Infected Total Knee Replacements

Russell E. Windsor, MD, and James V. Bono, MD

Abstract

Deep infection is a devastating complication following total knee arthroplasty. Prompt diagnosis and definitive treatment of this complication are essential for a successful outcome. The treatment options for an infected total knee replacement include (1) antibiotic suppression alone; (2) aggressive wound debridement, drainage, and antibiotic suppression therapy; (3) resection arthroplasty; (4) arthrodesis; (5) two-stage reimplantation; and (6) amputation. Successful salvage of this complication can be accomplished only by extensive investment of surgical and infectious disease efforts in eradicating the infection. Two-stage reimplantation has been the most successful functional option and should be used whenever possible to definitively eradicate the infection and ensure good function of the knee joint.

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Next to a life- or limb-threatening complication, nothing can be more devastating than infection after total knee arthroplasty. Only through identification of risk factors and development of prophylactic regimens has the incidence of infection decreased. The management of this problem requires a considerable expenditure of the patient's and the surgeon's energy for definitive diagnosis and treatment. Successful treatment depends on a team approach, with cooperation of the orthopaedic surgeon, the plastic surgeon, and the infectious disease specialist.

Incidence of Infection

The incidence of infection after total knee arthroplasty ranges from 1.1% to 12.4%.[1-5] At the Mayo Clinic, 1.2% of 3,000 primary total knee replacements developed infection.[3,6] The higher rates of infection occurred after implantation of cemented linked hinges, such as the GUEPAR prosthesis (now obsolete).[1] Patients with rheumatoid arthritis, who often are immunologically deficient,[7,8] are at greater risk for infection. Wilson et al[5] studied 4,171 total knee arthroplasties that were performed at the Brigham and Women's Hospital in Boston and found that 67 replacements became infected. The risk of infection was significantly increased in patients, particularly men, who had rheumatoid arthritis; in patients with skin ulceration; and in patients who had undergone previous knee operations. Skin infections were the most common source of infection; it is, therefore, necessary to heal skin ulcers, especially those peripheral to a joint with a prosthesis.[5,9] Antibiotic prophylaxis is recommended until the wound is healed. In addition, infection was associated with obesity, recurrent urinary tract infections, and oral corticosteroid use, although the correlation did not achieve statistical significance.

Tooth extraction always causes bacteremia.[10] Although antibiotic prophylaxis in dental procedures is universally recommended,[11] it is still debated, and prospective studies have shown a low risk for bacterial seeding around prosthetic joints.[12]

Patients with chronic renal insufficiency and neoplasm requiring chemotherapy are at risk for infection due to chronic neutropenia and, in some cases, compromise of the immune system. Diabetes mellitus may pose an increased risk of infection due to the increased risk of wound-healing problems. Superficial wound necrosis may at times communicate with the deeper tissues of the knee and lead to deep infection.[13]

The surgeon can influence the ultimate infection rate not only by technique but also by selection of the prosthesis. For example, surface replacements have an overall infection rate of less than 1%. In contrast, metal-on-metal constrained hinge prostheses, such as the GUEPAR prosthesis, have an infection rate that approaches 14%. Many of these infec-

Dr. Windsor is Associate Professor of Surgery (Orthopaedics), Cornell University Medical College, New York, and Associate Attending Orthopaedic Surgeon, The Hospital for Special Surgery, New York. Dr. Bono is Senior Clinical Associate in Surgery, Cornell University Medical College, and Junior Attending Orthopaedic Surgeon, The Hospital for Special Surgery.

Reprint requests: Russell E. Windsor, MD, The Hospital for Special Surgery, 535 E. 70th Street, New York, NY 10021.

tions occur late, sometimes several years after implantation. The reason for this very high incidence of infection is not altogether clear, but is probably related to the presence of metallic debris, which in turn causes the formation of a membranous sac containing fluid and debris around the prosthesis.[14,15] Impregnation of the bone and soft tissues with metallic fragments and the large bone-cement interface may become factors, especially when the prosthesis becomes loose. Disturbingly, constrained prostheses with metal-on-plastic bearing surfaces also seem to have a higher infection rate. For example, the stabilocondylar prosthesis had a 8.3% infection rate in a small series of 36 cases. Consequently, constrained hinged prostheses with cemented intramedullary stems have become largely obsolete in this country. For the great majority of clinical situations, a non- or semiconstrained surface total knee replacement will perform well and reduce the potential for infection.

Skin necrosis with secondary deep extension may lead to a deep prosthetic infection. Incisions placed at the side of the knee, for synovectomy or open fracture reduction and internal fixation, may predispose to skin necrosis. They are generally unsuitable for knee arthroplasty, which requires a midline, longitudinal incision. Although previous incisions should be utilized as much as possible during any knee replacement, sometimes it is necessary to use a separate longitudinal incision to gain exposure despite the risk of creating an island of devascularized skin between the new incision and the healed old one. A skin bridge of at least 7 cm may minimize the risk of skin necrosis. If this complication occurs, the knee should be immobilized until spontaneous separation of the eschar occurs. Early and aggressive attempts at debridement may lead to deep contamination that might otherwise have been avoidable. Very large areas of necrosis, however, should be handled aggressively, utilizing appropriate skin grafts in consultation with a plastic surgeon.

Slight wound drainage often requires no modification of the postoperative regimen. When profuse wound drainage occurs, the knee should be immobilized until it stops. Antibiotics should not be given, as their administration may mask a latent deep infection. Some degree of wound drainage occurs in about 25% of the cases and may be further classified as culture-negative or culture-positive. There appears to be no relationship between culture-positive wound drainage and subsequent deep infection. In the early postoperative period, a few patients have persistent drainage, a tense knee effusion, and persisting significant pain. In these patients, aggressive open debridement, evacuation of the retained hematoma, copious lavage, and reclosure should be considered.

The organism most frequently found in infected total knee replacements is *Staphylococcus aureus*. Schoifet and Morrey[4] found that 58% of 31 infected total knee replacements cultured *S aureus*. Wilson et al[5] observed *S aureus* in 42 of 67 infected replacements. Staphylococcal organisms were responsible for infection in the majority of patients who had concurrent skin ulcerations. Gram-negative organisms, such as *Escherichia coli* and *Pseudomonas aeruginosa*, have been found less frequently. A mixed polymicrobial infection is usually encountered in cases in which there is an actively draining wound through which the surface bacteria can gain entrance to the knee. In addition, patients treated with chronic antibiotic suppression may develop resistant bacterial strains.

Diagnosis of Deep Infection

Deep or periprosthetic infection may be either early (within 3 months of surgery) or late (more than 3 months after surgery). An early infection, provided that its course is not modified by injudicious use of antibiotics, is usually not difficult to recognize. The clinical course is abnormal, with prolonged pain, swelling, inflammation, and fever. The leukocyte count, C-reactive protein level, and erythrocyte sedimentation rate remain elevated. Late infection is much more common than early infection, and the diagnosis is usually straightforward unless antibiotics have previously been given. The usual presentation is one of acute pain and swelling in the knee of a patient with a previously satisfactory arthroplasty. Late infection usually develops from hematogenous spread of microorganisms from a distant site.

Pain about a prosthesis for which a cause is not readily apparent should be assumed to be due to infection until proved otherwise. In a study of 52 patients with infected knee replacements treated at our institution, the preoperative workup was evaluated for accuracy in determining infection.[16] Considerable pain was present in 96% of the patients, 77% had swelling of the knee, 27% were febrile, and 27% had active drainage. The average erythrocyte sedimentation rate was 63 mm/h (range, 4 to 125 mm/h). The average leukocyte count was 8,300/mm^3 (range, 5,800 to 14,000/mm^3). Aspirated knee fluid was positive in all cases except one; in that case, no organism was cultured until aspiration was done at the time of the revision arthroplasty for what was thought to be aseptic loosening.

The diagnosis of an infection after total knee arthroplasty must depend

on the results of examination of knee fluid aspirated under strict aseptic conditions. Knee radiographs are unclear in showing infection, which may be present without radiographic signs of loosening. Large complete radiolucencies usually indicate an advanced stage of infection (Fig. 1). Technetium and gallium bone scans also may not conclusively show presence of infection. Cultures of wound drainage and sinus tracts, if present, often do not truly reflect the microorganisms found deep in the knee, since there is the likelihood of contamination of the fluid by other skin flora. Thus, knee aspiration is the standard of care for conclusively determining whether there is deep joint infection. The fluid aspirated from the knee is sent to the bacteriologic laboratory for direct smear, Gram stain, and cultures with antibiotic sensitivities for aerobic and anaerobic bacteria, acid-fast bacilli, and fungi.[16-18] If fluid cannot be easily obtained in the office, a fluoroscopically assisted aspiration should be considered.

Fig. 1 Infected prosthesis 11 months postoperatively. Note radiolucency beneath tibial component.

If enough fluid is aspirated from the knee, a complete blood cell count and a differential white blood cell count may also give valuable information. If the former shows more than 25,000 polymorphonuclear leukocytes per cubic millimeter and the latter reveals a value greater than 75%, infection should be suspected.

Fluid should also be sent for determination of glucose and protein levels. In normal synovial fluid, protein levels are about a third of serum levels. Glucose values in synovial fluid are similar to those in plasma. In the presence of infection, synovial glucose values are decreased due to the presence of organisms that utilize sugar in their metabolism. Thus, low glucose and high protein values are compatible with infection. If the diagnosis is still unclear, an open biopsy by arthrotomy or arthroscopy is recommended.

Frequently, patients referred from other institutions are already receiving antibiotic therapy, which may suppress the infection enough to render the knee aspiration fluid falsely negative. The importance of obtaining positive bacterial cultures preoperatively cannot be overestimated. The cultures not only provide identification of the microorganisms but also enable the infectious disease consultant to obtain minimum serum bactericidal concentrations regularly during the course of intravenous antibiotic therapy. If the patient has been receiving antibiotics, they should be immediately discontinued, and serial aspirations of the knee should be done at weekly intervals until a positive culture is obtained. This method not only will provide a positive culture for the infectious disease specialist but also will increase the possibility that deep knee cultures obtained at the time of surgery will yield adequate microorganism growth. After antibiotics have been discontinued, it may take up to 1 month before a positive culture is obtained. Patients taking antibiotics may, in fact, have positive cultures that will inaccurately reflect the bacteriologic status of the wound. In this case, other organisms may be suppressed, leading the surgeon to erroneously think there is only a single organism present.

Infections complicating primary total knee replacement should not be treated with antibiotic therapy alone.[9,15] This treatment might suppress the symptoms of infection transiently and may be indicated only as a temporary measure if surgery is contraindicated due to medical reasons or if the patient does not accept other surgical options. Antibiotic therapy alone is unlikely to cure the infectious process.[2,19-22] Furthermore, its use can complicate the problem by selecting resistant bacterial strains. An unusual exception to this rule is the patient with a previously successful arthroplasty who presents acutely with pain, swelling of no more than 24 to 48 hours' duration, a positive culture, and an obvious source of hematogenous bacterial contamination. If aspiration demonstrates an organism that is exquisitely sensitive to antibiotic treatment, such as a *Pneumococcus* or *Streptococcus* organism, antibiotics may be considered for definitive treatment.

Procrastination and the prolonged use of oral antibiotics should be condemned, particularly when infection is suspected but not confirmed by bacteriologic evidence. The end result of this course is likely to be an indolent subclinical infection and a painful prosthesis. In addition, it may make subsequent culture of the organism very difficult even after the components have been removed, so that appropriate antibiotic therapy is impossible and ultimate salvage of the arthroplasty by reimplantation becomes much less likely.

Treatment Options

The treatment options for an infected total knee replacement include (1) antibiotic suppression alone[2,20-22]; (2) aggressive wound debridement, drainage, and antibiotic suppression therapy[4,20,23,24]; (3) resection arthroplasty[25,26]; (4) arthrodesis[22,27,28]; (5) two-stage reimplantation[3,16-18,29]; and (6) amputation.[2,30]

Because the knee joint is relatively superficial, care of the wound is preeminently important. Success of any treatment option will be severely compromised by inadequate wound care or inappropriate choice of incisions.

The original midline incision should be utilized whenever possible. Provided the skin margins remain viable, the original midline incision should heal well. This incision may be extended proximally and distally to improve surgical exposure of the knee joint. New incisions should be avoided at all costs. Well-healed medial or lateral incisions from operations that predate the total knee replacement should not be reopened, even if wound drainage develops in those areas. Frequently, drainage stops and the wound heals nicely after implant removal and thorough debridement. Large areas of skin necrosis or wound breakdown should be treated by rotation of a gastrocnemius muscle pedicle graft or free vascularized muscle transfers.

Antibiotic Suppression

The rheumatology literature has shown that treatment of knee sepsis may be accomplished adequately by serial aspirations and antibiotic treatment.[2,20-22] However, treatment was successful in knees in which a total joint replacement was not implanted. The implant and acrylic cement act as foreign bodies that limit the ability of the immune system to adequately combat the infection. However, infection is not confined to cemented total knee replacements. Wilson et al[5] found that infection developed in 2.8% of 35 uncemented total knee prostheses, 1.5% of 138 hybrid total knee replacements (with an uncemented femoral component), and 1.6% of 3,998 total knee replacements with totally cemented components. These incidences were not statistically significantly different but show that infection is possible regardless of the method of implant fixation.

The success of this treatment option is quite limited.[2,20-22] However, although not generally recommended, antibiotic suppression alone may be the only option for a patient who is a poor surgical candidate and does not have other total joint replacements that would be at risk of becoming infected by hematogenous spread of the original infection. Only organisms with extreme sensitivity to antibiotics, such as *Streptococcus* species and *Staphylococcus epidermidis*, can be treated in this way. The disadvantages of this treatment include the development of resistant bacterial strains, eventual painful loosening of the prosthesis, and the risk of antibiotic toxicity due to long-term use of the medication. This method does not definitively treat the infection, but rather suppresses it, and is useful only in the few patients who are so medically compromised that surgical methods would threaten their survival.

Debridement With Antibiotic Suppression Therapy

Vigorous wound debridement and antibiotic therapy with retention of the components has demonstrated limited success, even with the addition of an ipsilateral gastrocnemius muscle flap to provide adequate soft-tissue coverage and enhance vascularity.[20,23,24] It has been found that the success is greater if infection is diagnosed within 3 weeks of implantation of the original device. Schoifet and Morrey[4] specifically studied the treatment of infection after total knee arthroplasty by debridement with retention of the components. The most successful results were in seven knees in which the average time from the onset of infection to debridement was 21 days. However, the overall success rate was 23%, which reflects the fact that most of their patients had been infected for longer than 2 to 3 weeks. Borden and Gearen[17] also found that this method was somewhat more successful than more radical treatment options when the infection was diagnosed within 2 weeks of total joint implantation.

Organisms such as *Streptococcus viridans* and *S epidermidis* may be successfully treated by this method if they demonstrate exquisite sensitivity to parenteral or oral antibiotics. If this option is chosen, the patient must take antibiotics for the rest of his or her life. However, lifelong antibiotic suppression poses the risk that resistant bacterial strains may develop and create breakthrough infections that are chemically difficult to treat.

Patients with replacements of other joints are not usually candidates for debridement and suppression due to the risk of hematogenous seeding of the resistant microorganism strains from the site of infection to the noninfected total joint replacements.

More radical options may become necessary if infection persists. If one thorough attempt at debridement proves unsuccessful, subsequent attempts are usually futile, and the prosthesis should be removed.

Repeated attempts at debridement without removing the implants may compromise skin viability and may complicate definitive treatment by other surgical means.

Debridement may be performed by arthroscopy or formal arthrotomy. Formal arthrotomy allows removal of most of the scar and devitalized tissue but may cause significant quadriceps weakness in the postoperative period due to the incision through the extensor mechanism. The surgeon should remove all synovium and scar tissue and clear the medial and lateral gutters of debris. It may be necessary to fully expose the knee replacement in order to properly debride the posterior joint capsule.

Arthroscopic intervention may accomplish the same goals; however, multiple (up to six) portals may be required. The procedure is generally longer than arthrotomy because of the slower extraction of tissue by rotary suction blades. Infections that create significant scarring may render arthroscopy impossible as a treatment option.

Regardless of the surgical method used, a thorough debridement is done. Frozen tissue sections, Gram stains, cultures of the tissue, and the macroscopic appearance of the wound should provide diagnostic information. After debridement, the wound is closed over suction drains, which should remain in place for 36 to 48 hours. Using ingress and egress tubes with continuous irrigation is no longer recommended, as there is a significant risk of fluid extravasation as well as a risk of exogenous superinfection due to communication of the deep anatomic structures with the skin. Under no circumstances should the wound be left open to close by secondary formation of granulation tissue.

The wound is inspected after 2 weeks and is reaspirated under strict aseptic conditions. If the wound is benign and the cultures are negative, antibiotic therapy is continued for a further 4 weeks. When this is not the case, reoperation with removal of the prosthetic components and all cement is performed. This decision should be made quickly before further compromise of the underlying tissues develops.

Resection Arthroplasty

The two previous treatment options preserve the total joint replacement. Due to their limited success, more radical surgical options are usually required to eradicate the deep infection. Resection arthroplasty involves the complete removal of all components of the knee replacement, acrylic cement, scar tissue, and synovium[25,26] (Fig. 2).

This option as a definitive procedure is generally reserved for medically fragile patients who cannot tolerate another major operation. It may also serve as an intermediate step for the patient who has reservations concerning arthrodesis. Falahee et al[25] reported on 28 knees that underwent resection arthroplasty because of infection after total knee arthroplasty. Eleven patients had multiarticular rheumatoid arthritis, 14 had osteoarthritis, and one patient had multiarticular neuropathic arthropathy. Six patients with monarticular osteoarthritis considered resection arthroplasty unacceptable and subsequently underwent successful secondary arthrodesis. In three patients, spontaneous bone fusion developed after the resection with the knee in good position. The patients who had had the most severe disability before total knee arthroplasty were the most likely to be satisfied with the functional results of resection arthroplasty. Conversely, the patients who had had the least severe disability were more likely to find the results of resection arthroplasty unacceptable. Fifteen patients were able to walk independently without assistance. Five of those patients were able to stand and walk without external limb support. The other 10 patients used either a knee-ankle-foot orthosis or a universal knee splint. All 15 patients, however, required either a cane or a walker and remained either moderately or severely restricted in their overall walking capacity.

Fig. 2 Resection arthroplasty in a medically fragile patient following sepsis.

Resection arthroplasty is very useful for the severely disabled person with a sedentary lifestyle. The procedure is least suitable for patients who had a relatively minor disability before their original total joint replacement. Those patients will obtain more tolerable function from arthrodesis or reimplantation of a total knee replacement, depending on the sensitivity of the infective organism and the adequacy of the antibiotic treatment.

The advantage of resection arthroplasty is that some motion is preserved to allow sitting and to

facilitate transferring into and out of automobiles and aircraft. The disadvantage is the possibility of persistent pain and instability on walking.

Arthrodesis

Arthrodesis may be the only option for treating the infected total knee replacement when other forms of treatment are contraindicated.[28] Successful arthrodesis depends mainly on technique and the availability of adequate bone to accomplish fusion. The success of arthrodesis can be as low as 50% when it is used to salvage an infected hinge prosthesis[1] (Fig. 3). Significant bone loss is often associated with removal of these implants, making the remaining bone stock inadequate to attain successful fusion. Successful arthrodesis has been accomplished in as many as 90% of the cases in which surface replacements were utilized and bone stock was well preserved.[22,28]

The indications for arthrodesis are (1) complete destruction of the extensor mechanism by infection, rendering the patient incapable of actively extending the knee; (2) a resistant bacterial infection that requires high toxic doses of antibiotic therapy to reach adequate bactericidal levels; (3) a knee with inadequate bone stock for placement of a new total knee prosthesis; (4) a knee with inadequate soft-tissue coverage and multiple incisions that may compromise future wound healing; and (5) a young patient in whom the likelihood of subsequent infection or revision is great.

Fig. 3 Hinged prosthesis with severe periprosthetic bone loss.

Arthrodesis may be accomplished by different techniques. Adequate bacteriologic control of the wound should be obtained beforehand. We do not recommend performing arthrodesis at the time of the original debridement, as the risk of persistent infection is high in the setting of active wound sepsis when metallic implants are needed to accomplish fusion. Therefore, we perform arthrodesis in a staged manner. However, some advocate immediate arthrodesis.[28]

Our protocol is as follows: The first stage involves complete removal of the prosthesis and cement, along with complete wound debridement. The second stage involves a 4- to 6-week course of intravenous antibiotic therapy, maintaining a minimum bactericidal concentration of 1:8. Arthrodesis is then performed as the final stage.

External fixation and intramedullary rod fixation are two methods of arthrodesis particularly applicable to this clinical situation. External fixation is particularly appropriate in patients who have an ipsilateral total hip replacement above the affected knee joint and in patients with an especially virulent microorganism.

In the second method, a curved intramedullary rod is placed through the knee joint from the greater trochanter of the femur down to the distal aspect of the tibia just above the malleoli. The widest-diameter rod that can fit in the tibial intramedullary canal should be used. Although Puranen et al[28] believe that no secondary bone grafting is needed with this technique, adequate bone may be obtained from the anterior tibial flare or the patella to aid fusion. Care should be taken to provide adequate bone contact between the femur and the tibia. Postoperatively, the patient may begin ambulating immediately without the need for external supports. Puranen et al reported the success of intramedullary arthrodesis in 33 patients. Fifteen patients had failed total knee replacements, eight of which were infected. In the 33 cases, four nails broke, three at the line of fusion and one in the area of an infected supracondylar pseudarthrosis. Therefore, protected weightbearing should be maintained until fusion is proved radiographically.

The advantages of arthrodesis as treatment for an infected total knee replacement are that it is a definitive treatment for the infection with little chance of recurrence and that it promises reasonably good long-term function without the risk of future mechanical failure. The disadvantages of arthrodesis are inability to bend the knee; difficulty in transferring from a car or sitting in a small space, such as an airplane; and the large increase in the energy required to walk with a stiff knee, which may be a particular problem for patients with cardiovascular and pulmonary problems.

Two-Stage Reimplantation

The most successful functional results for the treatment of late infection of a total knee replacement are obtained by a technique of two-stage reimplantation of a new total knee replacement,[3,16-18,29,31] with success

rates averaging 90%. This method represents the procedure of choice to definitively eradicate the infection and preserve knee function.

Adequate preoperative planning is necessary and the availability of special instruments is recommended. Removal of the prosthetic components and acrylic cement can prove difficult, particularly if the septic process is of recent onset. In this case, the prosthetic components will most likely be well fixed, and removal of the tight interdigitation between bone and cement demands meticulous technique in order to prevent unnecessary loss of bone stock. The removal of hinged total knee replacements with intramedullary stems in the femur and tibia can also prove difficult. For these cases, special cement osteotomes and a high-speed cement drill are helpful.

Surgical Protocol

The protocol involves three stages.[16,19] The patient must be in good general medical health to withstand the rigors of all the stages.

The first stage of the protocol involves complete debridement of all infected tissues, along with removal of the implants and all cement. All scarred, inflamed, and devitalized tissues should be thoroughly excised, leaving viable, healthy, well-vascularized tissues. Primary wound closure can usually be performed over closed suction tubes, which are removed after 24 to 48 hours. The knee is immobilized in a bulky Robert Jones dressing with plaster splints. During this initial debridement, a central intravenous access catheter (e.g., a Broviac or Hickman catheter) is introduced into the internal or external jugular vein to facilitate intravenous administration of antibiotics.

The dressing is changed after a few weeks to a hinged brace, with the knee in full extension or 5 degrees of flexion. Skeletal traction is not advised, and the bone ends are left in contact to reduce dead space. Some surgeons recommend the use of antibiotic-impregnated spacers to preserve the joint space and to facilitate wound exposure during the reimplantation stage of the protocol.[31,32] The spacer block does represent a foreign body in the knee joint, however, and would remain in place in the event of a medical complication.

The second stage involves a 6-week course of intravenous antibiotic therapy, based on the results of culture and sensitivity studies. Antibiotics are chosen to yield high bactericidal effect with low toxicity. The infectious disease consultant follows the minimum bactericidal concentrations and weekly examines the efficacy of the antibiotic blood concentration against the bacteria available on the culture media. A minimum bactericidal concentration of 1:8 must be maintained for the 6-week period. The time between the first and last stages of the protocol may be prolonged if this minimum bactericidal concentration is not achieved.

After 6 weeks, if the wound is completely benign and the patient has had an uneventful postoperative period, another total knee prosthesis may be inserted.[16,33] However, if the wound still shows signs of inflammation, reimplantation is postponed; a long cylinder cast is applied, and the patient starts ambulation and is discharged home as soon as he is independent.

Further inspection of the wound is made a month later. If it is benign, reimplantation is considered. Alternatively, the knee joint fluid may be serially aspirated after discharge to determine whether there is persistence of infection.

The last stage of the protocol involves implantation of a new total knee replacement. Frequently, a modular prosthesis is used, which enables the surgeon to reconstruct any bone loss by adding metal wedges to the tibial component and distal and/or posterior augmentation to the femoral component. Frozen tissue sections and Gram stains are obtained at the time of surgery to assess tissue inflammation. The macroscopic appearance of the wound should be completely benign; all scarred and devitalized tissue is excised, leaving only viable, well-vascularized, healthy tissues. Exposure can sometimes be difficult after prolonged immobilization; there is a danger of avulsing the tibial tubercle while attempting to mobilize the patella and flex the knee. If this event seems likely, either a quadriceps snip or a turndown is used.

Preoperative planning is essential in order to have adequate prosthetic components available. A special custom-designed prosthesis is occasionally necessary. In most cases, proper alignment can be reestablished with adequate tissue tension and the use of press-fitted fluted intramedullary rods. The proximal end of the tibial component and the distal end of the femoral prosthesis are cemented. Some surgeons cement the prosthesis completely.

Excision of the patella has proved helpful in cases in which the skin closure was too tight. If the patella has insufficient bone stock to accept a prosthesis, it may be left unresurfaced. Normally, reconstruction can be achieved using standard designs that provide a substitution for the posterior cruciate ligament; in some cases, designs that preserve the posterior cruciate ligament are used.

In our experience, revision arthroplasty in a wound without an acrylic spacer block may be accomplished with only slightly greater difficulty than in one with a spacer. Other surgeons believe the use of acrylic spacers makes later surgery

significantly less difficult. They also feel that the extension of the spacer into the suprapatellar pouch reduces scarring.

The use of constrained components is often unavoidable. When this is the case, a constrained condylar knee prosthesis (e.g., the Total Condylar III) is selected; such a device has intramedullary stems on both components and restricts varus/valgus, anteroposterior, and rotary motions by means of a centrally positioned peg. Intramedullary stems are fitted in a modular fashion to the femoral or tibial prosthesis and are press-fitted into the intramedullary canal. While a stemmed component in the tibia, femur, or both is required because of bone deficiency, constraint at the prosthetic surfaces is not automatically required unless there is uncontrollable ligamentous instability.

The use of antibiotic-impregnated cement has been recommended for reimplantation after infection.[31,34] However, the effectiveness of this technique in preventing reinfection has not been statistically proved.

Postoperative Management

Postoperative management after reimplantation is the same as that used after a primary arthroplasty unless a quadriceps turndown was done to facilitate exposure. In this event the knee is immobilized with plaster splints for 3 weeks before motion is begun. On the assumption that the knee is sterile at the time of reimplantation, there is no need for prolonged antibiotic therapy. Perioperative antibiotics are administered for 4 days until the final operative culture readings are obtained, after which time no additional antibiotics are given. In most cases the antibiotic that is used for the 6-week course is continued through the postoperative period, and additional antibiotics may be given to provide broader antimicrobial coverage during the reimplantation procedure.

Results

Since 1977, it has been the policy of the knee service at our institution to implant a new prosthesis whenever possible. Between January 1977 and December 1985, 48 patients in whom 52 total knee arthroplasties were complicated by infection were admitted for treatment.[16] Four patients had bilateral infections. Thirteen patients (14 knees) were excluded from study for a variety of reasons. The reasons for exclusion can be reduced to a few: (1) patient preference, (2) antibiotic toxicity risk, (3) medical infirmity, and (4) inadequate skin viability and extensor mechanism function.

With an average follow-up time of 4 years (range, 2.5 to 10 years), 37 of 38 knees were successfully treated without recurrence of the original infection (97% success rate). In the 37 patients who underwent the procedure, there were 11 excellent, 13 good, 6 fair, and 7 poor results, based on the Hospital for Special Surgery Score. The reasons for the poor results were reinfection by a different organism and compromise of extensor mechanism function with persistent pain. Overall function was well maintained in the group, with a range of motion averaging 95 degrees (range, 80 to 120 degrees). Twenty-three patients complained of some pain when walking, 15 patients had mild pain, 6 patients had moderate pain, and 2 patients had severe pain. All patients underwent reimplantation of a cemented prosthesis, which frequently had press-fitted intramedullary stems.

Although Insall et al[18] cautioned against using this protocol for reimplantation in the presence of Gram-negative infection, it has been more recently shown by Windsor et al[16] that it is feasible to perform this protocol when certain sensitive Gram-negative infections are present. *Escherichia coli* and *P aeruginosa* infections have been successfully treated with this protocol, and the presence of newer nontoxic bactericidal agents has made it possible to eradicate these Gram-negative infections.

Other authors have tried to accomplish successful reimplantation by utilizing shorter periods of intravenous antibiotic therapy. However, Rand and Bryan[3] found a 2-week course of therapy totally unacceptable in definitively eradicating the infection. Borden and Gearen[17] studied a small number of infections that had been treated with a 4-week course of intravenous antibiotics. The overall results fell between the poor results reported by Rand and Bryan[3] with a 2-week course and the excellent results obtained by Windsor et al[16] and Insall et al.[18] Therefore, use of a 6-week course of intravenous antibiotic administration can ensure success in the majority of patients with an infected knee prosthesis, with a 97% overall success rate in eradicating the original infection.[16,18,29,31]

It is our opinion that the most successful method of treating infection of a total knee replacement with definitive eradication of the bacteriologic organism is by the two-stage reimplantation procedure. This protocol requires meticulous attention to detail by the surgical and infectious disease staff, but a predictable outcome can be ensured in most cases.

Amputation

Amputation may be the final salvage procedure for severe infections that are associated with large-bone loss and compromised antibiotic treatment.[30] This procedure was required most frequently in infected knee

replacements with cemented, stemmed hinges, which for the most part have become obsolete. The remaining shell of bone was frequently inadequate for subsequent arthrodesis or reimplantation, making the limb essentially flail. Amputation may be the only option in patients with mixed infection for whom antibiotic treatment has proved inadequate or in whom there is such massive tissue destruction that knee function is unsalvageable. This frequently occurs with mixed infections in which multiple abscesses and sinus tracts are present and significant destruction of the surrounding soft-tissue sleeve and muscle occurs. If successful treatment cannot be accomplished in any other way, a successful above-knee amputation may provide the best function for patients who otherwise would have a functionless knee joint and distal extremity.

Summary

Successful treatment of the infected total knee replacement represents the most difficult form of revision surgery. A two-stage reimplantation procedure for treating this condition has been the most successful functional option and should be utilized whenever possible to definitively eradicate the infection and ensure good function of the knee joint. It is the procedure of choice for younger healthy patients who can medically tolerate the protocol. Other options may be necessary, depending on the medical condition of the patient. Initial debridement with antibiotic suppression should be considered only in infected total knee replacements during the first 2 to 3 weeks after the operation. Antibiotic suppression is limited to the small minority of patients medically unable to tolerate further surgery and to those few patients with acute hematogenous infection of 24 to 48 hours' duration in whom the infecting organisms are exquisitely sensitive to antibiotics.

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