Clean air symposium—Part I

Prevention of operative infections

Harlan C. Amstutz, M.D.*

The axiom that prevention is the best treatment is especially applicable to infection in hip surgery. The discovery that a joint replacement has become deeply infected is a devastating experience for both patient and surgeon; this usually indicates an immediate or ultimate failure which necessitates surgical intervention and removal of the prosthesis. Despite improvement in sepsis rates, infection remains the major obstacle to achieving successful operative results and patient rehabilitation.

The main modes of surgical infection, direct, airborne, and endogenous, should be considered with relevance to existing preventive measures and controls. Whatever the mode, the immediate postoperative wound provides an excellent locus for development of infection.

Proposed solutions to this problem include: (1) preoperative evaluation to exclude all direct sources of infection and preparation of the local operative site; (2) the use of antistaphylococcal prophylactic antibiotics; (3) evaluation of methods of reducing or eliminating airborne bacteria at surgery; (4) stringent control and reduction of urological procedures, and control of other potential sources of bacteremias and septicemias; (5)

* *Department of Surgery, University of California, Los Angeles, California.*

early diagnosis and treatment of subcutaneous infection to prevent the involvement of the deep space.

Manifestations and symptoms of infections vary widely and depend on the degree of exposure to infecting organisms, their virulence, and susceptibility of the host, or altered by the degree of obesity or debility, the presence of diabetes or rheumatic arthritis, and steroid therapy.

Good surgical principles that are essential adjuncts of prevention and minimize tissue damage are: excision of devitalized tissue and elimination of dead space, control of hemorrhage, and lessening possible hematoma formation by the use of suction drainage.

Preoperative evaluation to exclude all direct sources of infection and preparation of the local operative site. To exclude preexisting local infection, fluid aspirated from all patients who have bone erosion or had previous operation should be cultured, especially when the prosthesis has failed. Total hip replacement is generally precluded if there is active or recent sepsis.

Once operation is undertaken, contamination of the wound can occur by direct contact from surgeons or from instruments and implants which are not sterile, as well as from the patient's skin. Gowns and drapes which are impermeable are desirable; double gloves should be used because it is common to tear a single glove with instruments or sharp splinters of bone. Methods of preparing and cleansing the operating room should be investigated carefully with involved personnel to insure that aseptic requirements are met.[1] The wound site should be shaved just before operation, so that cuts in the skin will not become areas of bacterial multiplication. The surgical field should be prepared with an iodine-containing compound, and walled off with paper drapes which are secured with adhesive, clear plastic sheets. To increase adherence of the drapes, the skin of the hip region is cleansed with alcohol and dried prior to application.

The use of antistaphylococcal prophylactic antibiotics. Experience accumulated from total hip replacements provides an excellent source for the study of immediate postoperative infections. The organisms isolated from the infections of a series of 100 McKee-Farrar replacements followed 3 to 5 years were five micrococci (staphylococcus coagulase negative), one each staphylococcus coagulase positive, gram positive cocci (identified by smear but not by culture), anaerobic micrococcus, *Escherichia coli,* Herellea species, and *Micrococcus tetragenes.*[2] In addition there was one reinfection with *Pseudomonas aeruginosa.* With the exception of the one acute infection (*Staphylococcus aureus*) the others were of the latent type, although all but one was diagnosed within the first year postoperatively. Any diagnosis of infection was vigorously pursued in this series of patients. Any who did not function as anticipated, or in whom pain persisted, underwent aspiration, and if the culture of the aspirant or irrigant was negative, aspiration was repeated.

Since most of the organisms encountered were sensitive to antistaphylococcal agents; methacillin was subsequently introduced as a prophylactic antibiotic.

Recently Wilson[3] reviewed the statistics on the series of the first 100 Charnley total hip replacements performed at Hospital for Special Surgery with a 2-year follow-up. All but 13 of the patients who underwent operations had the following regimen of prophylactic antibiotics: 1 g of oxacillin given intravenously every 4 to 6 hours, begun 12 hours before operation and continued postoperatively up to 4 days or more. Subsequently, 500 mg of dicloxacillin was given orally four or six times a day, as early as the third postoperative day if the patient could tolerate this medication. Patients with penicillin allergy received 1 g of sodium cephalothin (Keflin) or 500 mg of erythromycin every 6 hours through the fourth postoperative day instead of oxacillin. In addition, 500 to 1,000 cc of local triple antibiotic irrigant solution was used, consisting of 1% neomycin, 0.1% polymycin, and 500 μg/ml bacitracin in saline solution. There have been no infections to date in those patients who received the prophylactic antibiotics. Of the other 13 who did not receive antibiotics, deep infections developed in 2. Admittedly, the series is small and the follow-up is not as long as in the McKee series. Nevertheless, the surgical techniques in the McKee and Charnley groups were essentially the same with comparable blood loss and operating time.

The number of patients who had postoperative hematoma and wound drainage with or without positive cultures remained the same in both series, and we believe the differences were largely due to the prophylactic antistaphylococcal antibiotics. Apparently, potential contaminating airborne bacteria were killed or prevented from establishing an infection.

The results of postoperative infections in other series from Mayo Clinic[4] and New York Columbia Presbyterian[5] indicate that infection rates are close to 1% in patients treated with prophylactic antibiotics in conventional operating rooms.

Table. Organisms cultured from operating room

	Conventional	Directed	%
Micrococcus species	72.0	77.0	74.0
Diphtheroids	15.0	12.0	14.0
Bacillus species	3.9	5.0	4.3
Pseudomonas species	4.8	0.2	3.5
Nocardia species	0.9	1.0	0.9
Aspergillus species	0.36	2.0	0.9
Pseudomonas maltophilia	0.2	0.1	0.5
Pseudomonas multivorans	0.5	0.2	0.4
Montaspora species			
Penicillium species	0.6	0	0.4
Moraxella species	0.4	0	0.3
Candida species	0.3	0.4	0.3
Pseudomonas aeruginosa	0.3	0	0.2
Staphylococcus aureus	0	0.2	0.1
Escherichia coli	0	0.2	0.1

At the University of California at Los Angeles (UCLA), the first 167 total hip replacements were done in a conventional operating room using a similar prophylactic antibiotic regimen and local antibiotic irrigation. The types of organisms cultured on settle plates and slit and Anderson samplers from the wound site were predominantly sensitive to antistaphylococcal antibiotics (*Table*). Four deep infections occurred during an 8- to 28-month follow-up. All were gram-negative organisms of the type not found routinely in our operating room. The evidence suggests that the prophylactic antibiotics were effective against the airborne bacteria in our operating room. Although there are many factors involved in prevention of deep infections in any medical center, apparently the common denominator in these series is the use of prophylactic antistaphylococcal agents.[6] This has significantly reduced infections due to micrococcus and other organisms sensitive to these antibiotics.

The value of local antibiotic irrigant solutions has been widely debated. Recent reports indicate that local antibiotic solutions kill a variety of organisms, including those commonly found in the air of operating rooms when exposed for 60 seconds.[7] Based on these data, it is our present plan to continue to use both prophylactic systemic antistaphylococcal antibiotics[8] and local, triple antibiotic solutions.

Evaluation of methods of reducing or eliminating airborne bacteria at surgery. Airborne contamination may be reduced by a variety of measures. Many of these are simple and economical, such as keeping the size and movement of the surgical team to a minimum. This requires maximum preparation and preoperative planning. The fitness and health of this team is vitally important and a matter of individual integrity. Personnel with obvious infections should not be allowed in the operating room.

More controversial than antibiotics is the use of an operating room which utilizes a directed high velocity unidirectional sterile air flow. It is germaine to examine the efficacy of these systems. The commercially directed flow units available are of two types, horizontal and vertical. The horizontal system has the advantage of simplicity and low cost. Using this system for hip surgery, it is possible to keep the operating room team relatively out of the way of the flow. However, there is always some turbulence at the wound site with contamination due to exposed skin. With other types of surgery, such as knee replacement, there is more risk of contamination due to closer proximity of the surgeon's face to the wound and the difficulty of staying downwind. Lighting is not a serious problem, because the lights can be located away from the wound site and not influence air flow near the wound. With a vertical system, however, it is virtually impossible to keep exposed hair and skin out of the air flow. For this reason, either an aspirator or body exhaust system is necessary. This type of equipment makes communication more difficult and limits teaching. In addition, lighting remains a problem, particularly when using a lateral approach to the hip, with the patient on his side. To minimize turbulence and undesirable vortices, the lights must be positioned laterally. The lights, if small, may be upwind if they are adequately sterilized and at an adequate distance from the wound.

It is possible that unnecessary expense was incurred in present installations because highly efficient HEPA filter systems were used. These filter any particle larger than 0.3μ to 99.97% efficiency. If less efficient filter systems are used, considerable noise, air conditioning, and economic savings could be achieved. Evidence[9] suggests that particles of 4μ to 20μ may be necessary to transport viable organisms, and considerable reduction in cost might be effected by a less efficient system. The filters used by Charnley filter only 1μ to 2μ particles, and he has demonstrated a significant reduction in infection rates as a result of the introduction of a vertical laminar flow system without antibiotics.[10, 11] However, the reported reduction in postoperative sepsis from 9.0% to 3.1% is clouded by several other possibly significant changes in technique including the use of prophylactic anticoagulants, use of adhesive plastic film, introduction of double gloves, and a more secure method of fascial and subcutaneous closure. The most serious obstacle to finding the causal relationship of improved air and reduced infection rate may be the types of organisms cultured from the septic cases he has reported. There were 40% *S. aureus,* 12% sterile, 14% gram-negative, and only 5% micrococcus. If these infections were due to airborne contamination, then his original operating room must contain more of the high virulence organisms than ours.[12] However, it seems equally apparent that the direct or endogenous modes could be equally implicated. One other startling difference in the infections of the Charnley series as opposed to ours and others reported in this country is the high percentage of draining sinuses.[10] This has been an unusual finding in our series, indicating either higher virulence organisms or longer duration of infection, or both. In our experience low virulence organisms may cause pain, but drainage occurs late, if at all.

If in the Charnley series low virulence organisms are infrequent, then speciation data would be helpful in correlating airborne contamination with the infections.

Our studies at UCLA have shown a marked reduction in bacteria at the wound site in the laminar flow room. However, the types of organisms were the same except for near elimination of *Pseudomonas maltophilia* in the laminar room. This was believed due to isolation of the anesthesia equipment downwind. Although the microbiological situation is improved with the introduction of the laminar flow system, total elimination of infecting organisms is not achieved. Nelson et al[13] and Charnley[10] have shown a further reduction in organisms with the surgical team aspirator and full body exhaust systems. However, the elimination is not absolute and it is possible that prophylactic antibiotics may be a helpful adjunct.

Based on analysis of current data, it does not seem reasonable to perform total hip reconstruction surgery without the use of prophylactic antistaphylococcal antibiotics even in the laminar flow room, and if antibiotics effect virtual elimination of infectious organisms which directly contaminate the wound, then we must consider whether the use of high velocity flow is needed. However, if an addition of team aspirators and exhaust systems prove as effective or more effective than prophylactic antibiotics, then this will be a significant advance because there is always some morbidity or risk even with the use of relatively low toxic antistaphylococcal agents. It is also essential that the bacteriology in the operating room be monitored to ensure that the organisms cultured are sensitive to these antibiotics given. Charnley is one of the few now operating without prophylactic antibiotics and perhaps others will follow. However, comparative analysis of cases involved with different environment and techniques should be very carefully followed and analysed so that the importance of all factors may be assessed.

Stringent control and reduction of

urological procedures and control of other potential sources of bacteremias. Deep infections may result from a bacteremia or septicemia and localize in the postoperative wound or develop several months after surgery, indicating a blood-borne route. Analysis of infection rates at UCLA following total hip reconstruction and the types of infecting organisms indicated that three of four of the infections were caused by the same gram-negative organisms. In all four patients, urinary catheterization infections occurred in the postoperative period. The organisms cultured were the same as those first cultured from the wound infections implicating blood-borne infections. An acute or subacute infection with obvious bacteremia from organisms not generally found within the operating room is the clearest evidence of a blood-borne infection. To prevent bacteremias, a protocol which avoids instrumentation such as catheterization is advisable. If the patient requires catheterization, then he must be given a broad spectrum antibiotic such as sulfisoxazole (Gantrisin) or nitrofurantoin (Furadantin) followed by a course of gentamicin or ampicillin after catheter removal. Even after wound healing it is possible for organisms to seed in implant areas. The cardiovascular surgeons are acutely aware of this problem. This susceptibility to infection is possibly caused by foreign body response to the implant and may be influenced by the increase in surface area as small particles of debris from bearings accumulate. As a result prophylactic broad spectrum antibiotics should also be given before and after tooth extractions or other procedures.

Early diagnosis and treatment of subcutaneous infection to prevent involvement of deep space. Differentiation between superficial and deep infection is difficult. Usually, a subcutaneous infection has localized inflammation and drainage; the prognosis is good. This contrasts to the joint tenderness and positive aspiration of the deep infection with its very poor prognosis.

In treatment of early infections, rough guidelines exist in place of hard and fast rules. Wounds with hematoma formation and inflammation should be carefully followed, and those with drainage cultured. If the deep space is infected, it is recommended that the entire joint area be thoroughly debrided. We have apparently salvaged one deep infection by this method; however, the 9-month follow-up is admittedly short.

Summary

The many factors in prevention of postoperative sepsis have been reviewed. The interdependent nature of many, and the obvious complexity make it virtually impossible to assess any one factor. Analysis of infection rates must be examined and related to the preoperative local and general condition of the patient, the surgical technique including the use of local and systemic antibiotics and anticoagulants, the contamination to direct and airborne sources within the operating room environment, the effectiveness of measures to minimize bacteremias and the control of subcutaneous infections.

We recommend that surgeons periodically survey the types of organisms present in their operating rooms and use prophylactic systemic antibiotics which are effective against those or-

ganisms. There is also evidence to suggest that double or triple antibiotic solutions may be a helpful adjunct. Airborne bacteria are one source of wound contamination, and this contamination can be reduced with high velocity directed flow systems at the wound site. This concept is appealing but, even with surgical team aspirators and exhaust systems, the reduction is not absolute and its relationship to deep infections has not been proved. Justification of these flow systems must be based on either a lower sepsis rate when they are used alone or an even lower infection rate when a flow system is used as an adjunct to antibiotic therapy.

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