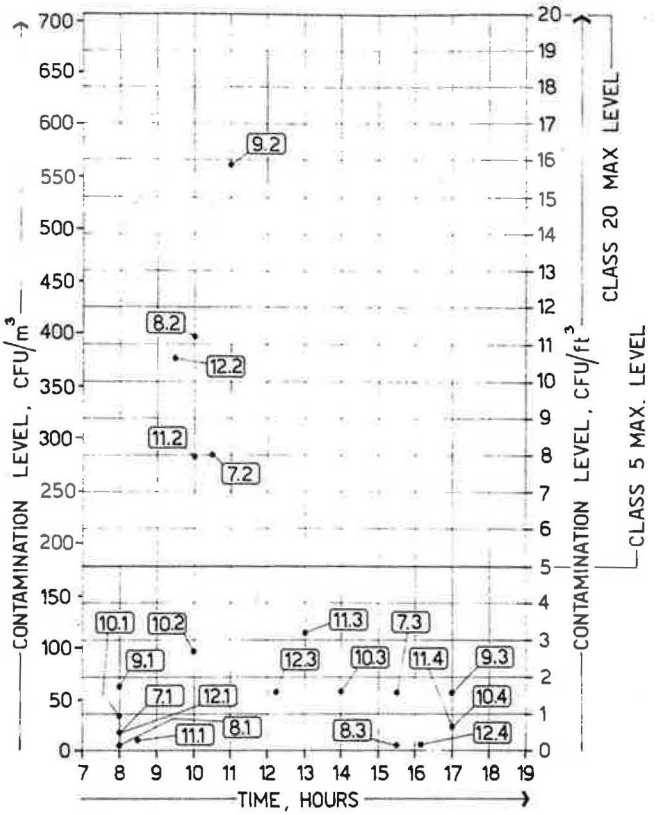

Figure 5. Test results in operating room A

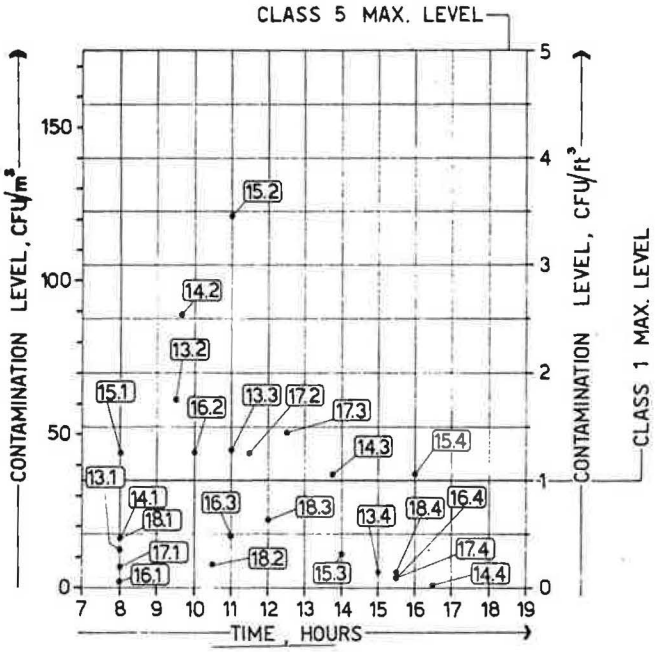

Figure 6. Test results in operating room D

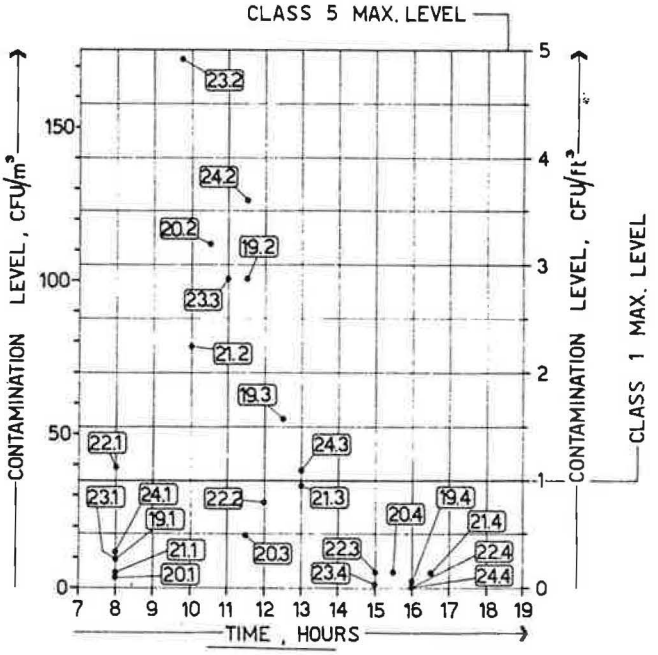

Figure 7. Test results in operating room D