Clean air symposium—Part II

A systems analysis approach to postoperative wound infections

Phase II. A microbiological assessment of the exogenous bacterial controls in the operating room

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Many factors have been implicated as exogenous sources of bacteria influential in postoperative wound infections. Can we evaluate all of these during actual operating room procedures and if so, can we determine which ones are of major importance?

Methods and procedures

In order to evaluate the relative importance of these environmental factors we first divided them into indirect and direct wound contact sources.

The indirect sources are: (1) number of personnel in the operating room, (2) number of scrubbed personnel, (3) number of personnel wearing caps, (4) number of personnel wearing hoods, (5) cloth gowns and drapes, (6) disposable gowns and drapes, (7) use of the expired air exhaust system, (8) length of the surgical procedure, (9) number of door openings, (10) change in room temperature, and (11) operating room floor microbial levels. For each clean orthopaedic case, recordings were made of the above items, location of the operating table in the room, equipment, personnel, sampling sites of the air, wound (as

mentioned in Phase I), gowns, floor, and whether the laminar air flow was on or off.

Nasal flora cultures of all patients and personnel were obtained by rotating a swab moistened in Dey/Engley (D/E) broth about the nares twice.[1] Gowns were sampled before and after each surgical operation by Rodac impression plates over the sternum.[2]

The floor about the operating room table was sampled by five Rodac plates containing D/E agar before and after surgery and after cleaning. The cleaning procedure involved pouring approximately 1 gallon of a phenolic disinfectant on the floor and removing it with a wet vacuum.

To evaluate the relative importance of these factors on the airborne contamination levels in the operating room we subjected each of the above variables to computer analysis.[3] The nonnumerical data were coded and with the numerical data were punched onto computer cards. The data were separated into two groups, one included all data taken with the laminar air flow off and the other included all data taken with the laminar air flow on. The data were processed by a stepwise linear multiple regression program, with control exercised over the possible selection of the various independent variables entering the regression. The regression equations obtained expressed a predicted number of bacterial counts in various locations of the operating room as a function of factors such as length of operation, number of persons in the room, door openings, the number scrubbed, the number of caps, the number of hoods, type of drapes, etc. The form of the regression equation would appear as follows: the predicted count (i.e., at the wound) = constant + C_1 number of persons in OR + C_2 number of scrubbed + C_3 number of door openings + C_4 duration of operation (minutes) + C_5, etc. The computer program supplies the constant, the coefficients, and an *f* value, so that one may determine how well the regression equation fits the actual data in terms of confidence limits.

The direct sources are: (1) implants, (2) acrylic cement, (3) sutures, (4) knife blades, (5) instruments, (6) types of surgical wound preparations, (7) sponges, and (8) surgical gloves. The ready to use orthopaedic hardware, acrylic cement (monomer, polymer, and mixed compound), sutures, knife blades, and instruments were placed in sterile trypticase soy broth (TSB) for sterility testing. The samples were incubated at 37 C for 7 days. The microorganisms isolated from contamnated specimens were identified by routine laboratory methods.

The surgical wound site was scrubbed with either Betadine or pHisoHex. Prior to the scrub, the wound site was sampled by rubbing a sterile swab moistened in D/E broth over a 1-square inch area. After the wound was prepared for surgery the site was once again sampled as before. The swabs were placed into D/E broth after sampling to neutralize antimicrobial compounds.

Laboratory sponges stored on the operating room shelves were randomly tested. The sponge packs were opened under a vertical laminar air flow laboratory work bench (Model ℵ728-3).*

Sterile gloves were worn only once; the two outer sponges were placed into 1 quart canning jars containing 500

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ml of thioglycollate medium (without the indicator resazurin). An applicator stick was placed under the lid during sterilization to prevent sealing and was removed after cooling. Cooling was achieved in the autoclave and under the laminar air flow work bench. The thioglycollate was prepared immediately before use and without resazurin, because of its toxic properties for certain anaerobes. The samples were incubated at 37 C for 2 days and at room temperature for 12 additional days. Microorganisms from contaminated specimens were identified according to routine laboratory methods.

Surgical gloves were sampled for external sterility immediately after use or before changing during actual operation. The gloves were tested by making an impression of as much of the fingers and palms as possible onto a 150 mm blood agar plate using a separate plate for each glove. When double gloves were used both the outer and inner gloves were sampled. The blood agar plates were incubated 2 days at 37 C, 5 additional days at room temperature, and then examined for the types and number of colony forming units (CFU).

Surgical wounds were cultured when the depth of the wound was reached and just before closure was begun. Two types of samples were collected at the beginning and before closure: (1) swabs were rubbed around the entire wound and plated on 5% sheep blood agar plates under aerobic conditions; (2) tissue from the depth of the wound was macerated in a glass tissue grinder and inoculated onto a blood agar plate (aerobic), and into high sucrose media (11.4% sucrose),* and chopped meat broth for anaerobes. The tubes, high in sucrose, were incubated for several months at 37 C. A portion of each was tested for growth whenever the tube appeared turbid, or after 1 week, 2 weeks, 1 month, and then every month thereafter for 1 year. The tubes high in sucrose were checked for anaerobes and aerobes. Culturing was discontinued if an organism was recovered. These tubes were used to isolate organisms whose cell walls may have been damaged, as with the L-forms of bacteria. Microbiological isolation and identification techniques were those employed by routine clinical microbiological laboratories.[4, 5]

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Table 1. Comparison of the number of personnel in a conventional operating room to one with horizontal laminar air flow during actual orthopaedic surgery

	Conventional operating room		Laminar air flow	
	No. personnel in the room	No. scrubbed	No. personnel in the room	No. scrubbed
Average	9.5	4.3	11.6	4.4
Range	3–15	2–6	9–17	2–6

Results

The results that follow for the indirect sources will be separated depending on whether or not the horizontal laminar air flow system was on.

Table 1 shows that the total number of persons in the room and the number scrubbed do not differ much for the two air handling systems.

Table 2 shows the number of caps and hoods used in each air handling system. The difference is related to the number of persons in the room versus those scrubbed.

Table 2. Number of caps and hoods per case in a conventional operating room versus one with laminar air flow

	Conventional operating room		Laminar air flow	
	Caps	Hoods	Caps	Hoods
Average	5	4	3	8
Range	1–10	1–9	1–9	1–15

Table 3 shows little difference between the percent increase in counts for cloth versus disposable gowns at the end of an operation. However, our sampling was probably insufficient, since we only used one Rodac plate per gown and impressions were taken high on the gown. Other work by the authors has shown a statistical improvement between disposable versus nondisposable material when sampling all over the front of the gown and especially if a hood is attached to the gown as one material.[6]

The air exhaust systems used by the surgeons were used only with the laminar air flow system on. It was therefore used in 60 of 125 cases by all the scrubbed personnel.

As noted in *Table 4* there is little difference between the two air systems as regards the average operating time and number of door openings per case.

Table 5 shows the temperature for the two air systems.

Table 6 shows that we do reduce the floor bacterial counts about the operating room table after cleaning, but the reduction is only minimal and very short-lived.

The above data tells us very little until combined and analyzed by computer analysis. *Tables 7 and 8* list the data for 242 cases, 117 without laminar air flow and 125 with laminar air flow. As can be seen, in the conventional operating room the largest source of contamination is the number of peo-

Table 3. Surface sampling of cloth versus paper surgical gowns. All counts represent the percent contaminated or percent increase in contamination

Conventional operating room						Laminar air flow					
Cloth			Paper			Cloth			Paper		
Preop	Postop	% inc.	Preop	Postop	% inc.	Preop	Postop	% inc.	Preop	Postop	% inc.
8.3	34.5	76	5.1	29.7	83	4.8	14	66	4.8	12.5	62

Table 4. Comparison of the length of surgery in minutes and number of door openings per case of a conventional operating room to one with laminar air flow during actual orthopaedic surgery

	Conventional operating room		Laminar air flow	
	Length of surgery	No. door openings	Length of surgery	No. door openings
Average	82	37	75	49
Range	11–270	1–164	25–125	14–103

Table 5. Comparison of the temperature change of the conventional operating room to that of the laminar air flow room during actual surgery

Conventional operating room			Laminar air flow		
Preop	Postop	Change	Preop	Postop	Change
71°	71°	0	75°	74°	−1

Table 6. Average number of colony forming units per Rodac plate as a means of evaluating the effectiveness of floor cleaning between surgical cases

Microbial levels of the floor			
Before surgery	After surgery	After cleaning	% change
43.13	50.78	27.05	46.73

ple in the room ($P < 0.025$) followed by the number of door openings ($P < 0.025$) and the use of caps instead of hoods. When the laminar air flow is on, no one factor stands out as it relates to airborne contamination at the wound site and back table.

Table 9 is a résumé of all the direct sources sampled and the percent contaminated. As is quite evident, laparotomy sponges and gloves are contaminated about one-third of the time. Double gloving does seem to help reduce glove contamination. Interestingly, when the outside glove was contaminated the inside glove was not. Is the contamination from the hands or from the sterile field and equipment?

Much of our data on tissue sampling is incomplete but to date 3.5% of our opening samples were positive initially and 13.6% were positive in 30 days. Of the closing samples, 2.7% were positive initially and 21.3% were positive in 30 days.

Table 7. Influence of indirect contact environmental factors in microbial sampling *rates* at various sampling positions with laminar air flow off

		No. people in room	No. door openings	Caps	Hoods	No. scrubbed	Duration of operation	Cloth drapes	P value
	W/R			+(1)	−(2)			−(3)	0.25
	BT/R			−(4)	−(1)	−(3)		+(2)	0.10
Air settle plate positions	W	+(1)		−(4)	−(2)			−(3)	0.025
	BT	+(1)	+(3)	−(6)	−(5)		−(2)	−(4)	0.025
	1	+(1)		+(4)	−(3)	−(2)			0.25
	2	+(1)		−(4)	−(3)	−(2)		−(5)	0.10
	3	+(1)	+(6)	−(3)	−(4)	−(2)	−(7)	−(5)	0.10
	4	+(1)		−(3)	−(4)	−(2)		−(5)	0.25
	5		+(1)	−(2)	−(3)			+(4)	0.25
	6	+(1)		−(2)	−(3)			+(4)	0.50

W = wound, BT = back table, R = Reynier, ( ) = order of importance, + = increases count rates, − = decreases count rates.

Table 8. Influence of indirect contact environmental factors on microbial sampling *rates* at various sampling positions with laminar air flow on

		No. people in room	No. door openings	Caps	Hoods	No. scrubbed	Duration of operation	Cloth drapes	Breath exhaust	P value
	W/R	−(1)		+(5)	+(4)	+(3)		+(2)		0.25
	BT/R			+(2)	+(4)		−(3)	+(1)		0.01
Air settle plate positions	W				−(2)	−(1)				0.25
	BT			−(2)	−(3)		−(1)	+(4)		0.025
	1			−(4)	−(3)		−(1)	+(2)		0.10
	2	+(1)	+(6)	+(5)	+(4)	+(3)		+(2)		0.025
	3		+(4)	+(5)	+(7)	+(2)	−(3)	−(6)	+(1)	0.25
	4	−(6)		−(7)	+(1)	+(3)	−(2)	+(5)	−(4)	0.10
	5			+(2)	+(3)		−(1)	+(4)		0.005
	6	+(1)	+(3)	+(5)	+(4)		−(2)	−(6)		0.025

W = wound, BT = back table, R = Reynier, ( ) = order of importance, + = increases count rates, − = Decreases count rates.

Table 9. Types of environmental direct sources tested, number contaminated, percent contaminated

Item tested	No. tested	No. contaminated	% contaminated
Screws	30	0	0
Cement	32	2	6
Cement powder	32	1	3
Cement liquid	32	0	0
Suture packages	14	1	7
Knife blades	20	0	0
pHisoHex	17	4	16
Betadine	57	2	3
Single glove	74	24	32
Double glove			
Outer	54	7	13
Inner	26	4	15
Sponges, ABD	31	12	39
Sponges, Raytex disposable	6	1	17

Discussion

There are many sources of exogenous bacteria, but only a few seem to have any statistical significance as they relate to contamination of the sterile field. The exogenous bacteria come mainly from people, indicating that controls must be centered around controlling people and the bacteria they shed. From Phase 1 the most significant factor in reducing environmental contamination is the use of laminar air flow ($P < 0.005$). If laminar air flow is not available, then one must reduce the number of personnel in the operating room to a minimum ($P < 0.025$), lock the doors, and wear hoods as routine operating attire.

The use of laminar air flow is not only the most important means of controlling the environment, but it also eliminates all the indirect sources as possible means of contamination. Since there are still counts at the wound site, we are now able to concentrate more of our attention on the direct sources of contamination, i.e., sponges and gloves.

In conclusion, we look at laminar

air flow as a means of controlling the environment and reducing the complexity of indirect variables. With this in mind, we can now begin to focus our attention back upon the wound and other possible sources of wound infections.

References

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