Infection in the Upper Body: Hand and Burn-Wound Microbiology and Considerations for Antimicrobial Therapy

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Gram-positive bacteria are the predominant organisms in hand infection and in burn wounds of the upper extremities. In a recent study of isolates from patients who were treated at our institution, *Staphylococcus aureus* and β-hemolytic *Streptococcus* group A organisms were the most common organisms in infection of the hand; they were found in 36.3% and 14.4% of cases, respectively. The most common organisms in burn wounds were *Enterococcus* species, *S. aureus*, and *Escherichia coli*, which were found in 21.2%, 20.5%, and 16.7% of patients, respectively. Between 1969 and 1989, the prevalence of *Pseudomonas* species in burns decreased markedly, whereas that of *S. aureus* remained relatively stable and that of *Enterococcus* increased substantially. Over this period, both enterococci and coagulase-negative staphylococci emerged as troublesome pathogens in patients with burns. Methicillin-resistant *S. aureus*, which was first seen in our institution in 1981, continues to be found in a small proportion of patients. We have achieved successful results in certain surgical settings with the use of gentamicin-dispersing polymethyl-methacrylate beads to provide sufficient antimicrobial concentrations in poorly vascularized or avascular tissue. Additional topical antimicrobials that are potent against gram-positive bacteria are needed.
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Infections in the upper half of the body endanger functionally and esthetically important areas, such as the face and the hands. The Division of Hand, Plastic and Reconstructive Surgery at the University of Zürich engages in three basic practices—"clean" esthetic and reconstructive surgery; hand surgery, which often entails dealing with wound contamination and infection; and surgery of burns, in which contention with wounds and bacteria is a way of life. These practices often differ with regard to bacteriologic characteristics. Herein we review patterns of infection and microbial prevalence in our patients and discuss the role of antimicrobial therapy as an adjuvant to surgery.

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INFECTION OF THE HAND

Given a general impression that the frequency of abscess had increased over recent years, particularly with the advent of disease as a result of human immunodeficiency virus infection, we recently conducted a study of infection types in 192 patients who were admitted to our clinic with infection of the upper extremities.[1] Table 1 compares the data from this study with data from a study that was conducted at our institution in 1977 in a similar unselected group of 289 patients from the urban environment (unpublished data). Contrary to expectations, we found that abscess was less common than it had been in the earlier study (14% vs 28%). We also found that the incidence of phlegmonous infection had increased, such that the combined incidence of abscess and phlegmon in 1990 was nearly identical to that in 1977. These findings suggest that patients are currently receiving adequate treatment earlier in the course of infection, that is, before an abscess is

Table 1. Infections of the upper extremities

	Percentage of patients with infection	
	1977 (n = 289)	1990 (n = 192)
Panaritium	46	61
Abscess	28	14
Superinfected wound	21	7
Phlegmon	2	14
Osteitis, arthritis	2	0

formed, and that the antibiotics that are administered are active against the causative organisms. It may be that patients seek treatment earlier nowadays, as suggested by the fact that we observed no cases of arthritis or osteitis and a much lower incidence of superinfection in the 1990 study.

In the recent study, cultures yielded a single organism in half of the cases, two organisms in 28% of cases, and more than two organisms in 10% of cases. The distribution of isolates is shown in Table 2. *Staphylococcus aureus* was by far the most common organism that was isolated; β-hemolytic *Streptococcus* group A was the second most frequently isolated species. Next in order of prevalence were normal nonpathogenic flora and *Haemophilus influenzae*, followed by various *Streptococcus* species. Unfortunately, no comparable data are available from the 1977 study. However, indirect evidence of increased resistance to penicillin has been passed on to the present day in that penicillin was replaced in treatment regimens by an antibiotic of the methicillin group. Therefore *S. aureus* must also have been the predominant microbe in 1977.

Table 2. Distribution of isolates in infections of the hand in 1990

Isolates (n = 192)	Percentage
S. aureus	36.3
β-Hemolytic *Streptococcus* group A	14.4
Normal flora (e.g. *Corynbacterium*, other *Streptococcus*, etc.)	12.3
Haemophilus influenzae	9.6
Streptococcus milleri	4.8
β-Hemolytic *Streptococcus* group B	2.7
α-Hemolytic *Streptococcus*	2.7
Anaerobes	2.7
Coagulase-negative staphylococci	2.1
Other bacteria	12.4

Table 3. Distribution of isolates in burns in 1990

Isolates (n = 290)	Percentage
Enterococci	21.2
S. aureus	20.5
E. coli	16.7
Coagulase-negative staphylococci	6.3
Pseudomonas aeruginosa	4.9
Klebsiella pneumoniae	3.1
Enterobacter cloacae	3.1
Proteus vulgaris	2.4
Proteus mirabilis	1.4
Other bacteria	20.4

BACTERIOLOGY OF THE BURN WOUND

The distribution of organisms that were isolated from burn wounds in our patients in 1990 is shown in Table 3. Although gram-positive bacteria also prevail in burn wounds, there is a marked difference between burn wounds and hand infection with regard to the frequency of isolation of the particular species. Enterococci lead the field in burn wounds, whereas they rank tenth in cases of hand infection. Although it is rarely seen in hand infection, *Escherichia coli* is quite common in burn wounds. Because of the nature of obtaining wound cultures and differences in the healing process, swabs of infected areas of the hand are often not obtained after initial culture at the time of admission, whereas every effort is made to continue culturing swabs from burns throughout the duration of treatment. Thus it is likely that the distribution of isolates in patients with burns is reflective of nosocomial factors, whereas that in patients with hand infections is reflective of the spectrum of organisms that are found in the general population.

Thanks to collection of data by our microbiology team, changes in the prevalence of organisms from burn wounds over a 20-year period can be demonstrated. As shown in Table 4, *Pseudomonas aeruginosa* is no longer a predominant organism. In 1969, silver nitrate was the agent that was used for topical treat-

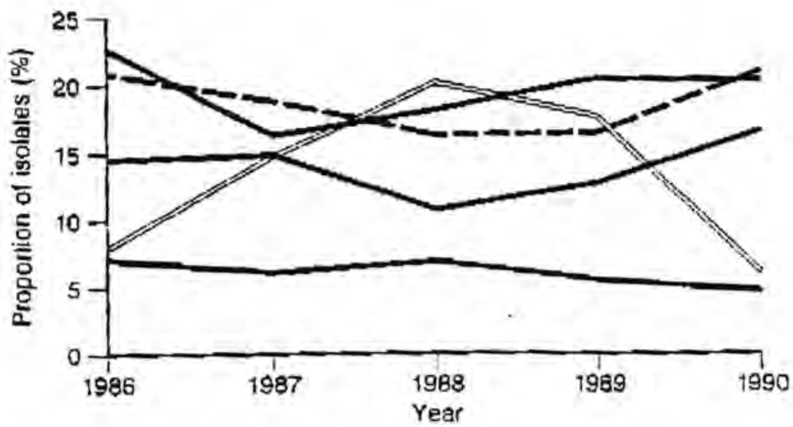

Figure 1. Proportion of isolates in burn wounds, 1986 to 1990.

Table 4. Distribution of isolates in burns over two decades

Isolates	Percentage of initial isolates		
	1969 (n = 156)	1979 (n = 322)	1989 (n = 403)
S. aureus	20	28	21
Coagulase-negative staphylococci	12	17	18
E. coli	16	17	17
Pseudomonas aeruginosa	30	12	6
Enterococci	10	11	17
Klebsiella pneumoniae	7	6	3
Proteus species	2	3	2
Other bacteria	3	6	16

ment of burns. This agent was succeeded in turn by mafenide acetate, povidone iodine, and silver sulfadiazine, the latter of which has very potent activity against *Pseudomonas* organisms. The availability of antibiotics that are more effective than gentamicin alone and the concerted effort of surgical and intensive care teams to close wounds early have also contributed to the decline in prevalence of this organism.

Frequencies of isolation of the predominant bacteria in burn wounds over the most recent 5-year period are shown in Figure 1. It can be seen that the frequency of isolation of coagulase-negative staphylococci varies more than that of *S. aureus*. Since these organisms do not appear in the form of the once harmless *S. epidermidis*, close attention must be paid to their presence in the clinical setting. A similar statement can be made with regard to *Enterococcus* organisms; these organisms are found twice as frequently today as they were 10 or 20 years ago, and what is more disagreeable, they have definitely become pathogenic. With regard to their clinical effects, we rank them between *E. coli* and *S. aureus*. We have also observed that *Enterococci*, like *S. aureus*, frequently remain relatively unaffected by topical silver sulfadiazine. Enterococcal infections are thus treated with systemic ampicillin, which is not useful for treatment of infection that is caused by other organisms in burn wounds. In burns combination therapy with two or often three antibiotics is required. This approach stands in marked contrast to treatment of hand infections in which monotherapy is appropriate in nearly all situations that involve gram-positive bacteria. More antibiotics are used today than were employed 5 years ago. One consequence of this practice is an increase in the incidence of fungal infections that require treatment, a phenomenon that was also observed in the mid-1970s.

β-Hemolytic *Streptococcus* group A organisms have been found in only one of the last 493 patients with burns whom we have treated. Because no prophylactic antibiotics are given, this low incidence is astonishing but certainly welcome, since the devastating effects of this organism on skin transplantation are well known.

We are seldom able to follow the path that is taken by bacteria in the hospital. However, regarding the first strain of methicillin-resistant *S. aureus* that was documented to appear in the surgical setting, we know that the strain arrived at our hospital via a patient from northern Africa, rummaged around the emergency ward and two surgical intensive care wards, was brought to a regular surgical ward (and

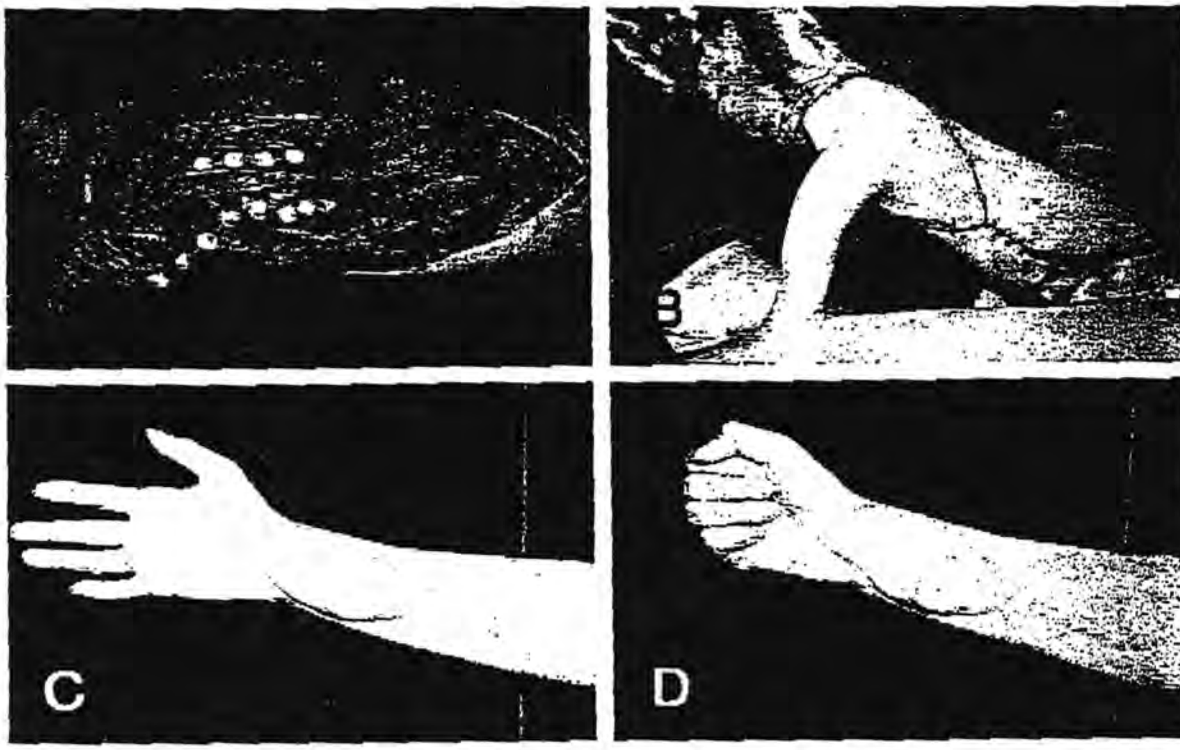

Figure 2. A, Electrical burn of the wrist on the twelfth day after debridement and introduction of gentamicin-polymethyl-methacrylate beads under flexor tendons and median nerve; **B,** coverage with groin flap; **C,** full range of motion on extension; **D,** full range of motion on flexion.

was by that time on other patients), and finally, was carried from the surgery ward by a friendly nurse who was helping out in the burn intensive care unit. Two brothers with severe burns were being treated in the same room in the unit and one brother's wounds became contaminated with the organism. Strict discipline in keeping contaminated and uncontaminated materials apart and in preserving virtual boundaries in the room prevented cross-contamination of the brother whose wounds were not contaminated. Since this event in 1981, methicillin-resistant *S. aureus* continues to be found in a small number of patients (Table 5). Fortunately, its presence frequently does not require treatment; otherwise, infection can be treated well with vancomycin.

DISCUSSION

Periodic reappraisal of the prevalence, variety, and resistance patterns of bacteria in infections of the hand and in the wounds of such patients as those with burns is necessary. There appears to be great variability among institutions with regard to bacte-

Table 5. Sensitivity of *S. aureus* to antibiotics of the methicillin group

Year	No. of isolates	No. of susceptible isolates	Percentage of isolates susceptible
1986	78	74	95
1987	80	80	100
1988	103	97	94
1989	82	81	99
1990	59	58	98

riologic profile. For example, in a recent study, Dellinger et al.[2] in Seattle not only found a much higher incidence of multiple isolates per infection of the hand (84% vs our 39%) but also reported a much higher incidence of isolation of β-hemolytic streptococci (70% vs our 14%) and a greater prevalence of *S. aureus* (57% vs our 36%). There is no explanation for the variety and number of organisms per infection in that study other than the high proportion of patients with human bites who were included in

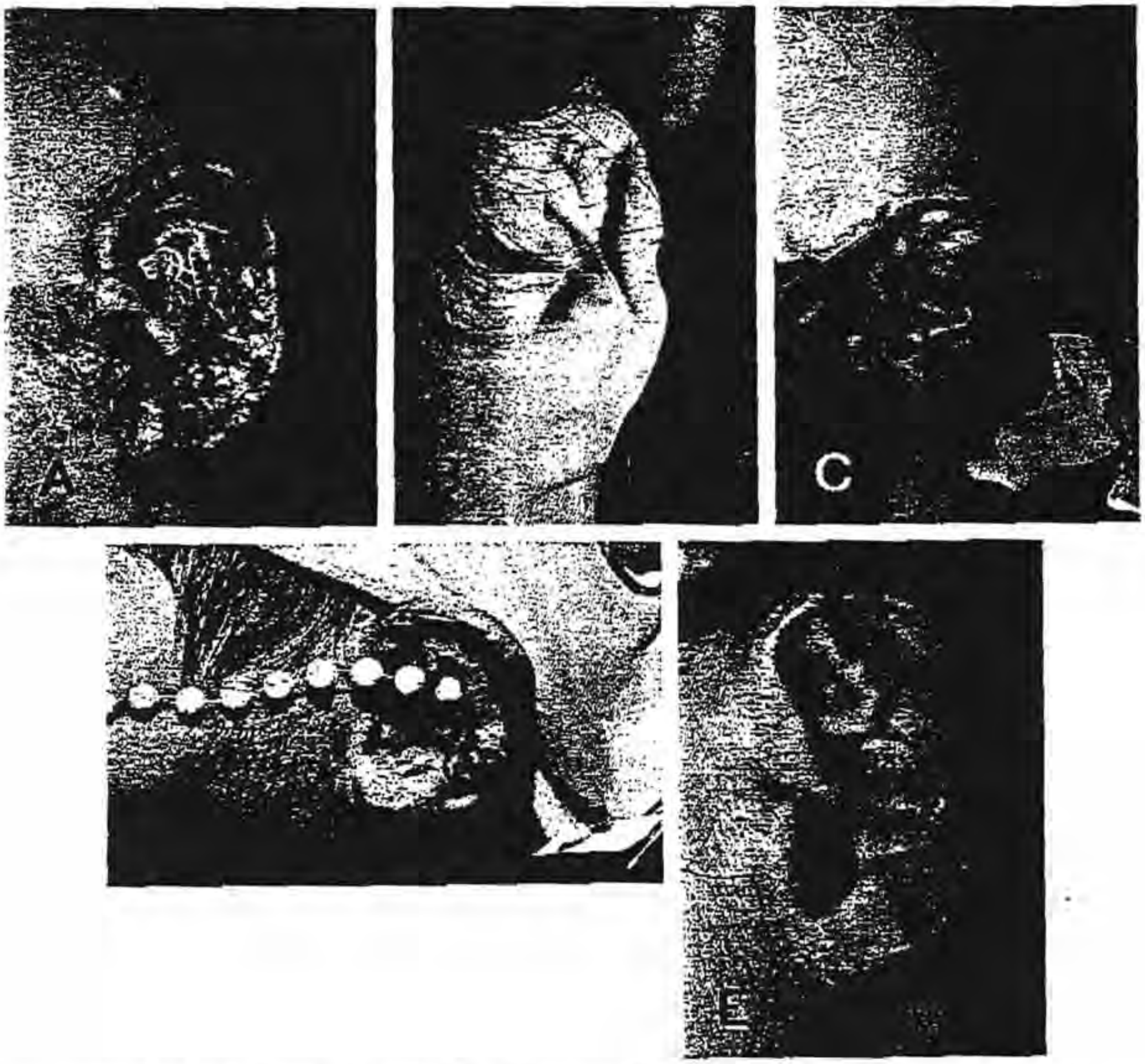

Figure 3. A, Acute chondrities of a burned ear; B, scarring and deformation of ear after chondritis; C, acute chondritis of a burned ear before insertion of gentamicin-polymethylmethacrylate beads; D, insertion of beads after resection of infected cartilage; E, resulting form of ear with some remaining beads visible in the anterior crus.

the series (61 of 193 patients compared with 1 of 192 patients in our series).

Great variability is also true for the flora of various burn units. At the time when *Pseudomonas* species were found in 30% of our patients, Müller[3] reported the presence of the organism in only 8% of patients in Bochum, Germany. This discrepancy might be thought to be due to the fact that mafenide was being used to combat the organism in the latter center, whereas in our center in Zürich silver nitrate soaks were being used. However, when they were treating burns topically with nitrofurazone or mafenide, Heggers et al.[4] found *Pseudomonas* species in 29% of their patients; at the same time, we were using silver sulfadiazine and found the organism in 9% of our patients. Similar considerations apply to the ubiquitous *S. aureus*. Müller[3] reported that in 1965 the organism was present in 66% of patients, and the proportion decreased to 31% and 12% over the next 2 years, respectively, when infections were treated with topical gentamicin and mafenide. In 1987, Heggers et al.[4] reported that they found *S. aureus* in 50% of their patients, whereas we found the organism in 20% of our patients. With regard to resistance patterns. Varaldo et al.[5] reported that one third of *S. aureus* isolates in hospitals in Italy were resistant to methicillin at a time when we found such resistance in only 5% of our isolates. These investigators also reported that the incidence of methicillin resistance among coagulase-negative staphylococci in burn units was 46% at a time when we found such resistance in only 25% of such isolates.

Given the great epidemiologic variability among centers, one is forced to evaluate and attempt to explain changes and patterns in one's own series of patients. Knowledge of predominant bacteria and their resistance traits is necessary, since antimicrobial therapy must be initiated before antibiograms are available in most instances. It is clear, however, that the flora in each center undergo changes in the type and aggressiveness of constituent organisms. New means for combating emerging organisms must constantly be sought and developed by the clinician. In particular, what is currently needed is a practical topical agent that is active against gram-positive bacteria.

The lack of antimicrobial effect of systemic antibiotics in the avascular burn eschar and poorly vascularized tissue, such as bone in osteitis and cartilage in chondritis, indicates the need for topical application of potent agents. A high local concentration of gentamicin can be achieved by the introduction of gentamicin-polymethyl-methacrylate beads into the surgically debrided wound. When placed into the femoral cavity of dogs, these beads produced gentamicin concentrations of 5 to 24 μg/gm in cancellous bone, 2 to 20 μg/gm in cortical bone, and 100 to 200 μg/gm in tissue in the surrounding hematoma.[6] These concentrations, which are well above the minimal inhibitory concentration for a large number of bacterial species, are achieved via the gradual release of the drug for up to 10 weeks. (The half-life of the drug is 6 to 10 days.)[6-8] Dingledein[9] found that minimal inhibitory concentrations of gentamicin for 20 to 29 gentamicin-resistant staphylococcal strains were 128 μg/ml or greater, and a total of 27% (10) of the *S. aureus* strains and 31% (19) of the *S. epidermidis* strains that were tested had resistance defined as a minimal inhibitory concentration of greater than 4 μg/ml.

We have successfully used gentamicin-dispersing beads in a variety of surgical settings. Figure 2 shows the course of recovery in a patient with an electrical burn of the forearm. Use of the gentamicin-dispersing beads in combination with surgery resulted in uneventful healing by obliterating dead space and combating infection until the groin flap was well healed. At the time of detachment of the flap from the groin, the beads were removed. Six months later, the sensitivity of the median nerve was near normal and the function of the fingers was excellent. In the setting of osteitis of the sternum as a result of the occurrence of *S. aureus* infection after cardiac surgery or after partial resection of the thoracic wall in patients with breast cancer, the beads have been inserted in the wound under a latissimus dorsi flap rotated into the wound to provide proximity of tissue with antiinfectious potency. After 10 days, the beads are gradually removed.

The use of local instillation and iontophoresis of antimicrobials after surgical removal of infected cartilage in chondritis of the ear has been described.[10,11] In 1979 we[12] initiated the practice of introducing crushed gentamicin beads into the debrided skin folds of the ear; the beads serve to both release antibiotic and provide some structure to the ear, which would otherwise collapse and retract. Today we use minibeads of 2 to 3 mm in diameter on a wire strand to provide a more rigid structure. The usual outcome of chondritis of the ear after burn injury is shown in Figure 3, *A* and *B;* outcome with insertion of beads after debridement of much of the auricular tissue is shown in Figure 3, *C, D,* and *E.* Most patients do not want a cartilage replacement, and the presence of the beads does not appear to disturb them. A greater variety of materials with different physical properties that release various antibiotics to combat resistant bacterial strains could be of considerable use in reconstructive surgery.

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