Hip arthroplasty infection

Current concepts

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Due to systemic or local antibiotic treatment and other preventive procedures, the incidence of deep hip-prosthetic infections in Scandinavia is less than 1 percent, with the majority hematogenous. Coagulase-negative staphylococci and anaerobes are involved in more than half of the cases. The diagnosis is sometimes difficult; preoperative aspiration often gives misleading results; and granulocyte scanning usually adds valuable information. In deep infection the current strategy is to revise with a two-stage procedure. Revisions should be carried out at specialized centers with bacteriologic competence and sufficient experience with implants.

Incidence and classification

The incidence of deep hip-prosthetic infections is at present less than 1 percent in Sweden (Ahnfelt et al. 1989), and early postoperative infections appear in less than 0.2 percent (Lidwell et al. 1987, Lidgren et al. 1988). Thus, most of the infected hip arthroplasties are hematogenous in origin (Ahnfelt et al. 1989).

An infection starting within 3 months after operation is classified as *early*, between 3 months and 1 year as *delayed*, and after 1 year as *late*. Early infections are often associated with a draining hematoma (Surin et al. 1983). Delayed infections are most often due to contamination at the time of surgery, but may be hematogenous. Late infections are nearly always hematogenous. Both delayed and late infections may have an acute onset.

Etiology

Foreign bodies cause decreased phagocytic and bactericidal activity in polymorphonuclear leukocytes (Elek and Cohen 1957, Zimmerli et al. 1982). This leads to an increased risk for infection (Lidgren 1973). Various polymers, as well as cobalt, nickel, chromium, and titanium all modify the immune response (Rae 1975). Adherence of bacteria to the surfaces of implant materials has been reported (Gristina and Kolkin 1983, Gristina 1987).

Certain patients are more predisposed to prosthetic joint infection. Patients with rheumatoid arthritis (Maderazo et al. 1988) and particularly patients with ongoing purulent infections distal to the arthroplasty are highly susceptible to mostly staphylococcal and streptococcal hematogenous infections (Thomas et al. 1983). *Streptococcus viridans* and probably also anaerobic bacteria may spread from the teeth and oral cavity (Lindqvist and Slätis 1985).

Pathology

The microbes, together with foreign material and damaged tissue, will also affect the immune system. This is evident as an increase of specific antibodies to bacterial antigens in the serum or in the joint fluid. The infections are usually followed by a neutrophilic polymorphonuclear leucocyte-mediated response.

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Mononuclear cells are also found locally. These mononuclear accessory cells and immunocompetent lymphocytes form the essential elements in the specific immunologic response (Konttinen et al. 1989), and can be used to differentiate between rheumatoid, reactive and septic conditions (Santavirta et al. 1989). In situ hybridization with probes labeled by high-affinity monoclonal nucleotides, e.g., digoxigenin, may be one way of identifying certain microbial nuclear sequences (Santavirta et al. 1989).

Current work has shown that particles of methylmethacrylate cause a nonimmunologic lymphocyte activation to the prosthesis-cement complex (Santavirta et al. 1990a). In cementless prosthesis an equal phenomenon is caused by pulverized polyethylene originating from the acetabular component (Santavirta et al. 1990b), and probably the same could happen with metals. The stimulation usually causes a fourfold rise of specific antibodies in the serum or in the aspirate (Konttinen et al. 1989). Even a minor inflammatory reaction around the implant will lead to increased microbial adherence (Gristina 1987).

Diagnosis

Pain upon weight bearing but especially at rest and an elevated erythrocyte sedimentation rate (ESR) should evoke suspicion of a deep infection. The definite diagnosis of deep infection may sometimes be difficult. The ESR together with C-reactive protein is usually quite sensitive in nonrheumatoid patients, differentiating between mechanical loosening and infection (Shih et al. 1987, Sanzén and Carlsson 1989, Thorén 1989). Plain radiographs, although not specific, often show a rapidly developing irregular zone of resorption around the prosthesis, sometimes with an extensive periosteal reaction (Bergström et al. 1974). Autologous granulocyte scanning has proved to be helpful in differentiating mechanical prosthetic loosening from infection (Merkel et al. 1985, Pring et al. 1986). The sensitivity and specificity for ^{111}Indium has been reported to be about 80 percent, whereas the combination of sequential technetium and gallium has a sensitivity of 50 percent with a specificity around 80 percent. New promising isotopes, such as ^{99m}Tc Nanocolloid have recently been introduced (Gericke et al. 1989). Immune-inflammatory analysis of aspiration samples (Santavirta et al. 1989) can also distinguish infection from mechanical loosening.

Bacteriology

Deep prosthetic infection can be caused by a large number of bacterial species (Charnley 1972, Hunter and Dandy 1977, Lidwell et al. 1983, Inman et al. 1984, Sanzén et al. 1988). Often only one microbe grows on multiple cultures obtained during revision surgery, but mixed infections occur and electron microscopic studies suggest that they are common (Gristina and Costerton 1985). The most reliable cultures can be obtained if there has been no antibiotic treatment for several weeks and if multiple tissue biopsies are taken for both aerobic and anaerobic cultures. The culture is considered diagnostic if the same bacteria are identified in at least half of the cultures (Kamme and Lindberg 1981). Preoperative hip aspiration for culture is theoretically advantageous but often misleading; 23/130 false-positive results in noninfected cases and 45/205 incorrect results in infected cases, have been reported by Phillips and Kattapuram (1983) and Buchholz et al. (1981), respectively.

Ongoing antibiotic treatment and insufficient bacteriologic technique may cause false-negative cultures in up to 20 percent (Lidwell et al. 1983). When antibiotic prophylaxis is commonly used, the proportion of *Staphylococcus aureus* infections has been reduced to about 10 percent (Wroblewski 1986, Sanzén and Carlsson 1989), but together with streptococci they are still the most common pathogens in hematogenous infections (Blomgren 1981). The coagulase-negative staphylococci (CNS), of which *Staphylococcus epidermidis* is the most important, were only reported as uncommon pathogens, e.g., 4 out of 85, in Charnley's early series (1972). Today, however, CNS are the most important bacterial species involved, with 40–50 percent in recent series (Inman et al. 1984, Wroblewski 1986, Sanzén 1989). Elson et al. (1989) have reported on variable strains of CNS with a multiple antibiotic resistance in infected total hips.

Aerobic gram-negative bacteria, such as *E. coli*, *Proteus* and *Pseudomonas*, cause 10–20 percent of all deep infections (Sanzén 1989); about 10–20 percent are anaerobic (Kamme et al. 1974), usually caused by *Propionibacterium acne* or cocci.

Local and systemic preventive antibiotics cause different patterns of infection and bacteriology; local antibiotics cause more superficial infections than systemic treatment (Surin et al. 1983, Lidwell et al. 1987).

Prevention

Controlled studies have shown a substantially lower infection rate after hip arthroplasty when antibiotic prophylaxis has been given for 5–14 days. The antibiotics mostly used have been cloxacillin (Ericson et al. 1973), lincomycin (Schulitz et al. 1980), and cefazolin (Hill et al. 1981). However, comparison of 12 hours' cephaloridine prophylaxis with 14 days of cloxacillin showed no difference in outcome (Pollard et al. 1979).

The most important pathogens in prosthetic infections today are coagulase-negative staphylococci, and the hospital staff may carry multiresistant strains (Lowy and Hammer 1983). However, in a Swedish orthopedic department only 3–11 percent of the surgical staff and the patients before operation were found to be carriers of methicillin-resistant CNS, although cloxacillin has been used for prophylaxis for 15 years (Sanzén and Walder 1988). Metronidazole can be added for complete activity against anaerobic bacteria (Sanderson 1988). An alternative or complement to systemic antibiotics is bone cement impregnated with antibiotics, i.e., gentamicin (Josefsson et al. 1981), which is recommended in cemented revisions. Lynch et al. (1987) reported a lower rate of deep infection when comparing antibiotic-loaded cement with plain cement in a series of exchange hip arthroplasty.

Subinhibitory concentrations of antibiotics cause a decrease in surface charge and hydrophobicity and prevent colonization of cell surfaces (Proctor et al. 1983, Gristina 1987).

Shortening the patient's preoperative hospital stay and minimizing the risk of bacterial contamination of wounds during surgery are important. The staff is the primary source of airborne bacterial contamination in the operating theater. Preventing the bacteria-carrying particles from reaching the wound should thus prevent airborne infection. Particles should either be enclosed within the staff's clothing and/or transported away from the air inside the clothing or from the operating room air before reaching the wound. Reduction of all unnecessary traffic in the operation theater decreases the risk of airborne contamination (Concensus statement 1988).

The air in a standard operating room during a hip operation contains 50–500 colony-forming units (cfu)/m^3. In a so-called ultraclean environment, air contamination during surgery should not exceed 19 cfu/m^3 on the average (Whyte et al. 1983). With a laminate downward flow of about 0.4 m/s and special clothing, air contamination below 1 cfu/m^3 is regularly achieved (Sanzén et al. 1990).

According to Charnley (1964), and recently verified by Andersson et al. (1984) and Lidwell et al. (1987), most postoperative infections result from contaminated air. Lidwell et al. demonstrated that wound irrigation reduces the airborne contamination. Salvati et al. (1982) pointed out that horizontal air flow is less effective than vertical air flow; the infection rates were 3.4 and 1.7 percent, respectively. The addition of an exhaust body system gives a further reduction to 0.75 percent and antibiotic prophylaxis to 0.1 percent (Lidwell et al. 1987). These figures have been supported by a prospective multicenter study (Lidgren et al. 1988).

Treatment

If a deep infection is suspected, the strategy for the treatment should be outlined without delay. One of the following alternatives is proposed.

1. Debridement, suction-irrigation drainage, and systemic high-dose antibiotics in early infections.
2. Excision arthroplasty.
3. One-, two-, or three-stage revision.
4. Arthrodesis.
5. Life-long antibiotic treatment in the elderly where the general condition of the patient does not allow further surgery and in those who refuse operation.

Debridement alone (Fitzgerald et al. 1977, 1984) or in combination with suction-irrigation drainage without prosthetic removal may occasionally salvage the prosthesis; success rates vary from 0 to 4.5 percent (Nolan et al. 1975, Amstutz and Kass 1977, Hunter and Dandy 1977, Nelson 1977, Stinchfield et al. 1980, Goulet et al. 1988, Härle 1989). These techniques may be useful in an early fulminant infection if the treatment is initiated within 24–36 hours after the onset of signs of infection. Closed suction-irrigation drainage alone is seldom successful (Antti-Poika et al. 1990), and if used for more than 72 hours carries a risk for superinfections. The result of local revisions depend on the type of bacteria and on the patient's immune response (Dubois 1984, Goodman and Shurman 1988). The patient must also be able to tolerate antibiotics in high doses for at least 6 months, preferably longer (Goulet et al. 1988).

Permanent resection is still a recommendable method, but it does not always erradicate the infection, and a remaining infection has been reported in 12–31 percent (Hamblen 1988). Some studies indicate that there is less fistulation in patients with all cement removed at revision (Fitzgerald 1986, Kantor et al. 1986), and other studies that the healing

rate is the same with bone cement left (Canner et al. 1984). Most of the patients are not satisfied, because function is usually poor (Clegg 1977, Hunter and Dandy 1977, Bittar and Petty 1982, Hamblen and Fischer 1983, McElwaine and Colville 1984, Kantor et al. 1986). Shortening has been reported to be on an average 5 cm, with positive Trendelenburg instability and pain (Bittar and Petty 1982). Traction has been recommended for the first 2 weeks (Kantor et al. 1986).

Canner et al. (1984) reported that the healing rate was 90 percent without residual cement after excisional arthroplasty compared with 71 percent with residual cement. A greater difference has been shown by Fitzgerald (1986); 50 and 12 percent healing, respectively.

In late infections the prosthesis must be removed. The question remains as to whether the revision should be carried out in one or two or even in three stages (Fitzgerald 1986). Healing rates of 77–91 percent have been reported when antibiotic-impregnated bone cement was used (Buchholz et al. 1981, Carlsson et al. 1978, Wroblewski 1986). However, radiographic loosening is frequent after a cemented revision: up to 50 percent after 5–10 years (Pellici et al. 1985, Echeverri et al. 1988, Sanzén et al. 1986). The studies concerning revisions with antibiotic-impregnated cement have included all revisions irrespective of the bacterial flora and ongoing fistulation (Buchholz et al. 1981, Sanzén et al. 1986). The main comparable reports with plain cement have excluded patients with gram-negative infections or ongoing fistulation (Hunter et al. 1979, Salvati et al. 1982).

In Scandinavia today, a two-stage procedure is used with a second procedure being either a noncemented or cemented prosthesis using antibiotic-impregnated bone cement. The time interval varies; 2 to 3 weeks has been recommended by Wahlenkamp (1983); 3 to 12 months by Fitzgerald and Kass (1986); and 1 to 2 years by Amstutz (1977). One way to improve the results could be to use antibiotic-containing beads in the bone cement as a temporary treatment (Hovelius and Josefsson 1979). In the very few series that have been reported with this method, healing occurred in the majority (Salvati 1988, Sanzén et al. 1988, Härle 1989).

Probably the interval could be shortened to 4–6 weeks. The use of C-reactive protein (Shih et al. 1987) together with a second granulocyte scan (Hedström and Lidgren 1988) can be of value to determine the length of the interval. A thorough examination of the radiograph should also be carried out to ascertain whether or not there is any residual bone cement.

At the revision, preparation of the femoral stem, meticulous cementation techniques including intramedullary plugs, and application of the cement with pressure are considered essential (Arajärvi and Santavirta 1987, Lidgren 1988, Lidgren et al. 1988, Russotti et al. 1988) because early micromovement may provoke loosening and recurrence of infection. If there is a need for bone transplantation this could be carried out in a second procedure and the prosthesis preferably inserted in a third stage (Fitzgerald 1986). In younger patients a cementless prosthesis has been tried (Eskola et al. 1988, Hedley et al. 1988, Suominen et al. 1989).

There is only one report of the results after arthrodesis (Kostuik and Alexander 1984): 14 hip arthroplasties with seven infections. Thirteen of these fused and all except one patient could return to work. The average shortening was 5 cm.

No deep infection that has persisted for more than a few days has been reported to heal without revision (Murray 1981, Klenerman 1984). However, life-long treatment with antibiotics may reduce pain, decrease the ESR, and prevent the progression of radiographic changes (Lidgren et al. 1976).

Deep infection following hip arthroplasty is associated with substantial morbidity and also mortality (Antti-Poika et al. 1990). In a Canadian study of 135 patients Hunter and Dundy (1977) reported that 21 patients died after the insertion or removal of the prosthesis. The ultimate success is judged by two factors: the prevention of recurrent infection and the function of the arthroplasty. A failure to cure the infection can lead to further trials; as many as five exchanges have been reported and even exarticulations (Buchholz et al. 1981).

Revision surgery for deep infection should only be carried out at special centers with experience in this treatment and access to bacteriologic competence, and a sufficient choice of implants.

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