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Revision Total Knee Arthroplasty: What the Practicing Orthopaedic Surgeon Needs to Know

By David J. Jacofsky, MD, Craig J. Della Valle, MD, R. Michael Meneghini, MD,
Scott M. Sporer, MD, and Robert M. Cercek, MD

An Instructional Course Lecture, American Academy of Orthopaedic Surgeons

Total knee arthroplasties are done commonly, and the overall results are excellent, with 95% of the implants surviving for at least fifteen years^{1,2}. The 5% that fail represent a substantial number, and orthopaedic surgeons are seeing an increasing number of patients who initially had a successful total knee replacement but then had pain, radiographic evidence of failure, and/or dysfunction due to failure of the arthroplasty. Extensive bone loss, instability, infection, dysfunction of the extensor mechanism, and periarticular arthrofibrosis are frequent challenges encountered during revision surgery. A systematic approach to the evaluation of patients requiring revision total knee arthroplasty can help identify the correct diagnosis and guide the surgical intervention, thereby optimizing success.

Before doing a revision, the surgeon should know the cause of the pain in a patient who has had a total

knee arthroplasty. A revision total knee arthroplasty done for unexplained pain has a very low probability of success³. The surgeon should identify the current implants by reading the previous surgical records. Medical comorbidities should be appropriately managed so that the patient can be in the best health before a revision is done. Sometimes revision surgery is contraindicated, such as in a patient with Charcot arthropathy or neuromuscular disease. Wound-healing after revision total knee arthroplasty is critical to success and is often more difficult to achieve than it is after a primary total knee replacement. If there is doubt about soft-tissue coverage and/or viability, use of a rotational muscle flap or consultation with a plastic surgeon should be considered.

Preoperative Evaluation

The causes of dysfunction and pain after total knee arthroplasty are numerous⁴⁻⁶. There are two broad categories to

consider: extrinsic (extra-articular) and intrinsic (intra-articular). Extrinsic sources of pain include the ipsilateral hip, the lumbar spine (stenosis or radiculopathy), soft-tissue inflammation (pes anserinus bursitis or iliotibial, patellar, or quadriceps tendinitis), complex regional pain syndrome, neuroma, vascular claudication, fracture (tibial stress fracture, patellar stress fracture, femoral stress fracture, or traumatic fracture), and rarely an intrapelvic lesion compressing the medial or lateral femoral cutaneous nerve. Intrinsic sources include aseptic loosening, polyethylene wear, osteolysis, malalignment, instability (coronal instability, flexion instability, or global instability), infection, implant fracture, arthrofibrosis, soft-tissue impingement, component overhang, and dysfunction of the extensor mechanism (instability, fracture, maltracking, lateral patellar facet impingement, excessive component construct thickness, patella baja,

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and patellar or quadriceps tendon rupture). A working and complete knowledge of this list improves one's ability to correctly determine the cause(s) of failure.

History and Physical Examination

The history and physical examination are critical first steps in the evaluation of patients with pain after a total knee arthroplasty, and often they alone allow identification and/or elimination of the majority of pathologic etiologies. The primary symptom should be clearly defined (pain, swelling, instability, or stiffness), as should the time of onset, the duration, and the frequency of the symptoms as well as any activities that are associated with them. Pain that was present prior to the surgery and has persisted without change suggests an extrinsic etiology. Pain that began within the first year after the surgery suggests infection, malrotation, or soft-tissue impingement. Pain that began after a year suggests wear, osteolysis, loosening, or infection (acute hematogenous or late chronic). Comorbid conditions, such as diabetes, peripheral vascular disease, and lumbar stenosis, should be considered. The physical examination should include visual inspection; careful palpation (for swelling or point tenderness); stability testing in extension, midflexion, and 90° of flexion^{7,8}; and evaluation of patellofemoral stability, including palpation of the patella and its retinaculum. The surgeon should (1) watch the patient walk; (2) measure the active and passive ranges of knee motion; (3) evaluate patellar tracking (patellar clunk refers to impingement of scar tissue on the undersurface of the quadriceps tendon as the knee extends from a flexed position; this is less common with modern trochlear and femoral box designs⁹); (4) perform a thorough neurovascular examination with careful assessment of quadriceps and vastus medialis obliquus strength and the quality and symmetry of peripheral pulses; and (5) examine adjacent joints, including the hip, lumbar spine, foot, and ankle (a planovalgus foot deformity can lead to failure of a cruciate-retaining arthroplasty¹⁰).

Radiographic Evaluation

Examining plain radiographs can reveal many of the intrinsic causes of pain in a patient who has had a total knee arthroplasty, and examining a series of radiographs made over time, including preoperatively, can be particularly useful. Hip-to-ankle weight-bearing anteroposterior, lateral, and Merchant views of the knee and radiographs of the ipsilateral hip should be evaluated. The anteroposterior radiograph should be scrutinized for evidence of polyethylene wear; osteolysis; radiolucent lines; and overhang, subsidence, or a change in the position of the tibial component. The lateral radiograph should be assessed for the femoral component size, posterior femoral offset, patellar height and thickness, and tibial component slope and subsidence. The Merchant radiograph should be evaluated for patellar tilt, malalignment, femoral overhang, lateral patellofemoral impingement, and patellar composite thickness. Serial radiographs are invaluable for determining subtle signs of loosening, such as late progression of radiolucent lines, changes or fractures in the cement mantle, progression of osteolysis, or subtle change in component position.

Fluoroscopic examination may be useful for evaluating the interface in cementless arthroplasty designs. The extent of osteolytic lesions is seen better on computed tomography or magnetic resonance imaging with metal artefact suppression, but these modalities are not universally available¹¹. Computed tomography and magnetic resonance imaging can also be used to accurately assess the rotation of the femoral and tibial components; the femoral component is compared with the transepicondylar axis, and the tibial component is compared with the medial third of the tibial tubercle. Excessive internal rotation of either component can be associated with patellar instability¹² and lateral flexion laxity¹³, leading to poorer clinical function. Radionuclide scans may help in the diagnosis of aseptic loosening, infection, complex regional pain syndrome, and periprosthetic stress fractures. These scans are non-specific and may be falsely positive in

the first few postoperative years; a technetium bone scan demonstrates increased uptake around 90% of tibial and 65% of femoral components at one year after total knee arthroplasty¹⁴. The value of radionuclide scans in the diagnosis of infection has been explored with mixed results¹⁵⁻¹⁷. Technetium bone scans are sensitive but unable to differentiate septic from aseptic failure. Indium¹¹¹-labeled white-blood-cell scans have value for the exclusion of infection when they are negative, and their specificity is optimal when they are combined with sulfur colloid bone marrow scans to correct for marrow packing in the vicinity of prosthetic components. Positron emission tomography and magnetic resonance imaging may be useful for the diagnosis of infection; however, their utility has not yet been determined. Given the ease, accuracy, and low cost of knee joint aspiration and synovial fluid analysis and culture, advanced imaging should be utilized only for second-line testing—i.e., if no fluid can be obtained with an aspiration or if repeated aspirations lead to equivocal findings.

Preoperative Laboratory Testing

Every patient who presents with a failure of, or pain following, a total knee arthroplasty must be evaluated for a deep periprosthetic infection. Even if the cause of failure seems obvious, concomitant infection may be present and treatment of an infection-related failure of a total knee arthroplasty is fundamentally different from the treatment of aseptic failure. The patient's medical history and the history surrounding the index arthroplasty may suggest an infection. Patient-related risk factors include diabetes mellitus, inflammatory arthritis, obesity, a history of septic arthritis of the native knee, skin disorders, prior ipsilateral knee surgery, revision as opposed to a primary procedure, malnourishment, renal insufficiency (especially when it requires dialysis), and any immunocompromised state. The patient should be specifically questioned regarding the presence of wound-healing problems immediately following the surgery, the extended use of antibiotics, or a return to the

operating room, as the patient may not understand the importance of such events with regard to the present pain symptoms. Lack of pain relief since the operation, particularly if the character of the pain is different from that experienced preoperatively, increases the clinical suspicion of infection, as does a recent systemic illness (particularly if it was associated with bacteremia), which may indicate hematogenous infection. Finally, early loosening of a prosthetic component (within the first two to five years postoperatively) should be considered suspicious for infection.

Basic laboratory testing includes evaluation of the erythrocyte sedimentation rate and C-reactive protein level. These are sensitive tests for identifying infection, and it is unlikely both will yield normal results if there is an infection¹⁸; thus, they are ideal screening tools for the identification of patients who require additional testing. If either test is abnormal or clinical suspicion remains high, the joint should be aspirated and the aspirated fluid should be sent for Gram stain, culture, and a synovial fluid white blood-cell count and differential. The patient should not receive antibiotics for a minimum of two weeks prior to the aspiration to optimize the culture results¹⁹. The aspiration should be repeated if clinical suspicion remains high. A synovial fluid white blood-cell count of between 1100 and 3000 cells/mm³ from the site of a total joint arthroplasty is strongly suggestive of an infection²⁰⁻²². This is much lower than the 50,000 to 100,000 cells/mm³ range that suggests an infection in a native knee. The percentage of neutrophils in the aspirated fluid is also an accurate predictor of infection. If the percentage of neutrophils is between 60% and 80%, infection is likely. When the white blood-cell count is <1100 cells/mm³ and the percentage of neutrophils is <64%, the negative predictive value is 98.2%; on the other hand, when both are greater than these values the positive predictive value for infection is 98.6%²³. Determining the white blood-cell count in aspirated fluid has a low cost, is objective, can be performed preoperatively or intraoper-

atively, and is available to surgeons worldwide.

Intraoperative Laboratory Testing

Both intraoperative appearance and intraoperative Gram stains have been shown to have low sensitivity²⁴ and should not be relied on for the diagnosis of periprosthetic joint infection. Histopathologic examination of periprosthetic tissues has been shown to be useful for diagnosing infection²⁵; however, for this examination to be accurate a skilled pathologist must be available. The histologic criteria for diagnosing infection are controversial, but in general an average of more than ten polymorphonuclear cells per high-power field is diagnostic for infection. The most suspicious-appearing areas should be sampled, and the leukocytes must be in tissue (and not fibrin) to be counted. The possibility of an occult infection should be discussed with the pathologist so that the synovial tissue can be prepared and interpreted properly.

Preoperative Planning

The surgeon should thoroughly review the radiographs, while remembering that the degree of bone loss surrounding the components is underestimated on the basis of plain radiographs²⁶. The function of the extensor mechanism should be ascertained prior to surgery. A preoperative extension lag may be due to relative shortening of the lower extremity secondary to component loosening or catastrophic bearing failure and a subsequent loss of resting tension. This type of extension lag can improve with revision surgery. Conversely, chronic quadriceps or patellar tendon dysfunction may require augmentation with an extensor mechanism or Achilles tendon allograft at the time of the surgery. The surgeon should assess the appropriate height of the joint line to improve the kinematics of the knee. Radiographs available from before the index arthroplasty or radiographs of the native contralateral knee help to determine the anatomic location of the joint line and the amount of posterior femoral offset in a given patient. Patella baja is frequently encountered during

revision surgery and may be a result of an intrinsic contracture of the patellar tendon. Not infrequently, distal femoral augmentation is required in revision surgery to avoid excessive elevation of the joint line. The joint line can be approximated on the basis of the fibular head, the femoral epicondyles, or the superior pole of the patella in relation to the superior aspect of the trochlear groove.

Isolated patellar revision²⁷ or tibial polyethylene exchange²⁸ is rarely indicated as they do not usually address the underlying failure mechanism, which is often component malposition. The indications for arthroscopy for a patient with pain related to a total knee arthroplasty are also very limited. Some authors have reported successful arthroscopic lysis of adhesions for the treatment of arthrofibrosis²⁹, and others have reported successful arthroscopic débridement in cases of soft-tissue impingement, such as patellar clunk³⁰ or popliteus tendon impingement³¹.

Surgical Technique

Exposure

Adequate exposure is essential for a successful surgical reconstruction. The exposure must allow complete exposure of the implant, a thorough débridement of osteolysis, visualization of the remaining bone stock, and reimplantation of the components. Exposure can be quite challenging in the presence of arthrofibrosis, osteoporotic or osteolytic bone, patella baja, and/or obesity.

The medial parapatellar arthrotomy is the workhorse of revision total knee arthroplasty³²; however, a previous lateral arthrotomy may dictate a repeat lateral approach in order to avoid patellar osteonecrosis. Often, only a single incision was used previously, and this incision can generally be employed for the revision surgery. The incision may be straight and anterior, medialized, or curvilinear. If a transverse or oblique incision was used, it should be crossed at the most obtuse angle possible to minimize wound-healing complications at the corners created by this intersection. If multiple longitudinal incisions were utilized, the more

lateral incision should generally be used, as the blood supply travels from the medial to the lateral side of the knee³³. However, if all incisions were made more than two years previously and did not involve a surrounding soft-tissue flap, the surgeon should choose the one that is most advantageous for the revision surgery. A minimum 6-cm skin bridge should be maintained if previous incisions cannot be utilized. When there is excessive tension on the skin edges, making the incision longer is advisable, full-thickness flaps should be made, and undermining of tissue should be avoided.

During the exposure, previously placed sutures should be removed as part of the débridement whenever possible. The medial and lateral gutters are recreated, and the suprapatellar pouch is freed of fibrotic tissue to assist with mobilization of the extensor mechanism. In cases of arthrofibrosis and stiffness, a quadricepsplasty is beneficial to free the extensor mechanism from the anterior aspect of the femur³⁴. A release of the soft-tissue adhesions between the anterior aspect of the tibia and the patellar tendon proximal to the level of the tubercle insertion will also improve patellar mobilization. Patellar subluxation (as opposed to eversion) is generally sufficient to allow adequate exposure of the knee. The extensor mechanism must be protected throughout the procedure, as fibrosis, osteolysis in the region of the tibial tubercle, and multiple prior surgical procedures place the extensor mechanism at risk for iatrogenic avulsion. A copious medial release to the posteromedial corner of the tibia should then be performed if component revision is required; this allows tibial external rotation and anterior subluxation for removal of the polyethylene liner. This step is often referred to as an "MCL slide." The polyethylene insert is then removed to improve the surgeon's ability to mobilize the soft tissues, and in many cases this provides sufficient exposure for revision surgery³⁵.

A more extensile approach should be considered if patellar subluxation persists and/or visualization of the

components remains difficult. The quadriceps snip is the first option for improvement of exposure. It is particularly helpful in patients with patella baja. It consists of an oblique apical extension of the arthrotomy from the superomedial capsulotomy, and it continues proximally and laterally, exiting the quadriceps tendon laterally and splitting the fibers of the vastus lateralis obliquus. This improves patellar eversion, knee flexion, and lateralization of the extensor mechanism. The quadriceps snip should exit the quadriceps tendon distal to the musculotendinous junction of the rectus femoris muscle (Fig. 1). Proximal extension of the arthrotomy beyond the tendon prior to the oblique snip will lead to transection of a portion of the rectus femoris fibers and should be avoided. As the closure is nearly identical to a normal capsular closure and there is no change in postoperative rehabilitation or outcome³⁶, the quadriceps snip may be used liberally to improve exposure.

If exposure is still inadequate, an extended tibial tubercle osteotomy can be performed. It is most useful in the presence of patella baja, for the removal of a cemented tibial stem, and in cases of extensor mechanism maltracking and tibial tubercle malposition that require correction³⁷. The tibial tubercle osteotomy is a long osteotomy—that is, at least 8 cm in length. Ideally, a proximal shelf of bone is left to prevent proximal migration of the osteotomy fragment (Fig. 2); in practice, however, extensive osteolysis, or the need to move the tibial tubercle proximally, often obviates one's ability to leave a structurally sound proximal shelf. The osteotomy is made along the proximal and medial aspect of the tubercle and is hinged about the lateral side with osteotomes. The soft-tissue sleeve is left intact laterally, and the osteotomy is repaired with cerclage wires at the time of closure. Holes for these wires can be predrilled prior to the osteotomy being hinged open. When the patient has reasonable bone stock, no alteration in postoperative rehabilitation is necessary. Although there may be symptoms related to the hardware,

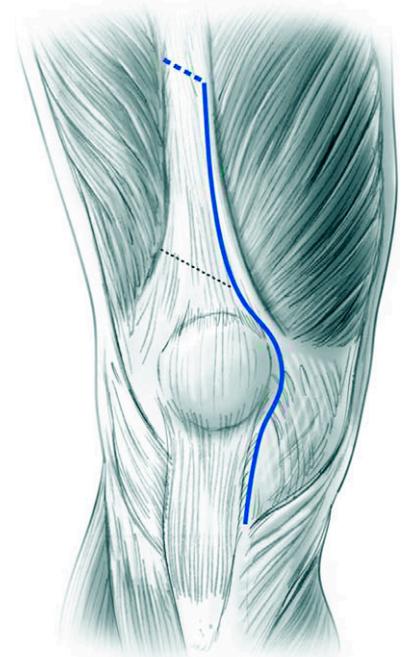


Fig. 1
Illustration depicting a medial parapatellar arthrotomy (solid line) and quadriceps snip modification (blue dashed line). It is important to keep the longitudinal incision in the tendon and to extend it proximally to the top of the tendon before creating an oblique incision (quadriceps snip) at the proximal extent of the tendon. A transverse or oblique incision across the quadriceps tendon closer to the patella (black dashed line) must be avoided as this may be associated with postoperative extensor mechanism disruption. (Reprinted from: Nelson CL, Kim J, Lotke PA. Stiffness after total knee arthroplasty. Surgical technique. *J Bone Joint Surg Am.* 2005;87 Suppl 1[Pt 2]:264-70.)

nonunion is extremely rare unless the prosthetic site is infected³⁸.

If improved exposure of the components is still required, a medial femoral peel may be performed. This provides outstanding exposure of both the femoral component and the posterior aspect of the femoral condyles. It is often necessary when contraction of the medial side is found, such as during reimplantation following an infection and the use of static spacers. The medial femoral peel can be performed with cautery, achieving a subperiosteal removal of the origin of the medial

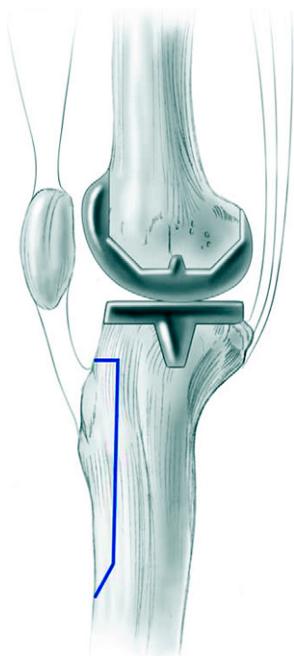


Fig. 2
Illustration depicting a tibial tubercle osteotomy site from the lateral view, emphasizing the transverse nature of the proximal extent of the osteotomy and the oblique nature of the distal extent of the osteotomy. (Reprinted from: Nelson CL, Kim J, Lotke PA. Stiffness after total knee arthroplasty. Surgical technique. J Bone Joint Surg Am. 2005;87 Suppl 1[Pt 2]:264-70.)

collateral ligament and the soft tissues around the medial side of the knee. It is imperative to keep the entire medial sleeve intact, from the region of the extensor mechanism proximally to the superficial medial collateral ligament distally, as this is critical to the maintenance of medial-sided stability. No alteration of postoperative rehabilitation is required³⁹. A medial epicondylar osteotomy can be performed in more severe cases, but generally it is not required unless a malunion is present. Should an epicondylar osteotomy be required, one must be certain that osteolysis of the medial femoral condyle is minimal, as extensive osteolysis may result in a large uncontained femoral bone defect.

In general, the most useful approach for the majority of revision procedures is a generous medial collateral ligament release to the posterior

aspect of the tibia, in conjunction with a quadriceps snip. A tibial tubercle osteotomy is a useful extensile approach for the removal of a cemented tibial stem or the correction of patella baja, and in cases of severe arthrofibrosis, such as during reimplantation total knee arthroplasty, a medial femoral peel may be required. In rare cases, a traditional V-Y turndown of the quadriceps may be indicated; however, this is now generally reserved for severe quadriceps tendon contracture. The turndown should never be used in a knee with multiple previous operations, a history of quadriceps fibrosis, or a previous infection (e.g., during reimplantation)⁴⁰. A fibrotic extensor mechanism may fail at the closure of the V-Y turndown, and quadriceps necrosis has been reported after this exposure. Additionally, a post-operative extension lag is frequently a result even in patients in whom an initially contracted extensor mechanism required lengthening to achieve an adequate range of motion.

Component Removal

Once adequate exposure has been obtained, the bone-cement or bone-implant interfaces of all three components should be fully exposed with a needle-nose rongeur. The components should be evaluated for loosening, malposition, or impingement. The determination of which components to revise depends on these findings and the preoperative diagnosis. The components can be removed with osteotomes, a Gigli saw, or a small oscillating saw. A thin narrow blade should be used for precise steering and to minimize inadvertent soft-tissue damage.

The interface beneath the tibial tray is disrupted with use of the saw from the medial and anterior sides. A small thin osteotome is then used to reach the far lateral side; placing the knee in extension can also improve access. Extensive damage to the bone may occur if the interface between the implant and the host bone is not fully developed. Even if the components appear grossly loose radiographically, the soft-tissue attachments and fibrous tissue must be released from the implant

prior to implant removal. The area between the tibial tray and the proximal tibial tubercle often contains fibrotic tissue. It should be exposed and débrided with a curved osteotome or cautery. In the case of a non-stemmed total knee prosthesis, a slap hammer or stepped impactor can then be used to remove the tibial tray. Osteotomes should not be used to lever the implant off the tibia, as even a relatively loose tibial component may be stronger than the surrounding osteoporotic bone, leading to a tibial fracture or unnecessary bone damage. If there is a cemented stem, a tibial tubercle osteotomy, as described previously, can be performed if necessary; however, axial impaction of the tibial tray often allows removal of the stemmed component, leaving the cement mantle behind. Cement removal is then performed; this may require use of ultrasonic equipment or specialized osteotomes.

The femoral component is addressed in a similar fashion. The interface is disrupted with a small oscillating saw. A slap hammer can be placed distally or a stepped impactor can be placed on the anterior flange, but it must be driven in a collinear manner to avoid a flexion moment and condylar fracture. A Gigli saw is quite popular for removal of components; however, one must use caution, as the saw will generally follow the path of least resistance and can often inadvertently remove excessive portions of bone from the anterior aspect of the femur. After the femoral component is removed, additional soft tissue along the posterior aspect of the tibia can be released to allow further anterior tibial subluxation.

Should a long, well-fixed cemented stem be present on the femoral or tibial side, windows can be created in the tibial or femoral diaphysis to assist with dislodging the implant. Rarely, a metal cutting tool such as a high-speed diamond wheel is needed to separate the articular tibial or femoral component from the stem while leaving the stem in place for later removal. Trephines that approximate the size of the stem should be available to assist with stem removal.

Subsequent cement removal is done as described above.

Tibial Reconstruction

Once the components have been successfully removed, the surgical reconstruction should begin with the tibia, as the platform created will affect both the flexion and the extension gap equally⁴¹. A reverse hook and reamers should be used to remove any remaining fibrous membrane from the tibial canal. An intramedullary stem can then be used as a cutting guide if tibial deformity is not severe. Extramedullary guides may be preferred, especially if tibial bowing is excessive. Most systems include revision instrumentation that allows the proximal part of the tibia to be cut with use of a 0° guide (Fig. 3); this allows the bone resection to be performed independent of the rotational

position of the cutting guide. Bone loss may be managed with cement, cancellous allograft, structural cortical allograft, metal wedges and augments, or custom implants⁴². In general, surgical options that minimize the removal of additional bone should be utilized. The Anderson Orthopaedic Research Institute Bone Defect Classification helps in defining the severity of bone loss intraoperatively. Type 1 is minor femoral or tibial defects with intact metaphyseal bone not compromising the stability of a revision implant. Type 2 is damaged metaphyseal bone requiring femoral or tibial bone reconstruction (with cement, augments, or bone graft); Type 2A is involvement of one femoral or tibial condyle, and Type 2B is involvement of both condyles. Type 3 is a deficient metaphyseal segment compromising a major portion of

either the femoral condyle or the tibial plateau.

Custom implants are now rarely used because of their expense and the inability to modify them intraoperatively. Most patients undergoing revision have some degree of cavitory bone loss within the proximal part of the tibia. This defect can generally be filled with cement, if a stemmed tibial implant is used⁴³. Impaction bone-grafting provides support for the tibial baseplate if a peripheral cortical rim is present and may be preferable in younger patients⁴⁴. Bulk allograft or metal augments should be considered when larger structural defects are present. Bulk allograft can be used if a segmental defect is present that involves a large portion of the tibial plateau⁴⁵, while metal augmentation has gained popularity as a result of its ease of insertion, lack of resorption, and ability to be easily customized intraoperatively⁴⁶. In general, the metal augment has become the workhorse of revision knee arthroplasty. A tumor prosthesis is generally reserved for severe bone loss in elderly low-demand patients.

A stem extension can be used during both the tibial and the femoral reconstruction. Stem extensions transfer stress from the deficient proximal part of the tibia more distally to the intact diaphyseal bone⁴⁷. They also provide additional surface area for fixation and can assist with component orientation. The optimal length of a tibial or femoral stem extension remains controversial. In general, uncemented stems should engage diaphyseal bone and should bypass any metaphyseal-diaphyseal defects. Stems can be fully cemented or a hybrid fixation technique can be utilized, whereby the tibial baseplate and metaphyseal region are cemented and the stem extension is press-fit into the canal⁴⁸. Undersized uncemented diaphyseal stems and metaphyseal engaging stems have a higher rate of loosening and should be avoided⁴⁹. The main advantage of uncemented stems is easier removal in the future. Disadvantages of uncemented stems include the difficulty of their use in deformed tibial bone,

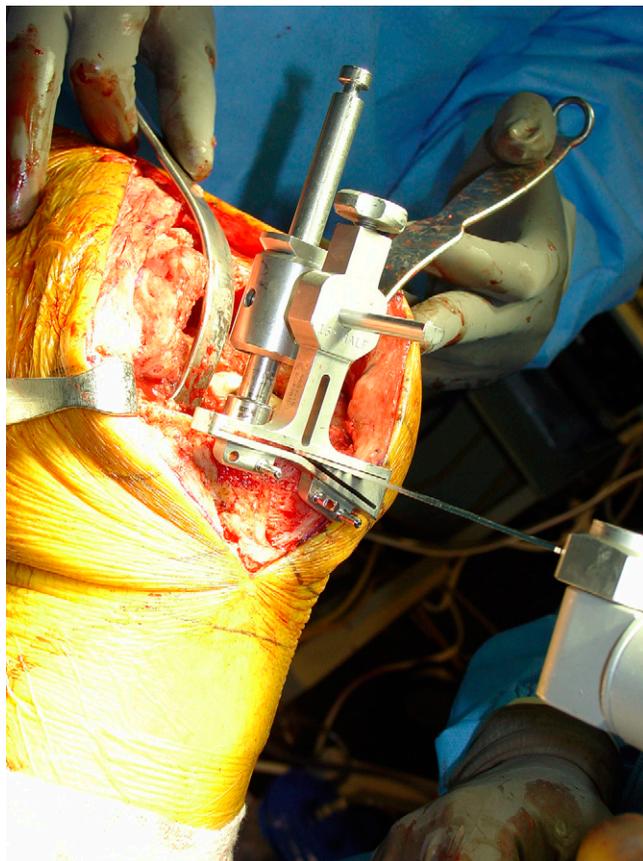


Fig. 3

A trial tibial stem can be used to hold the tibial cutting block. A minimal tibial resection that still provides a stable platform on which to rest the tibial component should be performed. The use of a 0° cutting block allows unlimited positioning of the saw capture without affecting the tibial cut.

occasional malalignment if excessive tibial bowing is present, the potential for pain at the stem tip, and their inability to fully offload the tibial plateau. Cemented stems allow improved surface area for cement interdigitation, but they are much more difficult to remove. Although cemented stems do not assist with alignment, as they do not fill the medullary canal, they can permit the use of an extramedullary cutting guide and a “perfect” proximal tibial cut without concern for the ability to seat an uncemented canal-filling stem in the presence of tibial bowing. Offset stem extensions offer the additional advantage of improved tibial coverage but are generally only needed if an uncemented stem is utilized. An offset tibial stem allows the implant to be placed anteriorly and laterally in relationship to the tibial canal. The optimal tibial component design is dependent on the degree of bone loss and associated ligamentous stability. Full block augments allow easier reconstruction of tibial defects than is possible with hemiblocks or wedges and may be preferred unless their use results in excessive bone resection. After reconstruction of the tibial side, the joint line should be within the midrange of polyethylene inserts available, and the final position is based on gap balancing and the femoral reconstruction.

Femoral Reconstruction

Femoral reconstruction begins once secure tibial fixation has been established. The surgeon should start with a thorough posterior capsular release before addressing any osseous defects. Tight posterior capsular structures result in an apparently loose flexion gap and a tight extension gap; removal of more distal femoral bone, which is usually the method for correcting this problem, can lead to inadvertent elevation of the joint line. Most femoral revisions require the use of a femoral stem extension. The degree of component valgus is generally between 5° and 6°. The femoral stem extension can be used to determine the coronal orientation. Most femoral revisions require augmentation of the distal part of the

femur to lower the joint line⁵⁰. Many revisions also require the use of a posterolateral augment to avoid inadvertent internal rotation of the femoral component. The transepicondylar axis remains a useful landmark to ensure appropriate component rotation. Additionally, more anterolateral than anteromedial bone should be exposed if femoral rotation is appropriate, although bone loss in this area often makes this guideline impossible to use. Severe femoral bone loss can be addressed with bulk structural allografts or the use of metal augmentation. While allografts have been used successfully in the past, metal augmentation is now common because of its relative ease of use and the avoidance of graft resorption. Type-3 femoral defects are typically associated with damaged or absent collateral ligaments, necessitating the use of a hinged component.

Undersizing of the femoral component, which is the tendency when there is femoral bone loss, should be avoided. An undersized femoral component results in a larger flexion gap and poor posterior femoral offset, leading to flexion instability and a limited range of motion. Once appropriate bone preparation has been completed, the long stem can be converted to a shorter, thicker stem. An offset stem can be used on the femur not only to improve coverage of the distal part of the femur, but also to allow adjustment of the implant posteriorly, which improves stability in flexion, or laterally, which improves patellar tracking. If a total hip prosthesis is present on the ipsilateral side, a femoral stem that allows a minimum of three cortical diameters between implants should be used to avoid creating a stress riser and the potential for an interprosthetic fracture.

The joint line should be recreated as close to the anatomic state as possible to optimize knee kinematics and stability⁵¹. The landmarks frequently used to assess the joint line may be absent during revision surgery because of bone loss and soft-tissue damage. Landmarks from which to choose include the previous meniscal scar, the fibular head (1 cm above), the inferior pole of the

patella (1 cm below), and the medial femoral epicondyle (25 to 32 mm below). The contralateral extremity should be examined as the height above the fibular head may be variable and the height of the patella may be altered by patella baja. The flexion gap generally opens more than the extension gap with a revision total knee arthroplasty; therefore, slight elevation of the joint line may be required to appropriately balance the flexion and extension gaps. Although restoration of the joint line is desirable, its importance is trumped by the need to balance the flexion and extension gaps, as there is a limit to how large an implant can be reasonably utilized to tighten the gap in flexion.

Patellar Reconstruction

The patellar component should be exposed and assessed during all knee revisions. The patellar component should be retained if it is well fixed, well positioned, and reasonably compatible with the revision femoral component. Removal of a well-fixed implant may result in bone loss and thereby preclude resurfacing and/or may result in subsequent patellar fracture. If the implant is loose, is incompatible with the femoral component, or shows severe wear, it should be removed. A sagittal saw is used to remove the articular portion of the implant, and a high-speed burr is utilized to remove the posts and cement. In some situations, the patellar remnant is <10 mm thick and will not accept an implant. A patelloplasty may be performed, or a so-called gull-wing osteotomy can be undertaken⁵².

Stability Assessment

Once the trial femoral and tibial components have been inserted, the knee is brought through a range of motion and its stability is assessed. The knee must have full extension, and the patella must track centrally throughout the range of motion. The stability of the knee should be assessed in full extension, midrange flexion, and deep flexion. Obtaining stability in both the coronal and the sagittal plane is crucial, but most instability patterns can be

addressed without the need for excessive constraint. A higher tibial post is generally sufficient in situations of unidirectional instability or a slight flexion-extension mismatch. One should use the least constrained insert possible to avoid increased stresses on the cement mantle. Longer stem extensions should be considered as the degree of constraint increases. A more constrained, hinge-type implant is reserved for patients with a marked flexion-extension mismatch, global instability due to collateral ligament insufficiency, or uncontrolled recurvatum⁵³.

Component Insertion

The technique of component insertion depends on the mode of stem fixation. If a fully cemented stem is chosen, a canal restrictor should be used to allow cement pressurization and limit distal extravasation. Cement should be applied to the undersurface of the tibial and femoral components as well as along the metaphyseal regions of the bone; small holes should be made in sclerotic cortical bone to improve cement interdigitation and fixation. It is crucial to examine the rotation of the tibial component during insertion, as inadvertent internal rotation is common.

Management of Infection at the Site of a Total Knee Arthroplasty

Treatment of an infection at the site of a total knee arthroplasty is most easily understood when one uses the classification described by Segawa et al.⁵⁴. This system describes four different clinical presentations of prosthesis-related infections.

Positive Intraoperative Cultures

This class includes patients in whom the cause of failure was thought to be aseptic but two or more of the intraoperative cultures are positive. Recent work has verified that a single positive culture does not necessarily indicate a need for treatment⁵⁵. It is wise to have an infectious disease specialist review such cases and help make the decision about whether further treatment is appropriate. Because of the potential for

this scenario, the routine use of antibiotic-loaded cement is recommended for all revision total knee arthroplasties. Recent work has shown a decreased risk of subsequent infection if antibiotic-impregnated cement is utilized⁵⁶. Furthermore, prophylactic antibiotic therapy should be continued for three days postoperatively or until the final culture results are known.

Acute Postoperative Infections

The treatment of an acute postoperative infection (a deep joint infection identified within the first four to six weeks after the arthroplasty) has become more controversial. The most commonly accepted treatment includes surgical débridement and exchange of the polyethylene liner, followed by six weeks of intravenous antibiotics and, at most centers, an additional course of oral antibiotics⁵⁷. However, recent series have shown that the rate of success of this regimen, particularly in patients who are infected with resistant and/or biofilm-producing organisms (such as *Staphylococcus*), is <20%⁵⁸. On the basis of these reports, patients should be counseled regarding the success of this approach and serious consideration should be given to component removal if the infecting organism is *Staphylococcus* and resistant to methicillin.

Late Chronic Infections

In North America, late chronic infections are most commonly treated with a two-stage exchange protocol. This is based on the results of multiple studies that showed a cure rate of approximately 90%⁵⁹⁻⁶¹. Attempts at débridement with retention of the components are associated with an unacceptable rate of failure, and this approach should not be used⁶². The first stage of the two-stage exchange protocol includes removal of all prosthetic components, all associated cement, and all infected-appearing tissues, followed by insertion of an antibiotic-loaded spacer that contains a minimum of 4 g of antibiotics per 40 g of bone cement (although the use of higher concentrations has been

reported)^{63,64}. The medullary canals of the femur and tibia should be opened, débrided, and lavaged, and intramedullary dowels of antibiotic-loaded cement should be inserted. The most commonly used antibiotics in the cement spacer are a combination of vancomycin and an aminoglycoside, as the combination of the two improves overall elution⁶⁵.

The spacer can be either static or articulating, and there is controversy over which approach is best. Studies suggest that the cure rates for the two are similar; however, a static spacer may be associated with more bone loss between stages, whereas an articulating spacer may allow limited weight-



Fig. 4
Postoperative lateral radiograph showing an all-cement articulating spacer constructed from plastic molds. Note the antibiotic-loaded cement dowels in the femur and tibia. The tibial dowel is incorporated into the tibial component to prevent it from dislodging.

bearing and joint motion, resulting in a greater final range of motion and higher knee scores⁶⁶. Regardless of the type of spacer used, the cement should extend into the metaphysis and antibiotic-loaded dowels should be placed into the medullary canals (Fig. 4).

Following removal of the implants, the patient is treated with a six-week course of organism-specific antibiotics. The erythrocyte sedimentation rate and C-reactive protein level are used to monitor treatment response. Although these values typically decrease in the face of successful treatment, they often do not return to normal even after the infection has been eradicated; they are not as reliable in identifying persistent infection as they are as an initial screening test, as outlined above⁶⁷. The knee is then aspirated and the aspirate is sent for a cell count and culture at a minimum of two weeks following cessation of the antibiotic therapy, although there is controversy regarding the value of cultures in this setting^{68,69}. If all data indicate that the infection has been eradicated, it is appropriate to proceed with reimplantation. Otherwise, a repeat débridement should be performed. At the time of surgery, specimens should be obtained for frozen-section analysis. Further débridement and lavage is performed, followed by the insertion of components with the use of standard-dose premixed antibiotic-impregnated cement. Intravenous administration of the antibiotics is once again continued postoperatively until negative results are obtained for all cultures. Antibiotic therapy may then be discontinued, although many surgeons prescribe oral antibiotics for an extended period of time (often for life).

Acute Hematogenous Infections

A patient is considered to have an acute hematogenous infection when a bacteremic event occurs at the site of a total knee arthroplasty that had previously been functioning well. Patients typically present with fever, acute severe pain, and the inability to bear weight on the extremity. Although only limited data on this subject are available, with most reports describing relatively small series of patients^{70,71}, it seems that many of these infections are associated with sensitive microorganisms; therefore, the recommended treatment is surgical débridement, modular polyethylene liner exchange, and component retention, followed by a six-week course of intravenous antibiotics (and potentially additional oral antibiotic treatment), particularly if the duration of symptoms has been short⁷². In practice, however, it is often difficult to determine exactly when the knee became infected, leading to an unclear distinction between an acute hematogenous and a late chronic infection. Failure is often associated with infection with a resistant staphylococcal organism, similar to the situation with early postoperative infection, and should be treated with a two-stage exchange.

Overview

The management of a failed total knee arthroplasty can seem quite daunting to the general orthopaedic surgeon, but with a systematic evaluation that includes a thorough history and physical examination, radiographs, and appropriate serologic testing, the etiology of the failure can be identified in the vast majority of cases. Infection must always be considered and ruled out. The etiology of failure then dictates the appropriate surgical intervention.

Useful adjuncts to the standard surgical exposure for total knee arthroplasty include a copious posteromedial release, the quadriceps snip, the tibial tubercle osteotomy, and the medial femoral peel. Care must be taken to minimize bone loss during component removal. Modular metal augments have proved to be very useful in the management of bone defects, and constraint should be minimized to the least amount necessary for a stable outcome. Finally, with the ever-increasing prevalence of drug-resistant organisms, strong consideration should always be given to a two-stage revision in the management of infection at the site of a total knee arthroplasty.

David J. Jacofsky, MD
Robert M. Cercek, MD
The Core Institute, 3010 West Agua Fria
Freeway, Suite 100, Phoenix, AZ 85027.
E-mail address for D.J. Jacofsky:
david.jacofsky@thecoreinstitute.com

Craig J. Della Valle, MD
Rush University Medical Center, 1611 West
Harrison Street, Suite 300, Chicago, IL 60612

R. Michael Meneghini, MD
University of Connecticut Health Center,
MARB 4th Floor, 263 Farmington Avenue,
Farmington, CT 06034

Scott M. Sporer, MD
1040 Golf Lane, Wheaton, IL 60189

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