CHAPTER 9
PREOPERATIVE PATIENT PREPARATION

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ANTIMICROBIAL CHEMOPROPHYLAXIS IN CLEAN ORTHOPAEDIC SURGERY

Approximately 40 years have passed since the introduction of antibiotics into clinical use. During that period, there have been dramatic reductions in the incidence of and in the morbidity and mortality due to infectious diseases. However, despite irrefutable evidence of the benefits of antimicrobial therapy, debate continues as to the appropriate use of these agents in preventing postoperative infection.(43) A large number of articles have appeared in the medical literature exploring the prophylactic use of antibiotics in every area of medicine and surgery. It is astonishing that despite this volume of literature, there are few situations in which the use of prophylactic antibiotics is a matter of virtual universal agreement.

Investigations have demonstrated the widespread irrational use of antibiotics.(37,40,50)These reports are often accompanied by well-documented accounts of adverse and often grave effects on both individual patients as well as the populations in general.(2,17,36-38) The deleterious ramifications of indiscriminate antibiotic use upon microbial ecology are manifested each day in clinical practice. Nonetheless, veterinarians and physicians steadfastly continue to employ prophylactic antibiotics in situations in which there is ample evidence to document either lack of efficacy or even frankly harmful effects.(34,36)

When examining the literature regarding surgical chemoprophylaxis, it is important to inspect critically the information that is presented. For example, a large number of articles have demonstrated unequivocal benefits to the administration of chemoprophylactic agents with regard to decreased incidence of postoperative infection in various clinical settings.(3,6,15,19,20,21,25,31,39,45) However, close scrutiny of these reports frequently reveals that the incidence of infection in the control groups is unacceptably high.(43)

For years, most authorities have expounded the concept that in clean operations, wound infection rates should not exceed 5%.(43) In most reports of antibiotic prophylaxis in various types of soft tissue surgery in which the rate of infection in the control group is 5% or less, it is difficult to find an instance in which the rate is even less in the antibiotic-treated group. At this low level of infection, results in the control and treated groups generally do not differ significantly. Only when infection rates rise into higher ranges is it possible to demonstrate that giving antibiotics prophylactically will reduce them.(43)

In this context, orthopaedic surgery may differ from most categories of soft tissue surgery; the well-executed studies of Boyd,(9) Pavel,(33) Lidwell,(30) and others have demonstrated significant reduction of post-operative infection rates already as low as 5% or lower in clean orthopaedic procedures with the administration of prophylactic antibiotics.

There are several factors that may contribute to this difference between orthopaedic and soft tissue surgery. Among the most important and most discussed is the presence of the hematoma that invariably accompanies fracture in bone. This hematoma influences the pharmacokinetics of the antibiotic agents and may also affect the bacteriologic efficacy of the drugs.(7,13)

In addition to the consistent presence of the hematoma, orthopaedic procedures are frequently characterized by extensive dissection of deep tissues, local tissue necrosis due to prolonged retraction, considerable exposure of bleeding bone surfaces, and rather long duration. Such procedures fall into the category of "clean" surgery, but as the length of the surgical procedure increases to 2 to 3 hours, the risk of contamination and subsequent infection is increased.(18)

Another characteristic of orthopaedic surgery pertains to the implantation of foreign materials, whether internal fixation devices or prosthetic implants. Even if they are of biocompatible materials, all such foreign bodies decrease markedly the local tissue antibacterial capability.(24)

In these instances, although the infection rate is low, infection may become a seriously disabling and expensive complication when it occurs.(24)

Although most authorities currently believe strongly that prophylactic antibiotics should not be employed in clean soft tissue or general surgical procedures, the studies of Boyd, Pavel, and Lidwell referred to above support the contention that in clean orthopaedic surgery, an already low postoperative infection rate can be significantly reduced by thoughtfully employed chemoprophylaxis (8,30,33)

The principles of application of antibiotic prophylaxis do not differ substantially between orthopaedic and soft tissue surgery. There are several elements that must be considered in order to rationally employ the antibiotic agents in a prophylactic context.

Clearly one of the most important aspects of the rational use of antibiotics is identification of the microorganisms against

which the chemoprophylaxis is to be directed. Delineation of the pathogens most commonly incriminated in postoperative infection will influence the choice of antimicrobial agent and may help to elucidate sources of exogenous contamination. The importance of determining the most frequently involved bacteria is illustrated in a quote from Dr. Louis Weinstein of the Harvard Medical School, who wrote:

When a single effective drug is used to avoid implantation of a specific microorganism or to eradicate it immediately or shortly after it has become established, but not yet clinically evident, chemoprophylaxis is, with uncommon exception, highly successful. However, if the aim of prophylaxis is to prevent colonization and/or infection by any and all microorganisms that may be present in the patient's internal or external environment, failure is the ruler[51]

In this context it is well recognized that the microorganisms implicated in postoperative wound infection vary significantly from hospital to hospital and institution to institution. Therefore, the preparation of hospital antibiograms should be regarded as an integral component of rationally employed chemoprophylaxis.

With regard to acute postoperative osteomyelitis, in most veterinary institutions that have analyzed their postoperative orthopaedic infections, the most frequently isolated bacteria are penicillinase-producing staphylococci and streptococci.[11,22,23,42]

It has also been hypothesized that the penicillinase-producing staphylococci are more prevalent in infections that follow the open reduction and internal fixation of fractures than in osteomyelitis from other causes. Escherichia colt, Proteus spp., and Pseudomonas spp. are the most common gram-negative organisms isolated. Other organisms such as Pasteurella may be prominent in a given institutional setting In humans, gram-negative bone infections are associated with an altered environmental flora in exposed traumatic or postoperative wounds as a result of prophylactic antibiotic administration.[48] Such an association has not been demonstrated in veterinary medicine. Mixed infections are also common in osteomyelitis, apparently accounting for about 40% of clinical cases.[42] According to one study,[42] about one half of these, or 20% of the total, have both gram-positive and gram-negative organisms present.

The overall incidence of anaerobic bacteria in bone infections is essentially unknowns However, the prevalence of anaerobes has been estimated as approximately 10%.[9] The importance of adapting the chemoprophylactic regimen to the microbial ecology of a given nosocomial setting cannot be overemphasized. However, rational employment of the antimicrobial agents must be based upon the pharmacokinetic considerations as well as bacteriologic factors. Final decisions regarding employment of specific agents is difficult, complex, and necessarily subjective.

From a microbiologic standpoint, it is difficult to assess the relative importance of the various isolates with regard to their incidence. Also, in the frequent instances of mixed infections, the relative roles of the organisms involved are not understood. Accordingly, it is difficult to determine the necessity of inclusion of all microbes isolated in an institution within the spectrum of activity of the chemoprophylactic agent.

Some of these obscure concepts are illustrated in studies of chemoprophylaxis in gastrointestinal surgery in humans. The main intestinal anaerobe is Bacteroides fragilis. Experiments have shown that this organism and other anaerobes promote abscess formation after intestinal operations, but only in the presence of aerobic bacilli. Since the results of chemoprophylaxis do not differ significantly with the efficacy or lack of efficacy of the antimicrobial agent against B. fragilis, there is a growing belief that most anaerobic infections following gastrointestinal operations occur in synergism with infection due to aerobic bacteria. Thus, a favorable environment of low redox potential may be more important than the presence or absence of a specific anaerobicidal antibiotic.[29]

Other, less clear-cut, interactions between microorganisms are certain to occur in any mixed infection, although the consequences may not be so dramatic. However, such considerations of bacterial interactions in acute or chronic postoperative osteomyelitis are merely conjectural at this time.

These points are important because on theoretic grounds, the antibacterial agent chosen for routine prophylactic use should be of as narrow a spectrum of activity as possible, consistent with providing adequate antimicrobial protection. It is well known that use of the broader spectrum antibiotics is associated with increased risk of adverse effects such as suprainfection and the emergence of resistant bacterial strains. However, another related principle of antimicrobial prophylaxis that is of paramount importance in the avoidance of adverse sequelae is the tenet that the duration of administration of the prophylactic agents should be kept to a minimum. Strict adherence to this latter principle may serve to minimize the hazards associated with broader spectrum compounds.

Elegant experimental work demonstrated a short and early period of "decisive biochemical interaction" between the contaminating microorganisms and the host tissues, during which the developing primary bacterial lesion was susceptible to the action of parenterally administered antibiotics.[10] This susceptibility was maximal when the antibiotic was in the tissue when the bacteria arrived. The antibiotic effect decreased as the time between introduction of the bacteria and administration of the antibiotic increased. The major antibiotic effect proved to be over in approximately 1 hour, and the systemic antibiotics had no effect on primary bacterial infection if the bacteria creating the infection had been in the tissue longer than 3 hours before the antibiotics were given.[10]

At least three important concepts can be inferred from this experiment. The first is that under the circumstances of the experimental protocol, there would appear to be no 6- to 8-hour "golden period" when the tissue is free of infection after contamination.

The second concept dictates that prophylactic antibiotics be given at an appropriate interval prior to surgery such that there is a bacteriologically efficacious concentration of antibiotic within the interstitial fluid (ISF) throughout the period when the wound is vulnerable to primary bacterial lodgement at surgery. Historically, "prophylactic" antibiotics have frequently been

begun after operation, when the evidence shows clearly that the drugs have no effect. Such practice is still commonplace.

Finally, the evidence also indicates that it is not necessary to begin the administration of antibiotics as long as 24 hours before operation, which prolongs the duration of antibiotic administration unnecessarily, thus increasing the hazards of selection of resistant bacterial strains. (1,24,47) Instead, the length of time that a prophylactic antimicrobial should be given preoperatively should be dictated by the rate at which it reaches an effective concentration in ISF by the route of administration to be employed.(24)

Also, while it does not follow directly from the above cited work, there is no documented benefit associated with continuing antimicrobial prophylaxis for as long as 24 to 48 or 72 hours postoperatively. As stated above, the principle is to have an effective antibiotic concentration at the site of primary infection during the period of risk of bacterial contamination. Since nontraumatic surgical wounds are usually seeded when the wound is open during operation, the time of this bacterial contamination is easily predicted.(10)

One point of controversy may arise with respect to this last concept: the possibility of metastatic infection at implant sites in the postoperative period. Venous or arterial catheters, central venous pressure lines, urinary catheters, and intratracheal tubes remaining in place after surgery may provide open avenues for entrance of bacteria into the bloodstream. If a bacteremic situation should occur, there is a possibility of hematogenous contamination of orthopaedic implants and attendant infection. Therefore, some clinicians may prefer to continue antibiotic prophylaxis until such tubes and catheters are removed. However, the necessity of this practice is debatable. Other authorities have stated that there is no conclusive evidence to support the use of prophylactic antimicrobial agents beyond 3 to 6 hours after a surgical procedure(46)

The above discussion corroborates the earlier statements regarding the spectrum of activity of the antibacterial agents. The hazards associated with antimicrobial agents in general and with broadspectrum agents in particular increase with increased duration of treatment. With antibiotic regimens lasting for several days, 40% to 60% of intestinal isolates may become drug resistant in part, owing to infectiously spreading resistance factors.(17) Limiting the duration of antibiotic prophylaxis to an absolute minimum may negate some of the potential disadvantages of broad-spectrum agents and permit the clinician to direct chemoprophylaxis against a greater percentage of the organisms isolated at his institution, possibly including even sporadic isolates. It must be noted, however, that most of the questions raised above can not be answered definitively with presently available information. Thus, the final decisions continue to entail a subjective assessment of risk/benefit factors. In order to properly confront such quandaries, the clinician must arm himself with the best data currently available.

As mentioned earlier, the pharmacokinetic properties of the drugs themselves must also influence the selection of chemoprophylactic agents. There are considerable differences among the various antibiotics in the rate at which they reach peak levels in the interstitial or wound fluidsÑthe site of initiation of primary bacterial infection. Also, the respective magnitudes of these tissue peaks may vary significantly. The reasons for these marked differences in the distribution of the antimicrobial agents are complex and generally unclear. Fortunately, for veterinary surgeons, many of the pertinent investigations have been carried out using the dog as an experimental model.

The importance of considering these factors can be illustrated by examples drawn from human medicine. In humans, some controlled clinical trials have indicated that cephalothin sodium may not be effective in a prophylactic context, whereas cephaloridine and cefazolin have been beneficial.(35) In a prospective study designed to examine these findings, Polk discovered that cefazolin and cephaloridine both achieved and maintained, for a period reasonable for the completion of major abdominal procedures, wound antibiotic levels exceeding the minimal inhibitor concentrations (MICs) for all bacteria ordinarily thought to be within their spectrum. Cephalothin, on the other hand, attained, but did not maintain, wound fluid levels consistent with effective antimicrobial activity, even in dosages twice those used for the other agents. This pattern did not suggest a reasonable likelihood of protection in any operation lasting more than one hour.(35) Other experimental investigations have both confirmed and denied these findings.

Despite Polk's study and at least four other articles demonstrating failure of prophylaxis with cephalothin (for whatever reason), Burke reported that cephalothin was used for prophylaxis ten times more frequently than the other two agents used in that study.(10) Such findings further emphasize the need for careful deliberation in the choice of antimicrobial compounds.

It has already been repeatedly emphasized that the basic tenet of successful chemoprophylaxis is to attain an effective concentration of an appropriate antibiotic within the interstitial fluid at or within a short time of the occasion of primary bacterial lodgement. Therapeutic concentrations of the antibacterial agent must also be present in the interstitial spaces throughout the duration of risk of bacterial infection. The appropriateness of the drug to be used is dependent upon microbiologic as wed as pharmacologic parameters. However, once these factors have been suitably addressed, additional variables may also influence the attainment of the above goal. Both the dose of the drug given and the route of administration have significant effects upon the ISF antibiotic concentration.

Basically, the distribution of antibiotic between the plasma and the wound or ISF appears to be a passive process of simple diffusion along a concentration gradient that is established across a poorly permeable or semipermeable barrier. Experimental work has demonstrated that the peak ISF concentration is consistently substantially lower than the peak concentration in serum.(12,49) It is clear that since the transfer of drug from serum to tissue fluids is regulated by passive diffusion, the magnitude of the initial serum peak exerts a profound influence upon the concentration gradient and subsequently the ISF concentration. The initial plasma levels must be high in order to obtain high concentrations in the surgical wound.

For a given drug, the dose and the route of administration are the most easily controlled factors influencing the peak serum concentration. The antibiotic concentrations in serum ISF demonstrate the same time-concentration response regardless of the dose given. Thus, doubling, tripling, or quadrupling the dose commonly administered has been shown to be an effective

means of rapidly achieving high ISF concentrations.(49) However, such practice may increase the amount of toxic reactions to the drugs, increase the amount of antibiotic released into the environment, and significantly increase the cost of antimicrobial therapy. Additionally, the lower doses of drugs currently employed seem to be effective when administered properly.

Therefore, a more practical and clinically useful method of ensuring therapeutic levels is to administer the antibacterial by a route that guarantees rapid attainment of high plasma peaks. The problem of assessing the influence of route of administration on wound fluid concentration of prophylactically administered antibiotics has been addressed in a study designed to examine the effects of intravenous (IV) bolus, intramuscular (IM) bolus and continuous IV administration.' The IV bolus route yields high peak plasma levels instantaneously. Therefore, the antibiotics appear more promptly in effective concentrations in tissue fluid when first administered by this route. However, because of more rapid excretion, administration by IV bolus generally results in less sustained serum concentrations than when the agent is first administered by the IM route. Accordingly, antibiotic administration by IM injection generally demonstrates greater duration of effective concentrations in the ISF, since a concentration gradient forcing antibiotic into the tissue compartment persists for a longer period of time. When a similar dose of antimicrobial is given by continuous IV infusion, peak levels are often not achieved in the wound fluid until after 18 hours and the fluid usually lags considerably behind the 3-hour period considered to be maximal if the drug is to be effective in preventing the development of wound infection after contamination. (1) The recommendation has therefore been made that prophylactic antibiotic administration be carried out by simultaneous administration of the therapeutic doses given IM and IV at the time of induction of anesthesia, or approximately 15 to 30 minutes prior to the start of operation.

Initial antibiotic administration for prophylactic purposes by the oral route is not satisfactory for a number of reasons. Most importantly is that low plasma levels, and therefore, low wound fluid levels, are consistently produced. In the dog, the same dose of ampicillin given orally results in only 20% of the peak plasma levels as when given IM.(14) Additionally, absorption from the gastrointestinal tract may be erratic and unpredictable, and a more prolonged duration of administration is required for attainment of effective tissue concentrations.

The duration of protection produced by the above protocol win obviously vary with the antibiotic chosen. Reliable experimental data documenting tissue levels of drugs after the simultaneous administration of IV and IM doses are available. However, based upon the many considerations discussed above, two alternate protocols of prophylaxis can be suggested:

Cefazolin sodiumÑ20 mg/kg IV and 20 mg/kg IM
Oxacillin sodiumÑ20 mg/kg IV and 20 mg/kg IM
Adoption of one of these protocols or development of an alternate regimen must be based upon analysis of one's own microbiologic data.

By inference and extrapolation, but not by experimental determination, either of the above protocols should provide effective ISF concentrations and therefore effective protection against microorganisms within their activity spectrum for a minimum of 3 to 4 hours. If the surgical procedure is longer than 3 to 4 hours, additional IV boluses will provide protection for at least 2 hours for oxacillin and 3.5 hours in the case of cefazolin.

A detailed discussion of the suitability or unsuitability of the many antimicrobials is beyond the scope of this chapter. However, information concerning serum, wound fluid levels, and other pharmacologic properties is available for most of the antibiotics in popular use. Hopefully, information has been presented here that will be helpful to the veterinary clinician in evaluation of this data and therefore in arriving at well-informed and valid conclusions regarding the use of prophylactic antibiotics.

IMMEDIATE PREOPERATIVE CONSIDERATIONS
Several rather important considerations eventuate as the animal is brought to the surgery-preparation area, placed under anesthesia, clipped, moved to the operating theater, and finally prepared for surgery. Many of these details seem so automatic and mundane that sufficient attention may not be given to their theory and execution. However, such factors as the positioning of the animal on the operating table, preoperative skin preparation, and draping techniques may contribute markedly to the comfort and convenience of the surgeon as well as to the incidence of such complications as postoperative wound infection.

A fundamental point that has not been mentioned previously is that food should be withheld from the animal for at least 6 hours prior to anesthesia. If the patient has eaten within the preceding 6 hours, vomiting is more common and the attendant risk of aspiration pneumonia is increased.

Once the animal has reached a depth of anesthesia that is sufficient to permit manipulation, the hair is removed from the surgical site. The most practical method of removing hair is by cutting with the surgical blade of an electric clipper. Such removal of hair must take place outside the surgical suite proper so that loose hairs are not introduced into this environment.

In general, a very liberal area of the animal is clipped. For surgical procedures involving an extremity such as cruciate ligament reconstruction or long-bone fractures, an entire quarter of the patient is clipped, extending from just above the pads of the feet to approximately the dorsal midline.

For any fracture repair, at least one donor site for cancerous bone grafting should be prepared. Suitable sites include the ipsilateral iliac crest and wing, proximal tibia, proximal humerus and greater trochanter of the femur; and the contralateral ilium. Again, these sites should have the hair removed over a broad enough area that ready access can be achieved without compromising the asepsis of the procedure.

For surgery on the thoracolumbar vertebral column, the hair is removed from the scapulae to the wings of the ilium, and approximately one half of the distance from dorsal to ventral midline on the thorax and abdomen, bilaterally. Similarly extensive areas are prepared for other surgical sites.

The initial clipping should be done with a coarse blade such as a No. 10, followed by a final clip with a No. 40 clipper blade. The clippers should be well maintained and well lubricated.

Final hair removal by shaving the animal with a safety razor or straight razor is generally not necessary.The additional benefit gained by removing the fine stubble remaining after thorough clipping is possibly outweighed by the microtrauma to the animal's skin. The abrasions and scratches that commonly accompany shaving may become infected during the first few postoperative days and could thus result in increased numbers of microorganisms in the perioperative area.

Similarly, chemical depilatories are not generally necessary to effect adequate hair removal. They may, however, be useful in regions such as the hock where bony protuberances and recesses make clipping difficult. Such agents are additionally quite irritating to the skin of many animals, which contraindicates their routine use. Cats appear particularly susceptible to the irritant properties of the chemical depilatories.

Once the removal of hair is completed, the animal and the litter upon which it is to be moved into the operating room are thoroughly cleaned of all loose hair with the aid of a vacuum cleaner.

The foot and foot pads are then covered with an impermeable material, since these areas are difficult to clean; this practice should substantially reduce contamination of the surgical field by microorganisms on the foot. A simple means to accomplish this is by use of clean surgical gloves or latex examination gloves that are securely taped to the foot with waterproof or adhesive tape.

The initial skin preparation should also be carried out in the preparation area, although it is common for the animal to first be moved into the operating room, positioned for surgery, and then subjected to the initial skin preparation.

This skin preparation is performed in order to remove as much dirt and bacterial flora as possible. Many bacteria are contained in dirt particles and thus are physically removed by washing. The clipped area is washed with germicidal soap and water for 5 to 10 minutes. The two most commonly used products are hexachlorophene and povidone-iodine in a synthetic detergent vehicle. The purpose is to combine the action of the soap or detergent, which removes all transient and some resident organisms, with the action of the antiseptic, which kills remaining organisms. Although it is considered important that this scrub possess residual antibacterial activity so that microorganisms rising to the skin surface with sebum flow will be inhibited, generous lathering and frequent rinsing may be more important than the bactericidal effect of the cleansing materials.(4,26)

The scrubbing is performed in a circular manner starting at the incision site and progressing toward the periphery. Once a given sponge or brush is used in this fashion, it should not be permitted to again contact the incision area.

For surgery upon the extremities, the limb is suspended from an IV fluid stand or other support throughout the course of this preparation so that 360¡ of the leg can be clipped, scrubbed, and prepared. This position is maintained through the total course of patient preparation such that the limb can also be draped free, permitting full manipulation of the appendage at surgery and access to all surfaces of the limb.

Once the initial scrubbing of the operative site is completed, the animal is transported into the operating room and the preparation is completed. If the residue from the first scrub has been left on during transport, it is wiped away and another surgical scrub is performed. Similarly, if contamination during transport and positioning is suspected, the operative site should be rescrubbed. (26)

Positioning of the patient is critical. In many operative procedures, improper positioning of an animal can have major adverse effects upon the attitude of the surgeon and can therefore have detrimental consequences on the course of the operation. For example, in many types of vertebral surgery such as thoracolumbar laminectomy or fenestration, ventral cervical decompression or fenestration, vertebral fractures, or surgery of the lumbosacral space, an animal that is rotated to either side only a few degrees or whose vertebral column is bent in inappropriate fashion by improperly placed sandbags or other supports can provide an extremely frustrating and unrewarding experience. Similarly, in the repair of complex fractures of the elbow, it has been suggested that the animal be placed in dorsal recumbency with the affected limb extended rostrally in order to provide access to both medial and lateral compartments of the joint. (16) However, it must be remembered that, since the days of freshman anatomy, the surgeon has in all likelihood approached this joint upon a laterally recumbent animal and by a lateral approach. The comfort and security associated with the familiar anatomical approach will generally more than compensate for the minor lack of medial compartment access that the lateral approach affords.

After positioning of the patient has been accomplished and the initial surgical scrub completed, the final step in preparation of the patient's skin is performed. This consists of the application of an effective germicide. Ideally, this product should be fat-soluble to provide greater skin penetration.(26) The solutions used most commonly are 70% alcohol and 1% iodine tincture in 70% alcohol. Quaternary ammonium compounds such as benzalkonium chloride may also be used, but these products may cause oral ulcerative lesions in animals that later lick the operative site, particularly cats.

Iodine tincture is a fast, effective antiseptic that destroys virtually all organisms present within 20 seconds. Skin sensitivity may occur with iodine tincture, and some surgeons therefore prefer to remove excess iodine tincture with 70% alcohol. Care should be exerted to avoid application of 1% tincture of iodine to the scrotum of dogs or to the ocular conjunction or cornea of any animal.

Bacteriologic studies have established that an antiseptic solution applied as a spray is less effective than the same agent applied with friction.26 Therefore, this final skin preparation is carried out as the step immediately preceding the draping of the animal; the antiseptic is "painted" on by the surgeon, who is wearing sterile gown and gloves and using sterile gauze sponges and sponge forceps.

DRAPING OF THE OPERATIVE SITE

Surgical drapes and gowns are intended to serve as barriers against the transgression of bacteria between the unsterile surface that they cover and the sterile surgical field, whether or not they become wet during an operations Since the introduction of drapes, the "standard" gown and drape material has been 140-thread count cloth (140 threads per inch) composed of either muslin or of a combination of 65% Dacron polyester, 34% cotton, and 1% metal. Thirty years ago it was shown that when such materials become wet, all layers of the cloth instantly become sieves to the moist strike-through of bacteria. Under these circumstances, bacteria are able to travel freely through the material in both directions. Moreover, this penetration will proceed through as many layers of material as liquid can traverse. Therefore, the piling of one layer on another is futile.(5)
Dry penetration may also occur by the rubbing-through of particulate matter, but the most severe hazard clearly accompanies the contribution of moisture as an aid to microbial penetration.

Admittedly, much benefit may be realized by the mere recognition that a wet drape is a contaminated drape. However, modern manufacturers have introduced a wide array of both woven and nonwoven, reusable and disposable surgical materials designed to serve as barriers against moist bacterial strike-through. Despite manufacturer's claims of the superiority of various materials, correlation of laboratory testing methods with in-use conditions, as well as standardization and demonstration of adequacy of testing protocols, have been lacking.

Both woven and nonwoven barrier materials have been found to vary greatly in their ability to protect against moist strike-through. The woven, reusable products are made of various grades and weaves of cotton with or without special waterproofing treatments. As a result, they range from those that offer no resistance to moist strike-through to those that remain totally resistant for up to 100 washing and sterilization cycles.(26) For woven materials, a waterproofing process such as that developed by the US Army Quartermaster's Corps and termed "Quarpel" has been shown to be more critical than the tightness of the weave.(28) However, the performance and durability of Quarpel are partly contingent upon the quality and weave of the material to which it is applied. It is not effective if applied to loose 140-type muslin. The more tightly woven 270-thread count cotton cloth gowns or drapes treated with Quarpel have been proven impermeable to bacterial solutions for at least 55 washing-sterilizing cycles. The Quarpel treatment is a fluorochemical finish in combination with a pyridinium or melamine hydrophobe that permeates every fiber, rather than coating the surface.(28) The number of washsterilize cycles to which these materials can be subjected varies among reports but can be assumed to be between 55 and 100 cycles. A potential problem associated with the use of these drapes is that the ability to withstand moist strike-through is lost before the material appears worn. Therefore, a system must be devised to tabulate laundering cycles.

A multitude of nonwoven single-use disposable products are also available. Among these are spunbonded olefin, fiber-reinforced tissue, spunbonded polyethylene, and spunlaced wood pulp-polyester materials. These products exhibit great variability in their ability to prevent bacterial contamination. Nonwoven materials manufactured as plastic-treated fabric without a reinforcing layer have been shown to be variably repellent, permitting moist bacterial strike-through in some tests but not in others.(27) These materials must be combined or reinforced with a polymeric plastic film to be consistently resistant to moist microbial penetration.

However, the disposable materials were determined in one human hospital study to cost approximately four times as much per year as reusable drapes and gowns of 270-count waterproofed pima cotton. Thus, cost factors are in favor of the reusable product, which has also been shown to be an effective barriers However, this study assumed 100 uses per gown, which may not be a realistic figure. Even with that precaution in interpretation of the results in mind, the reusable products still appear to be substantially cheaper than their disposable counterparts. If by using disposable drapes, the salary of a full-time laundry person can be saved, the financial considerations may be much more favorable for disposable drapes.

It must also be remembered that the towel clip used by most surgeons to hold drapes in place will destroy any barrier. Good solutions to this problem are not readily apparent. Many of the disposable nonwoven drapes incorporate adhesive strips that may be adequate to circumvent this concern, although proper application of such drapes may be difficult. Adhesive plastic "incise" drapes can also be used to hold other drapes in place and will render the most inefficient barrier impermeable in the area of their application. However, separation of the incise drape from reusable cloth drapes after operation can be troublesome.

At first glance, the routine use of such impermeable adhesive plastic incise drapes would appear to offer an easy solution to the barrier problem as well as to other issues in draping. However, despite their broad use in human surgery, these products have not met with widespread acceptance in veterinary medicine. They do not seem to adhere particularly well to the skin of animals, especially on irregular surfaces, and therefore often lift up near the incision site because of movement and blood. Also "sweating" has been reported to occur beneath these drapes, and thus fluid containing microorganisms may flow into the wound. Despite these points, some surgeons prefer the incise drapes for vertebral surgery, where there is a relatively broad flat surface. In these procedures, though, standard skin towels are easily and effectively applied after incision of the skin and superficial subcutaneous tissue. Plastic adhesive drapes are also useful for surgery performed on or near the feet, where standard draping techniques are difficult. An additional advantage of these drapes is that for fractures, arthrodeses, or other procedures in which proper orientation of the foot is critical, they enable direct visualization of the foot, thus decreasing opportunity for error.

Several basic principles apply to all operative draping. Initially as much of the animal as possible is covered. This should routinely include all of the animal except the surgical site, as well as the operating table. The surface of the drape to be

uppermost should at no time be allowed to contact the skin surface, hair coat, or table. Similarly a surface of drape that has contacted these areas must not subsequently be allowed to become exposed to the surgical field. This latter problem commonly occurs when an anesthetist folds back the most cranial extent of the drape in order to facilitate observation of the animal. At that time the undersurface of the drape, which has contacted the operating table, may be reflected into the surgical area. While this may not be of much consequence when operating upon the stifle of a German shepherd, it may be of major importance when performing surgery on the elbow of a Maltese. This problem can be easily avoided by having the anesthetist attach the leading edges of the most cranial drape to the upright poles of IV fluid stands or to an easily constructed aluminum frame so that the animal is accessible to anesthetic monitoring but contamination of the surgical field is avoided. The drape should be attached to the support via nonpenetrating clamps or adhesive tape. A major secondary benefit of making such practice routine is that the surgeon is freed to concentrate upon the operation at hand rather than devoting his attention to possible contamination from the front of the surgical field.

The initial coverage of the animal and table can be accomplished via standard four-quadrant draping according to the surgeon's preference. During this initial draping, a remote donor site for cancerous grafting is generally covered with a laparotomy drape to permit later access if necessary. For surgery upon the axial skeleton, this four-quadrant draping is completed, the drapes secured, and the incision performed without the hands of the surgeon contacting the skin of the animal. If plastic incise drapes are not used, impermeable skin towels are then applied with care taken to ensure that the upper surfaces of these towels do not contact the skin during their application.

The procedure for draping a limb for appendicular surgery is considerably more complex. As mentioned previously, the limb is suspended throughout the course of skin preparation. This is accomplished with nylon cord or adhesive tape. Once the final skin preparation is completed, the limb is released from the support and held by the foot by an operating room technician. The foot is then grasped by the surgeon through a sterile hand towel such that only the inner surface of the towel is permitted to contact nonsterile surfaces. The towel is secured with a small Backhaus towel clamp or similar device. The clamp, towel, and limb are then covered with a sterile orthopaedic stockinette and the stockinette is rolled proximally to cover the limb. The large drape that will lie beneath the limb is then positioned by the assistant surgeon, the stockinette-covered limb is allowed to rest upon this drape, and the remaining drapes of the fourquadrant system are applied. If a scrubbed assistant is not present, the first of the large drapes is positioned while the operating room technician is holding the limb. After both stockinette and four-quadrant drapes are in place, the stockinette is secured to the other drapes, thus isolating the limb within the sterile dressing to allow full manipulation of the appendage during surgery. The distal end of the stockinette may be knotted, tied with gauze, or secured with a towel clamp to prevent the foot and foot towel from protruding through the stockinette during the course of the operation.

Although the procedure just described is standard practice in many institutions, the employment of the orthopaedic stockinette as the only layer between the limb and the hands of the operating team in some institutions represents a major "weak-link" in the efforts to achieve surgical asepsis. Stockinette materials act as wicks and allow immediate wet bacterial penetration whether applied in single or double layer. Indeed, the stockinette is most often saturated during its application by the solution used for the final skin preparation. Generally, the stockinette is then cut with scissors in the area of the incision, the incision made, and the stockinette sewn to the subcutaneous tissues. This is an essentially ludicrous attempt to prevent contamination from the skin entering the wound. The application of skin towels to the wound margins may be somewhat superior in this regard, but only if the other areas of the stockinette not covered by these towels have not and do not become wet during the procedure. However, in fracture repair, skin towels that obscure the limb may contribute to a lack of orientation to the regional anatomy, particularly for relatively inexperienced surgeons.

Two solutions to this problem seem possible. The first is to proceed as outlined above, but after the stockinette is cut, to encircle the limb with a plastic incise drape that is firmly adhered to the skin in the area of the incision. Again, bacteriologic efficacy of this technique is contingent upon preventing moist contamination of the stockinette that is not covered by the adhesive drape. Such a contingency is not likely to be fulfilled.

Secondly, impermeable stockinette is now available. This stockinette is a coarser and less pliable material compared with the orthopaedic stockinette in common use, but such a concept offers the most promise for permitting complete manipulation of the limb in concert with the best attempt at surgical asepsis.

REFERENCES

1. Alexander JW, Alexander NS: The influence of route of administration on wound fluid concentration of prophylactic antibiotics. J. Trauma 16:488, 1976
2. Altemeier WA: Surgical infections: Incisional wounds. In Bennett JV, Brachman PS (eds): Hospital Infections. Boston, Little, Brown & Co, 1979
3. Andersen, B. Korner B. Ostergaard AH: Topical ampicillin against wound infection after colorectal surgery. Ann Surg 176:129, 1972
4. Archibald J. Blakely CL: Preoperative Preparation. In Archibald J (ed): Canine Surgery, 2nd ed. Santa Barbara, Animal Veterinary Publications, 1974
5. Beck WC: Aseptic barriers in surgery. Arch Surg 116:240, 1981
6. Bernard HR, Cole WR: The prophylaxis of surgical infection: The effect of prophylactic antimicrobial drugs on the incidence of infection following potentially contaminated operations. Surgery 56: 151,1964
7. Bowers WH, Wilson FC, Green WB: Antibiotic prophylaxis in experimental bone infections. J Bone Joint Surg 55A:795, 1973

8. Boyd RJ, Burke JF, Colton J: A double-blind clinical trial of prophylactic antibiotics in hip fractures. J Bone Joint Surg 55A:1251, 1973

9. Braden TD: Diagnosis and treatment of osteomyelitis. Presented at the Fourth Annual Advanced Course: Internal Fixation of Fractures, Non-unions and Reconstructive Surgery in Small Animals. The Ohio State University, March 1981

10. Burke JF: The effective period of preventive antibiotic action in experimental incisions and dermal lesions. Surgery J 50: 161, 1961

11. Caywood DD, Walace LJ, Braden TD: Osteomyelitis in the dog: A review of 67 cases. J Am Vet Med Assoc, 172:943, 1978

12. Chisholm GD, Waterworth PM, Calnan JS et al: Concentration of antibiotic agents in interstitial tissue fluid. Br Med J 1:569, 1973

13. Clark CH: Prophylactic use of antibiotics. Mod Vet Pract Feb 1980, p 122

14. Clark CH: Use of antibiotics in wounds. Mod Vet Pract April 1980, p 307

15. Donovan IA, Ellis D, Gatehouse D et al: One-dose antibiotic prophylaxis against wound infection after appendectomy: A randomized trial of clindamycin, cefazolin sodium and a placebo. Br J Surg 66:193, 1979

16. Dueland RJ: Triceps tenotomy approach for distal fractures of the canine humerus. J Am Vet Med Assoc 165:82, 1974

17. Eickhoff TC: Antibiotics and nosocomial infections. In Bennett JV, Brachman PS: Hospital Infections. Boston, Little, Brown & Co, 1979

18. Fogelberg EV, Zitzmann EK, Stinchfield PE: Prophylactic penicillin in orthopedic surgery. J Bone Joint Surg 52A:95, 1970

19. Fullen W. Hunt J. Altemeier WA: Prophylactic antibiotics in penetrating wounds of the abdomen. J Trauma 12:282, 1972

20. Giercksky K, Fuglesang J. Christiansen E et al: Short term chemotherapeutic prophylaxis in gastrointestinal operations. Surg Gynecol Obstet 151:349, 1980

21. Griffiths DA, Shonley BA, Simpson RA et al: Single dose preoperative antibiotic prophylaxis in gastrointestinal surgery. Lancet 2:325, 1976 Preoperative Patient Preparation

22. Griffiths GL, Bellenger CR: A retrospective study of osteomyelitis in dogs and cats. Aust Vet J 55:587, 1979

23. Hirsch DC, Smith JM: Osteomyelitis in the dog: Microorganisms isolated and susceptibility to antimicrobial agents. J Small Anim Pract 19:179, 1978

24. Hunt JK, Alexander JW, Burke JF et al: Antibiotics in surgery. Arch Surg. 110:148, 1975

25. Keithley MRB, Baddley RM, Burdon DW et al: A controlled trial of parenteral prophylactic gentamicin therapy in biliary surgery. Br J Surg 62:275, 1975

26. Knecht CD, Welser JR et al: Fundamental Techniques in Veterinary Surgery. Philadelphia, WB Saunders, 1975

27. Laufman H. Montefusco C, Siegal JD et al: Scanning electron microscopy of moist bacterial strike-through of surgical materials. Surg Gynecol Obstet 150: 165, 1980

28. Laufman H. Siegal JD, Eddberg SC: Moist bacterial strike-through of surgical materials: Confirmatory tests. Ann Surg 189:68, 1979

29. Lewis RT: Advances in antibiotic prophylaxis in gastrointestinal surgery. CMA, 121:265, 1979

30. Lidwell OM: Infection following orthopedic surgery in conventional and uni-directional air flow operating theatres: The results of a prospective randomized study. Presented at the 49th Annual Meeting, American Academy of Orthopaedic Surgeons, Jan 1982, New Orleans, LA

31. Longland CJ, Gray JG, Lees W et al: The prevention of infection in appendectomy wounds. Br J Surg 58:117, 1971

32. Paul JW, Gordon MA: Efficacy of a chlorhexidine surgical scrub compared to that of hexachlorophene and povidone iodine. VM/SAC, May 1978, 573

33. Pavel A, Smith RL, Ballard et al: Prophylactic antibiotics in clean orthopedic surgery. J Bone Joint Surg 56A:77, 1974

34. Petersdorf RG, Curtin JA et al: A study of antibiotic prophylaxis in unconscious patients. N Engl J Med 257:1001, 1957

35. Polk HC, Trachtenberg L, Finn MP: Antibiotic activity in surgical incisions. JAMA 244:1353, 1980

36. Price DJE, Sleigh JD: Control of infection due to KCebsieCla aerogenes in a neurosurgical unit by withdrawal of all antibiotics. Lancet, Dec 1970, p 1213

37. Roberts AW, Visconti JA: The rational and irrational use of systemic antimicrobial drugs. Am J Hosp Pharm 29:228, 1968

38. Rose HD, Schrier J: The effect of hospitalization and antibiotic therapy on the gram-negative fecal flora. Am J Med Surg 255:228, 1968.

39. Rowlands BJ, Clark RG, Richards DG: Single-dose intra-operative antibiotic prophylaxis in emergency abdominal surgery. Arch Surg 117:195, 1982

40. Scheckler WE, Bennett JV: Antibiotic usage in seven community hospitals. JAMA 213:164, 1970

41. Schwartz JT, Saunders DE: Microbial penetration of surgical gown materials. Surg Gynecol Obstet 150:507, 1980

42. Smith CW, Schiller AG, Smith AR et al: Osteomyelitis 176 Operative Considerations in Orthopaedic Surgery in the dog: A retrospective study. J Am Anim Hosp Assoc 14:589, 1978

43. Spievack AR: The prophylactic antibiotic puzzle. Surg Gynecol Obstet 148:922, 1979

44. Stone HH, Harper CA, Kolb LD et al: Antibiotic prophylaxis in gastric binary and colonic surgery. Ann Surg 184:443, 1976

45. Stone HH, Hester JR Jr: Incisional and peritoneal infection after emergency celiotomy. Ann Surg 177:669, 1973

46. Van Scoy RE: Prophylactic use of antimicrobial agents. Mayo Clin Proc 52:701, 1977

47. Veterans Ad Hoc Interdisciplinary Advisory Com mittee on Antimicrobial Drug Usage: I Prophylaxis in surgery. JAMA 237: 1003, 1977

48. Waldvogel FH, Vasey H: Osteomyelitis: The past decade. N Engl J Med 303:360, 1980

49. Waterman NG, Kastan LB: Interstitial fluid and serum antibiotic concentrations. Arch Surg 105: 192, 1972

50. Weiner JP, Gibson G. Munster AM: Use of prophylactic antibiotics in surgical procedures: Peer review guidelines as a method for quality assurance. Am J Surg 139:348, 1980

51. Weinstein L: The complications of antibiotic therapy. Bull NY Acad Med 31:500, 1954