since none was given during dialysis. For technical reasons 35-40 minutes elapsed from the time parenteral feeding was stopped until dialysis was established.

On the 13th day after admission, when dialysis had been in progress for some 50 minutes, she complained of drowsiness and rapidly became comatose. On that day 20 U soluble insulin had been added/l parenteral fluid, this amount having been calculated from her previous blood glucose concentrations and insulin requirements. Unlike on previous occasions, however, the infusion had been allowed to continue until dialysis was established.

A capillary blood sample was taken and glucose concentration determined with Dextrostix (Miles Laboratories Ltd, Slough); this gave a negative result. Simultaneously a venous blood sample was sent to the emergency biochemistry laboratory, and the plasma glucose concentration was reported as <1 mmol/l (18 mg/100 ml). She responded rapidly to a 50 ml intravenous bolus of 50% dextrose and suffered no permanent ill effect from the hypoglycaemic episode. Six weeks later she was discharged home having recovered full gastrointestinal and renal function but with residual paraplegia.

Discussion

Addition of insulin to intravenous feeding solutions is established practice in many centres[1] when stress from trauma or sepsis causes reduced use of exogenously supplied carbohydrate. Experience has shown that because the insulin is delivered as an additive to the hypertonic dextrose hypoglycaemia is not a problem even if the infusion is stopped abruptly.[2] In the case reported, however, dialysis was already in progress when the infusion was stopped and the patient then had both a mildly raised blood glucose concentration owing to the infusion of 25% glucose and an appreciable blood concentration of exogenously supplied insulin. The solution used for dialysis contained no glucose and so a shift of glucose occurred across the semi-permeable membrane from the blood to the dialysate, resulting in a rapid reduction in the blood glucose concentration. The exogenous insulin, having too great a molecular size to cross the membrane, remained in the patient's circulation to reduce the blood glucose concentration further to critical hypoglycaemic levels.

If the infusion is stopped 30-45 minutes before dialysis is started blood glucose and insulin concentrations are allowed to fall naturally and simultaneously so that even if dialysis subsequently depresses the blood glucose concentration there is insufficient residual exogenous insulin, with its physiological half life of 20-30 minutes,[3] to have a pronounced hypoglycaemic effect.

This case prompted us to make changes in our management of such patients, and we have not subsequently encountered this hypoglycaemic complication.

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Effect of ultraclean air in operating rooms on deep sepsis in the joint after total hip or knee replacement: a randomised study

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Abstract

In a multicentre study of sepsis after total hip or knee replacement the operations performed by each surgeon were allocated at random between control and ultraclean-air operating rooms. Records were obtained from over 8000 such operations.

In the patients whose prostheses were inserted in an operating room ventilated by an ultraclean-air system the incidence of joint sepsis confirmed at reoperation within the next one to four years was about half that of patients who had had the operation in a conventionally ventilated room at the same hospital. When whole-body exhaust-ventilated suits had been worn by the operating team in a theatre ventilated by an ultraclean-air system the incidence of sepsis was about a quarter of that found after operations performed with conventional ventilation. When all groups in the trial were considered together the analysis showed deep sepsis after 63 out of 4133 operations in the control group (1·5%) and after 23 out of 3922 operations in the ultraclean-air groups (0·6%) (ratio 2·6, 95% confidence limits 1·6-4·2; p <0·001).

The design of the study did not include a strictly controlled test of the effect of prophylactic antibiotics, but their use was associated with a lower incidence of sepsis than in patients who had received no antibiotic prophylaxis at their operations (0·6% (34/5831) v 2·3% (52/2221); ratio 4·0).

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Introduction

The importance of airborne bacteria in the operating room as a possible source of surgical wound sepsis has been a subject of controversy for over a century. With the development of

artificial joints in orthopaedic surgery concern increased, because infections were apt to occur at the site of the prosthesis months or even years after the operation, with potentially disastrous consequences for the new joint; the incidence of such infection was sometimes as high as 10%.

To reduce the risks of these infections, techniques for reducing bacterial contamination of air to extremely low levels have been adapted for use in the operating room.[1] In Britain this has been associated especially with the work of Charnley,[2] though many other studies on ultraclean air have been reported; Lindberg summarised these up to 1977.[3] They strongly supported the view that reduced bacterial contamination of air at operation leads to a reduced incidence of joint sepsis. Some surgeons,[4] however, reported sepsis rates as low as Charnley's after operations in conventionally ventilated operating rooms. The large and progressive reduction in sepsis rates reported by Charnley over a period of years was associated with advances in operative procedure and progressive improvement of the ultra-clean-air system.[2] In some studies there were too few operations for statistical comparison of ultraclean-air and control conditions, and in some the operations in ultraclean and control conditions were not strictly comparable. Also prophylactic antibiotics were used by some surgeons but not by others.

In 1974 the Medical Research Council and Department of Health and Social Security agreed to support a controlled investigation. This paper is a first report on that study. It is confined to the assessments of joint sepsis which led to reoperation in some patients after total hip or knee replacement. Other assessments—including bacteriological studies and the incidence of superficial infection—will be discussed elsewhere.

In this report we use the terms sepsis and septic to mean bacterial infection in the joint associated with clinically apparent tissue damage.

Plan and conduct of investigation

To give a reasonable chance (90%) of establishing a difference between sepsis rates of, say, 2% in a control series and 1% in an ultraclean-air series at the 95% confidence level we estimated that about 2500 operations would be necessary in each series. In addition to ventilation systems that provide the operating room with ultraclean air (arbitrarily defined as air containing fewer than 10 bacteria-carrying particles/m^3) body-exhaust-ventilated suits[2] were used by operating teams in some ultraclean-air rooms and claimed to reduce the incidence of sepsis still further. Two ultraclean-air groups, one with and one without use of body-exhaust suits, were therefore included, so that 7500 operations were needed in all; such numbers could be obtained in reasonable time only from a multicentre study.

Requirements for participation in the trial were as follows.

(1) Each surgeon and his team should operate on some patients in a conventionally ventilated room (control series) and on some in a room ventilated by an ultraclean-air system and either wear or not wear a body-exhaust suit; and they should allocate the patients by a randomising method between the two environments without altering any other procedures.

(2) The control operating rooms should be ventilated with a modern, positive-pressure air supply.[5]

(3) At each centre patients should be admitted to the study over three years; follow-up should extend to 12 months after the last patient had been entered at that centre.

(4) Records of the operation and subsequent progress should be entered on specially designed and centrally provided forms by a research nurse or other similarly appointed person.

(5) Air samples should be taken during operations in each operating room at suitable intervals throughout the study.

(6) At some hospitals bacterial contamination of a proportion of wounds should be estimated quantitatively from samples taken by a wound-wash culture technique after the prosthesis had been inserted but before resuturing.

Details of the organisation of the study have been reported.[6]

Nineteen hospitals agreed to participate—11 in England, four in Scotland, and four in Sweden. The first operation documented was performed in 1974, and the last before the end of July 1979. At two hospitals in England and one in Scotland the ultraclean condition was provided by plastic isolators.[7] Because the arrangement of operating rooms and other conditions varied among the different hospitals it was not possible to use a uniform method of random allocation. Hence random sequences were drawn up for some hospitals, and others used procedures of their own that had been approved by the co-ordinators of the trial. These random sequences allocated the operating conditions for each surgeon for each week; they were distributed in sealed envelopes, to be opened after the operating list had been prepared. Inevitably there were some unplanned changes in the lists, and the method could not guarantee a completely random allocation for surgeons who operated only occasionally and at irregular intervals.

Results

By the end of the study records of 8136 operations for replacement of hips and knees had been received. Forty-five were rejected as not complying with the protocol, including 39 breaches of the randomisation procedure, and for another 36 essential data were missing. The remaining 8055 comprised 6781 operations on the hip and 1274 on the knee. In 732 instances some kind of operation had been performed on the joint before. The mean duration of follow-up was between 2·0 and 2·5 years.

Of the operations for joint replacement for which there was no subsequent record of reoperation, 75% were followed up for one year or more and 45% for two years or more. Records of reoperation were received up to nearly four years after the primary operation, and the temporal distribution suggests that reoperations were effectively reported from each hospital over the whole period of participation. Thus the median follow-up time for reoperation and assessment of joint sepsis was almost 2·5 years.

Overall the methods used for randomisation resulted in a satisfactorily even distribution between the control and ultraclean conditions, though there were some exceptions. At one hospital it was impracticable to operate on right and left hips in the ultraclean environment, so that over three-quarters of the operations were performed in the control environment. There were smaller imbalances in other hospitals, but separating the data into those from hospitals with near-perfect balance (overall and for individual surgeons) and those with some irregularities showed no difference in the association between use of ultraclean air in the operating room and incidence of sepsis.

At four hospitals some operations under ultraclean-air conditions were performed by a team wearing conventional operating-room clothing and some by a team wearing body-exhaust suits; but in the other hospitals only one of these two ultraclean conditions was used. As a result the numbers of operations were divided among the control and two ultraclean-air conditions roughly in the ratio 2:1:1 (4133: 1789:2133).

BACTERIA IN AIR SAMPLES AT OPERATION

Air samples for bacterial counts were obtained close to the operation site during operations using a modified slit sampler or Sartorius gelatin filters. Various different ultraclean-air systems were used in different hospitals, which resulted in different levels of air contamination. Table I gives the values and shows the number of hospitals using each type of ultraclean-air system. Three hospitals used the Allander system of air curtains around the operating zone with ventilation from a perforated ceiling.[8] Since the median air contamination counts with this system were substantially higher than with the other special ventilation systems and well above the value arbitrarily defined as ultraclean (< 10 bacteria-carrying particles/m^3), the Allander system used with conventional operating clothes was regarded as providing a control ventilation condition; when used in conjunction with body-exhaust suits it provided conditions that approximated to those defined as ultraclean, though with this arrangement and with the use of horizontal air flow plus conventional clothing the amount of air contamination was not consistently below the threshold for ultraclean.

The values in table I are similar to those reported by others.[3] Downflow systems generally performed better than horizontal flow, and those with containing walls better than those without. Wearing body-exhaust suits clearly enhanced the reductions in air contamination with ultraclean ventilation. Median air contamination counts in the conventionally ventilated (control) operating rooms ranged from 50/m^3 to 500/m^3. This wide variation, which greatly exceeded that from sample to sample within any one hospital, was not easily explained but may have been due to differences in operating-room practice and different levels of bacterial dissemination from the operating teams.

TABLE I—*Air contamination in relation to ventilation and clothing. (Median values obtained as geometric means (unweighted) of logarithmic means for each hospital and condition)*

Ventilation system	Median No of bacteria-carrying particles/m³ (No of hospitals) for operations performed with:	
	Conventional-pattern clothing	Body-exhaust suits
Conventional (turbulent)	164 (15)*	51 (1)*
Allander	49 (3)*	14 (3)†
Horizontal flow	22 (3)†	1 (1)†
Downflow without walls	10 (3)†	—
Downflow with walls	2 (4)†	0·4 (6)†
Trexler isolator	0·5 (3)†	

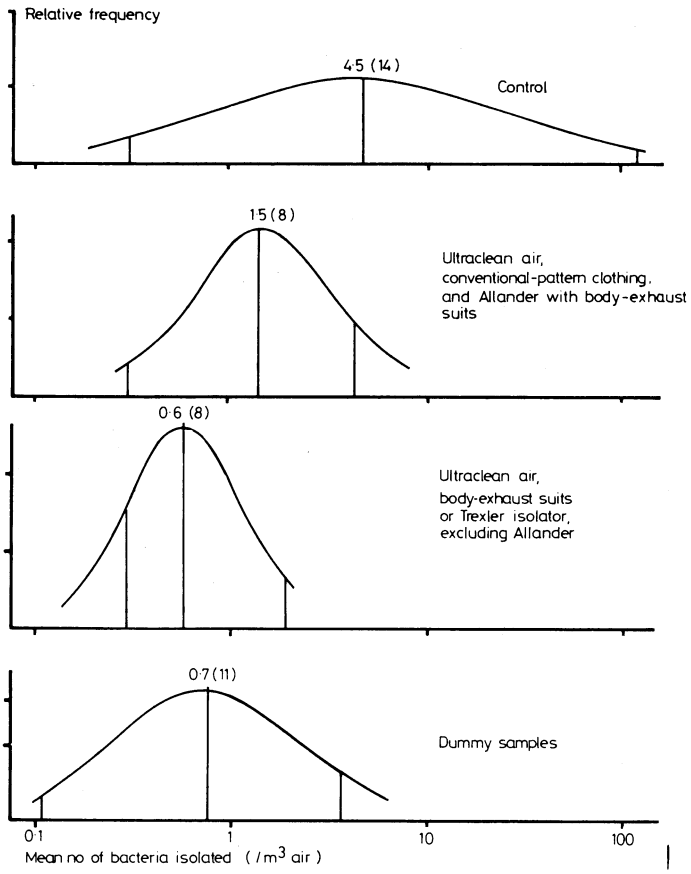
*Values from operating rooms regarded as controls.
†Values with ultraclean-air systems.

The value of bacteriological checks on the performance of the ventilation systems was well illustrated when the air contamination within a downflow system without walls rose to a value little different from that of the control. This was eventually traced to failure of the air-cooling plant, which is essential to effective working of this kind of system.[9]

BACTERIA IN WOUND SAMPLES AT OPERATION

Over 3000 wound-wash samples were collected during operations in 16 hospitals. Equivalent volumes of fluid were processed in a similar way to provide dummy samples. The figure shows that there was a substantial reduction in the mean numbers of bacteria isolated from wounds during operations performed under ultraclean-air conditions compared with those isolated from wounds during operations in the control series. In the cleanest-air conditions the mean numbers did not differ significantly from those in the dummy samples. There were considerable differences in results from different hospitals.

The numbers of bacteria in washings from operation wounds in ultraclean-air rooms were always small. At some hospitals much larger numbers were isolated in the control operating rooms, but in others the numbers differed little, if at all, from those found in the ultraclean operating rooms. This difference was not related to air contamination at the hospitals concerned. There is no entirely satisfactory explanation but it may have been due to differences in technique used by the surgeons in taking the samples, which could cause substantial differences in the efficiency of isolation of micro-organisms from the wound.[10]



Numbers of bacteria isolated from wound-washout samples. Logarithmic mean values calculated for each hospital and condition. Logarithms of numbers of bacteria isolated distributed approximately normally. Distribution constants for each set and smoothed curves shown calculated from mean values. Median value given for each curve with (in parentheses) number of hospitals contributing. Extreme values observed indicated by short vertical lines.

INCIDENCE OF DEEP JOINT SEPSIS

The clinical records of all operations for implantation of a prosthesis that were followed by a further operation or operations on the same joint (369) were examined by one of us (RB, EJLL, or WW), whose recorded assessments were then checked by OML. An assessment was made of the probable presence of sepsis and the result divided into three categories: (1) no evidence of sepsis, (2) some evidence of possible sepsis, and (3) strong evidence of sepsis. The criteria considered, in roughly descending order of relevance, were isolation from the joint of potentially pathogenic micro-organisms, pus in the joint, abscess, sinus, suggestive histological findings, abnormal *x*-ray appearances, abnormal pain, raised erythrocyte sedimentation rate (when previously not raised), and fever at the time of reoperation. The surgeon's recorded opinion was also taken into consideration. In over 90% of instances our assessments were in complete agreement with the surgeons' opinion.

On this basis 86 instances of sepsis or probable sepsis were recognised. Significant bacteria—that is, types considered likely to cause sepsis—were isolated from the joints in 70 (81%) of these instances; on 28 occasions (33% of instances of sepsis and 40% of all isolations of bacteria) these were strains of *Staphylococcus aureus*.

TABLE II—*Sepsis in relation to operating-room conditions*

Hospital group (No of hospitals)	Conditions in ultraclean-air series	Air contamination	Control series		Ultraclean-air series		Ratio‡ control: ultraclean	p (95% confidence limits)
			No of operations*	No (%) septic†	No of operations*	No (%) septic†		
1 (n = 6)	Conventional-pattern clothing	Low	1252	28 (2·2)	1058	11 (1·0)	2·2	<0·05
2a (n = 3)	Body-exhaust suits	Very low	832	6 (1·0)	954	1 (0·1)	6·9	<0·05
2b (n = 3)	Trexler isolator	Very low	411	9 (2·2)	338	3 (0·9)	2·5	0·2–0·1
2a + 2b (n = 6)		Very low	1243	15 (1·2)	1292	4 (0·3)	3·9	<0·01
3 (n = 4)	Conventional-pattern clothing	Low	1392	19 (1·4)	546	5 (0·9)	1·5	0·5–0·3
	Body-exhaust suits	Very low			841	2 (0·2)	5·7	<0·01
4 (n = 3)	Body-exhaust suits	Moderately low	246	1	185	1	—	—
1 + 3 (n = 10)	Conventional-pattern clothing	Low	2644	47 (2·0)§	1604	16 (1·0)	2·0	<0·02 (1·1–3·6)
2 + 3 (n = 10)	Body-exhaust suits or isolator	Very low	2635	34 (1·3)§	2133	6 (0·3)	4·5	<0·001 (1·8–11·0)
All groups (n = 19)			4133	63 (1·5)	3922	23 (0·6)	2·6	<0·001 (1·6–4·2)

*For insertion of prosthesis.
†Sepsis (category 3) confirmed after reoperation on joint.
‡Sepsis rate in control series/sepsis rate in ultraclean-air series.
§Weighted for contribution made to comparison by the two groups.

Table II shows the incidence of category 3 sepsis in relation to operating-room conditions. For the analysis of effects of ultraclean air the hospitals were divided into four groups, one of which (group 2) was separated into two subgroups. Group 1 comprised six hospitals where only conventional-pattern operating-room clothes were worn in ultraclean and control operating rooms. Group 2 comprised three hospitals (group 2a) in which body-exhaust suits were worn in the ultraclean-air operating rooms, and three (group 2b) in which Trexler plastic isolators were used. Group 3 comprised four hospitals where some operations in ultraclean rooms were done wearing conventional operating-room clothes and some wearing body-exhaust suits. Group 4 comprised three hospitals in which the Allander system of ventilation was used as the control environment and body-exhaust suits worn in the same operating rooms provided the ultraclean condition.

Table II gives the results as the proportions of operations that were followed by sepsis and as the ratio of sepsis rates after operations performed under control and ultraclean-air conditions. In each group the proportion of joint-replacement operations complicated by sepsis was greater in the control series than in the ultraclean-air series. When all the groups were taken together the sepsis rates were 63 out of 4133 (1·5%) in the control series and 23 out of 3922 (0·6%) in the ultraclean series; the sepsis ratio of control to ultraclean (2·6, 95% confidence limits 1·6-4·2) was highly significant ($p < 0·001$). When the operations at hospitals in groups 1 and 3 (done with conventional-pattern clothing in the ultraclean-air series) were taken together the ratio between the sepsis rates in the control and ultraclean-air series was 2·0 (95% confidence limits 1·1-3·6; $p < 0·02$). Combining the operations at hospitals in groups 2 and 3 (done with body-exhaust suits or in the Trexler isolator) gave a ratio of 4·5 (95% confidence limits 1·8-11·0; $p < 0·001$). The control to ultraclean-air ratio was consistently greater when body-exhaust suits or isolators were used, including those hospitals in group 3 where conventional-pattern clothing was also used for some operations. This provides valuable support for the additional benefit of special clothing or the isolator, since none of the comparisons between groups could be fully controlled. Too few operations were recorded in group 4 to show whether the incidence of sepsis in operating rooms using the Allander system of ventilation was reduced when body-exhaust suits were worn.

One hospital (in group 1) had a much higher sepsis rate than the others and a very high level of air contamination in the control condition; it accounted for nearly one-third of all the reported cases of sepsis. The variability of the sepsis rates in the different hospitals and the relation of these to air contamination will be discussed elsewhere. The analysis shows, however, that the effect of ultraclean-air conditions on the sepsis rate did not vary substantially among the different hospitals. When the figures for the hospital referred to are omitted from the overall comparison the sepsis rate in the control series becomes 42/3841 (1·1%) and that in the ultraclean-air series 16/3604 (0·4%). The ratio between the two is then 2·5 (95% confidence limits 1·4-5·1; $p < 0·001$), which is comparable to the 2·6 for the whole series. For the hospital referred to the ratio was 3·3.

The sepsis rate in patients who had had previous operations on the joint (8/732; 1·09%) was not significantly different from the rate (86/8055; 1·07%) for all patients in the trial. There was also little difference in the rate between patients with replacement hips (69/6781; 1·02%) and those with replacement knees (17/1274; 1·33%) ($p \approx 0·3$).

TABLE III—*Proportion of patients reoperated, and evidence of joint sepsis*

Category of evidence of joint sepsis	Control condition (4133 operations)	Ultraclean-air conditions (all systems; 3922 operations)	Ratio control: ultraclean
	No (%) reoperated	No (%) reoperated	
(1) No evidence of sepsis	119 (2·9)	122 (3·1)	0·9
(2) Some evidence of possible sepsis	20 (0·5)	21 (0·5)	0·9
(3) Septic or probably septic*	63 (1·5)	23 (0·6)	2·6

*As in table II.

JOINTS NOT SEPTIC AT REOPERATION

It is important to establish whether infection of the joint causes the failure of a prosthesis or whether infection is more likely to develop at the site of a prosthesis that has failed for some other reason. Table III shows that there was no difference between the ultraclean-air and control series in the proportion of prostheses that failed and showed no evidence of sepsis (category 1) on reoperation. Breakdown of the joint associated with infection was therefore presumptively due to infection. Table III also shows no difference in failure of prostheses between the ultraclean and control series when the records showed some evidence of possible sepsis (category 2). This seems to imply either that these joints were not, in fact, septic or that if they (or some of them) were septic the infection was not acquired from the air of the operating room.

TABLE IV—*Influence of prophylactic antibiotics on sepsis*

Operating conditions	Without antibiotics		With antibiotics		Ratio without:with antibiotics	p (95% confidence limits)
	No of operations*	No (%) septic†	No of operations*	No (%) septic†		
Control	1161	39 (3·4)	2968	24 (0·8)	4·2	<0·001
Ultraclean:						
Low	516	8 (1·6)	1279	9 (0·7)	2·2	0·1
Very low	544	5 (0·9)	1584	1 (0·06)	14·5	0·001
All ultraclean	1060	13 (1·2)	2863	10 (0·3)	3·5	<0·01
All groups	2221	52 (2·3)	5831	34 (0·6)	4·0	<0·001 (2·6–6·2)
Selected hospitals‡	1049	33 (3·2)	1129	14 (1·2)	2·5	<0·01 (1·4–4·8)

*For insertion of prosthesis.
†Sepsis (category 3) confirmed after reoperation on joint.
‡Five hospitals at which prophylactic antibiotics given to between 38% and 58% of patients.

There was a considerable difference in subsequent history between joints that were judged to be septic and those that were not. A complete revision operation was done on nearly 80% of the septic joints, and a replacement prosthesis was inserted in fewer than half of these. In contrast, when revision operations were done on joints judged not to be septic replacement prostheses were fitted to over 90%.

ANTIBIOTIC PROPHYLAXIS AND SEPSIS

The decision whether to give prophylactic antibiotics was made by the surgeon. They were given in over two-thirds of the operations for insertion of a prosthesis, and in over 80% of the operations the antibiotic was some form of penicillin, usually a β-lactamase-stable form such as flucloxacillin and often given parenterally in three or four doses started shortly before the operation and completed within 24 hours. Gentamicin-loaded cement was used in about 6% of operations. There were wide variations between hospitals in the use of antibiotics. At seven hospitals, with just under half of the operations recorded, antibiotics were used in more than 95% of operations, and at another three hospitals they were used in over 85%. In contrast, at four hospitals antibiotics were given for prophylaxis in fewer than one-fifth of the operations. At only five hospitals, with 27% of the operations, were antibiotics used in between 38% and 58% of the operations. Comparison between control and ultraclean-air series was not disturbed by these differences because the usage of antibiotics in the two conditions was closely similar within each hospital, and this similarity was apparent in respect of individual surgeons.

When the data for sepsis were analysed in relation to whether antibiotic prophylaxis, including antibiotic in the cement, was or was

not used (see table IV) the overall incidence of sepsis in patients given antibiotic prophylaxis was less than one-third of that in patients who did not receive such prophylaxis. Because patients were not allocated at random to an "antibiotic" or "no antibiotic" series the comparisons were not fully controlled. The "no antibiotic" data came predominantly from hospitals where antibiotic usage was low, and vice versa. A better comparison in this respect would be made for those hospitals in which prophylactic antibiotics were given to 38-58% of patients. This is given in table IV, which shows that the apparent effect of antibiotic prophylaxis in these hospitals was similar to the overall effect. Other forms of bias may be present—for example, more frequent antibiotic prophylaxis in patients considered more prone to infection. There was also a tendency for antibiotic usage to be highest in those hospitals with the lower air-contamination levels in the control series, which might exaggerate the benefits of antibiotic prophylaxis.

Discussion

These results are strong evidence that ultraclean air in operating rooms reduces the incidence of deep sepsis after total joint-replacement operations and that this reduction is enhanced when the operating teams wear whole-body exhaust suits. The similarity between the reductions in our trial and the findings of others[3] increases the confidence with which our conclusions can be accepted.

The results also substantiate the hypothesis of an airborne route of surgical infection, at least in some cases. In our study the hospital with the highest counts of airborne bacteria in conventionally ventilated operating rooms also yielded the highest incidence of postoperative joint sepsis in the control series; in that hospital, too, ultraclean ventilation of the operating room, without the use of body-exhaust suits by the surgical team, had a larger effect in reducing both the numbers of airborne bacteria and the incidence of joint sepsis than such ventilation was found to have in hospitals where less bacterial contamination was found in the air of the control operating rooms. The relation between airborne bacterial contamination and the incidence of postoperative joint sepsis will be discussed elsewhere.

Because of the formidable technical difficulties which this would entail we did not attempt to determine whether the strains of bacteria in the air of operating rooms at the time of operation were the same as those subsequently causing sepsis. Nevertheless, the species were similar, and the evidence therefore yields a statistical association consistent with what we know about the mechanism of infection. Moreover, in a substantial proportion of instances of infection with *Staph aureus* we have been able to identify carriers of similar strains of that organism who had been present at the original operation. These data will be reported separately.

This study was not set up to investigate the effect of prophylactic antibiotics, and comparisons between operations in which they were and were not used were not fully controlled. Nevertheless, the data suggest a substantial benefit from their use, with about four times as many incidents of sepsis in patients who had not received prophylactic antibiotics. This was closely similar to the results of a fully controlled study from France.[11] Table IV suggests that ultraclean air and antibiotic prophylaxis have independent and cumulative effects in preventing joint sepsis—for example, if ultraclean air causes a twofold reduction and antibiotic prophylaxis a fourfold reduction in sepsis rate, the two together will cause an eightfold reduction. The data are not precise enough to establish this beyond doubt, but the pattern of results is consistent with this interpretation.

The use of body-exhaust suits might protect the patient not only against airborne contamination (by reducing aerial dissemination of bacteria from the operating team) but also against contact contamination from the team; unlike conventional operating clothes, the small-pore-size textile of the body-exhaust suits was almost impenetrable to bacteria-carrying particles. Conventional-pattern gowns made of a fabric equally resistant to fluid penetration and airborne dispersal were worn at one hospital; these did not lead to the low levels of air contamination associated with the use of body-exhaust suits, nor was there any evidence that they reduced the incidence of sepsis. The plastic isolator interposed an even more complete barrier against contact contamination of the operation wound, but there were too few operations in the isolator series for comparison of the effectiveness of the isolator system with that of body-exhaust suits worn in ultraclean-air operating rooms. Nor could we estimate the sepsis rate that might be expected if infection by the airborne route could be completely eliminated. This must be very low and is probably beyond the reach of any practicable trial; the large numbers of operations in this study were only just adequate for its design purpose.

These results relate only to deep sepsis after operations for total hip or knee replacement, which expose large areas of tissue for a considerable time to possible contamination by bacteria in the air. The wounds, moreover, are clean, without appreciable risk of bacterial contamination from within the body, and the joint is susceptible to infection by many normal skin commensals and other bacteria usually regarded as of low pathogenicity; hence an infection that in other sites would usually be trivial may, in the prosthetic joint, cause serious sepsis. Whether our conclusions on the value of ultraclean air might have wider application in operative surgery will have to be critically assessed in relation to what is known about the risks of exogenous bacterial contamination and susceptibility to infection of other surgical procedures.

The data could not have been obtained without the collaboration of several-hundred surgeons, microbiologists, operating-room staff, recording nurses, and others; to all of these we and later patients who may benefit from their work owe a debt of gratitude. The participating hospitals were: Aberdeen Royal Infirmary; Academic Hospital, Uppsala; Bethnal Green Hospital, London; Chester City Hospital, Chester; Gartnavel General Hospital, Glasgow; Harlow Wood Orthopaedic Hospital, Nottingham; Huddinge Hospital, Stockholm; The London Hospital; Malmö General Hospital, Malmö; Northern General Hospital, Sheffield; Northwick Park Hospital, Harrow, Middlesex; The Nuffield Orthopaedic Centre, Oxford; The Princess Margaret Rose Orthopaedic Hospital, Edinburgh; The Royal Orthopaedic Hospital, Birmingham; The Royal Postgraduate Medical School, Hammersmith; The Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, Shropshire; St Thomas's Hospital, London; Stracathro Hospital, Brechin; and The University Hospital, Lund.

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