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# Preoperative Evaluations in Revision Total Knee Arthroplasty

*Jonathan Baré, MD, FRACS*; Steven J. MacDonald, MD, FRCSC*; and Robert B. Bourne, MD, FRCSC**

**There are many causes of total knee arthroplasty failure, and an accurate preoperative diagnosis is essential to optimize the results of revision surgery. We discuss our standard preoperative evaluation routine and we retrospectively reviewed the last 295 patients who underwent revision total knee arthroplasty to establish the clinical value of the most commonly performed investigations used to diagnose sepsis. Routinely performed preoperative investigations include erythrocyte sedimentation rate, C-reactive protein, microbiology, bacteriology cultures of preoperative knee aspirations, and intraoperative tissue bacteriology cultures. Each investigation was compared with the reason for revision (eg, septic or aseptic) to establish the sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of each. 79 cases (26.8%) were revised for infection. Of the investigations, the ESR had a sensitivity of 0.63, a specificity of 0.55, a positive predictive value of 0.39, a negative predictive value of 0.77, and an accuracy of 0.57. The respective values for C-reactive protein were 0.6, 0.63, 0.45, 0.76, and 0.62, and 0.53, 0.94, 0.75, 0.85, and 0.83 for intraoperative tissue culture. There was no preoperative investigation accurate enough to be solely relied on for diagnosing infection. We believe that clinical findings and the routine use of simple tests such as C-reactive protein, ESR, and knee aspiration yield predictable results.**

**Level of Evidence: Prognostic study, level II-1 (retrospective study). See the Guidelines for Authors for a complete description of levels of evidence.**

From the *Division of Orthopaedic Surgery, University of Western Ontario, London, Ontario, Canada; and University Hospital, London Health Sciences Centre, London, Ontario, Canada.

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Each author certifies that his or her institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.

Correspondence to: Steven J. MacDonald, MD, FRCSC, 339 Windermere Rd., London, Ontario, Canada N6A 5A5. Phone: 519-663-3689; Fax: 519-663-3096; E-mail: steven.macdonald@lhsc.on.ca.

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Short-term and long-term failures for total knee arthroplasties (TKAs) along with increasing numbers of TKAs have resulted in an ever increasing requirement for revision total knee replacement surgery. The mode of failure will generally dictate the type of revision that is required. Therefore, an accurate preoperative failure diagnosis is imperative. Vince and Long described nine different categories of TKA failure (Table 1). These include sepsis; fracture; stiffness; component breakage; extensor mechanism rupture; malrotation and patellar instability; tibiofemoral instability; undiagnosed pain; loosening and progression of arthritis in a unicompartmental replacement.[26]

A thorough history, physical examination, and basic radiography (plain weightbearing anteroposterior [AP], lateral, and patella skyline radiographs) are sufficient to make a confident diagnosis in most cases. The cause of some failures is more difficult to diagnose and requires additional investigations. Sepsis can often be particularly difficult to distinguish between other causes of pain and stiffness.

We treat all septic failures with a two-stage revision total knee arthroplasty (TKAR), while aseptic failures are generally treated with a one-stage procedure. Deep infection is reported as a complication in 1.1–2.4% of patients.[8,16,25] Because of the greater success rate of two-stage TKAR for septic failures,[4,6,9,11,15,17,20,22] and the increased morbidity and cost of a two-stage procedure, we believe that it is vital to distinguish between the two groups preoperatively to plan for the appropriate surgery. The gold standard investigation for the diagnosis of infection remains intraoperative tissue bacteriology cultures.[1] However, there is no investigation that is 100% sensitive and specific.

We discuss our standard preoperative evaluation routine and review our experience to ascertain the sensitivity, specificity, and accuracy of particular investigations, in isolation, to diagnose sepsis in our patient population.

## Preoperative Evaluation

Radiography is a routine investigation used in the evaluation of all TKAs. Radiography is used to evaluate prosthesis alignment, fixation, gross polyethylene wear, and quality of periprosthetic bone. A typical preoperative series would include a weightbearing AP radiograph, a lateral radiograph, and a patella skyline view. The AP radiograph is used to assess the overall sagittal knee alignment. The extent of the osteolysis should also be evaluated. It may be difficult to evaluate osteolysis on the femoral side on the AP view; however, epicondylar lysis and fragmentation should specifically be evaluated. The extent of tibial osteolysis should be evaluated, specifically lysis below the tibial tray and around screw holes. Lateral radiographs are also used to assess the amount of lysis. Lysis around the intercondylar notch is indicative of significant bone loss. Assessing the tibial slope is also important. A progressive increase in tibial slope may indicate posterior bone loss. A solid component inserted with excessive posterior slope may be a cause for sagittal plain instability in a cruciate retaining implant because of posterior cruciate ligament (PCL) disruption. Osteolysis around the tibial tuberosity must also be assessed. Significant lysis in this region may be a cause of extensor mechanism disruption or may be a contraindication to performing a tibial tubercle osteotomy. This assessment will help with preoperative planning if an extensile exposure is required. Cementation should also be assessed as all cement is usually removed at the time of revision surgery. Excessive cement around a tibial stem may be an indication to perform a tibial tubercle osteotomy to facilitate cement removal. The patella should be assessed with a skyline view. This will give some indication of patella tracking and will show the thickness of the remaining patellar bone so that appropriate preparations can be made if patella reconstruction is required.

Radiological signs of sepsis are progressive osteolysis, complete radiolucency around the prosthetic, bone interface developing over a short period of time, endosteal scalloping, and periosteal new bone formation (Fig 1).[19] Osteolysis is also seen commonly in aseptic loosening and in bone exposed to polyethylene wear debris. It is the authors' experience that radiographs tend to underestimate the true amount of bone loss. If the true bone loss is not anticipated, appropriate preparations may not be made for prosthetic augments, constraint, and the potential need for allograft replacement. Plain radiography is the investigation of choice to diagnose the failed TKA in the majority of cases (osteolysis, prosthetic loosening, fracture, and component failure).[21]

Although rarely used in our institution, computed tomography (CT) is a good tool for assessing malrotation of the femoral component. Internal rotation of the femoral component is one of the most common surgical errors leading to failure.[2,10] It causes patellofemoral maltracking and pain, problems with knee flexion, and potentially early prosthetic wear. A single slice CT scan through the epi-

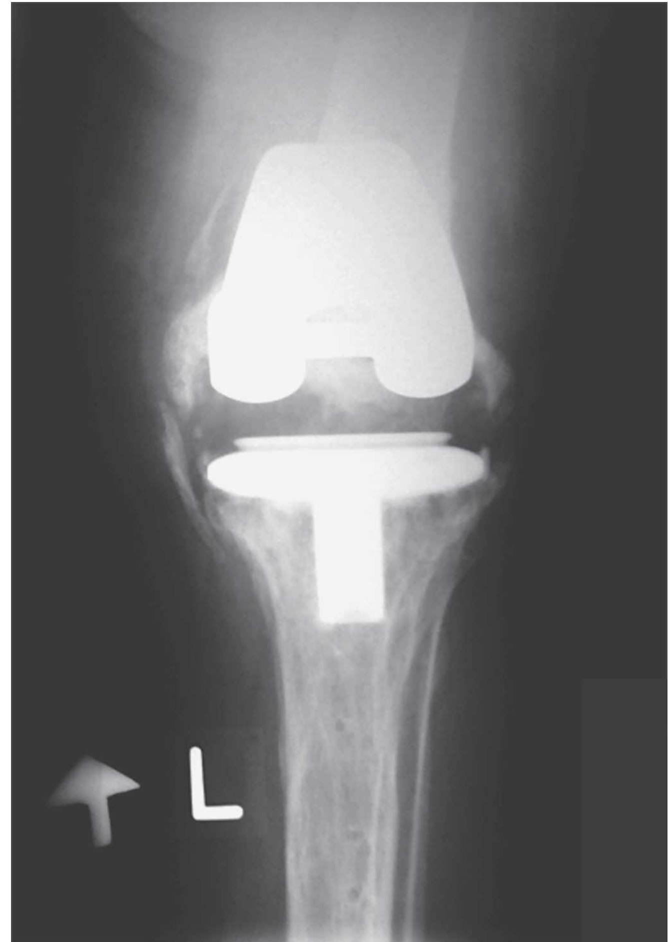


**Fig 1.** A preoperative radiograph shows a TKA that failed secondary to sepsis. Image demonstrates periosteal new bone formation, osteolysis and subsidence.

**TABLE 1. Types of Knee Arthroplasty Failure**

| Type | Characteristics |
|---|---|
| I | Loosening and progression of arthritis in a unicompartmental replacement |
| II | Tibiofemoral instability |
| III | Malrotation and patellar instability |
| IV | Undiagnosed pain |
| V | Component breakage |
| VI | Sepsis |
| VII | Extensor mechanism rupture |
| VIII | Stiffness |
| IX | Fracture |

condyles can diagnose this problem by comparing the epicondylar axis to the femoral component posterior femoral condylar axis. Correct femoral rotational alignment is achieved if these two axes are parallel. This represents external rotation of the femoral component by an average of 3° (Fig 2) to the posterior condylar axis. Computed tomography is not used in our institution for the assessment of bone loss and has no role in the diagnosis of infection.

Expensive, time consuming investigations such as technetium bone scans, gallium scans, and indium labeled white cell scans generally have comparable or lower sensitivities and much lower specificities than simple serology for the diagnosis of infection.[7,14] In our institution they are only used in combination with other investigations when preoperative diagnosis has been difficult. They should not be used as a first line investigation of sepsis.

The erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) serological analysis are very useful investigations in diagnosing and monitoring sepsis. Both are elevated in the presence of infection, but are also elevated in the presence of most other inflammatory conditions including postoperative states. The CRP is normally only present in trace amounts, but increases to a maximum value by 48 hours postoperatively.[23] It then returns to normal by 2–3 weeks postoperatively.[12] The ESR is normally less than 22 mm/hour, but tends to increase with age.[3] It takes longer to elevate after surgery and may remain elevated for many weeks.[12] This makes it less useful than the CRP in following the progress of infection once treatment has been initiated. For the diagnosis of sepsis in a total hip replacement (THR), Spangehl et al[24] reported a CRP of 10 mg/L and an ESR of 30 mm/hour to have a sensitivity of 0.96 and 0.82 and a specificity of 0.92 and 0.85, respectively. To our knowledge, similar values for sepsis in a TKA series have not been reported. It is less clear as to how ESR and CRP values should change when monitoring the response of infection during treatment. One would expect both values to decline after the infection was under control; however, there is no documented evidence on what the values should decline to before it is safe to reinsert the prosthesis when performing a two-stage revision for infection.

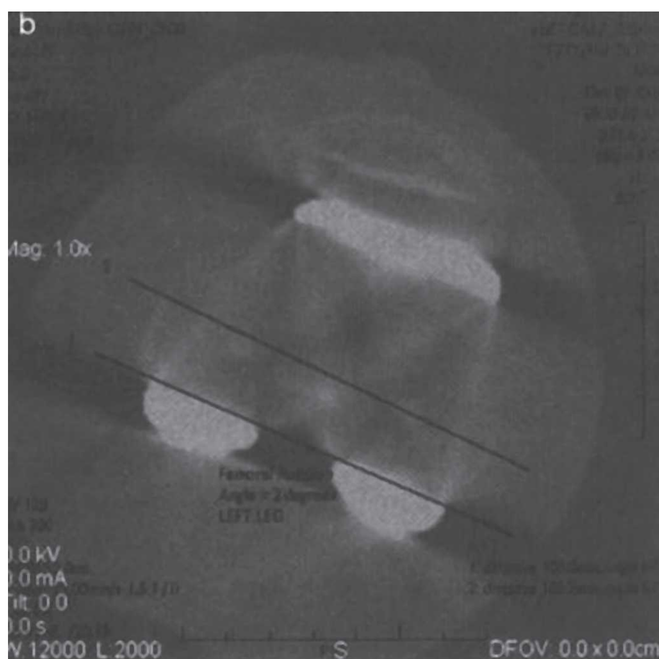


**Fig 2.** A single slice CT scan through the epicondylar axis of a TKA is shown. The posterior condylar axis and the epicondylar axis are parallel and demonstrate correct external rotation of the femoral component by 3°.

False positive results in knee aspirates can be seen with contamination of the specimen. False negative results are more frequently seen when the patient has been exposed to antibiotics preaspiration.[21] The temptation to perform repeat aspirations of a knee in the setting of a negative result should be avoided because of the potentially disastrous side effect of inoculating a previously sterile joint. In addition to bacteriology cultures, knee aspirations are used for microexamination.[16] A synovial fluid white cell count of more than 2500/mm$^3$ or a differential with more than 60% polymorphonuclear leukocytes suggest infection.[16]

Before performing a revision TKA every attempt should be made to locate medical records containing details of any previous knee surgery. Information such as surgical approach, any previous technical difficulties, and implant product stickers are essential for preoperative planning. Precise details of the previous knee implanted are always required if single component revision is contemplated for a modular implant. In our experience with this type of revision, a polyethylene exchange is the most frequently performed operation. In addition to the polyethylene matching the exact size and type of tibial base plate, the surgeon must be prepared for a variety of polyethylene thicknesses and in the case of cruciate retaining implants, polyethylene with increased constraint (eg, deep-dished). This will improve the chance of achieving a stable knee revision. Information on the implant product stickers may also be useful for implant removal because special extraction devices are occasionally required. This may be particularly important when removing stemmed implants.

## MATERIALS AND METHODS

We retrospectively reviewed the charts of a consecutive series of 295 patients who had a revision TKA at our institution. To be included in this group each patient must have had an intraopera-

tive tissue culture and at least one ESR, CRP analysis, or a preoperative knee aspiration. Our aim was to establish the sensitivity, specificity, and accuracy of these investigations to diagnose sepsis. There were 216 (73.2%) patients revised for aseptic causes and 79 (26.8%) patients revised for septic failure. Of the aseptic group, 17.4% of the patients had more than one reason documented for revision. The documented causes for aseptic revision were: loosening (46.2%), tibiofemoral instability (21.8%), polyethylene wear (20.8%), osteolysis (8.3%), patellofemoral failure (2.3%), and periprosthetic fracture (0.5%). Of all the revision cases, the most commonly performed investigations were intraoperative tissue culture in all 295 patients (100%), ESR in 242 patients (82%), and CRP in 222 patients (75%). Institutional ethics board approval was obtained prior to inclusion in the study.

A diagnosis of infection as the reason for revision was based on the classification of Spangehl et al.[24] The classification requires at least one of the following three criteria: (1) an open wound or sinus in communication with the joint; (2) a systemic infection with pain in the joint and purulent fluid with in the joint; and (3) a positive result on at least three investigations (ESR > 30 mm/hour, CRP > 10 mg/L, positive preoperative aspiration, positive intraoperative tissue culture and frozen section with > 5 polymorphonuclear leukocytes per high power field).

Each patient was classified as having a septic or aseptic revision according to the described criteria. These results were then compared with the preoperative ESR, CRP, and intraoperative tissue cultures to evaluate sensitivity, specificity, positive predictive value, and negative predictive value for each investigation. Sensitivity was calculated as the proportion of infected TKA (proven on intraoperative tissue culture) correctly identified by an elevated ESR, CRP, and positive tissue culture (the number of true positive results divided by the sum of the true positive and false negative results). Specificity was calculated as the proportion of aseptic TKA correctly identified by normal values for ESR, CRP, and a negative tissue culture. Accuracy was calculated as the ratio of true positive and true negative results divided by the total number of results. Positive predictive value was calculated as the ratio of true results to the total number confirmed as infected with a positive tissue culture. Negative predictive value was calculated as the ratio of true negative results to the number of cases found not to be infected.

## RESULTS

Intraoperative tissue cultures were the most accurate way of diagnosing sepsis. Fifty-six of the 295 patients had a positive intraoperative tissue culture, and 239 patients had a negative intraoperative tissue culture. This represents a sensitivity of 0.53, a specificity of 0.94, a positive predictive value of 0.75, a negative predictive value of 0.85, and an accuracy of 0.83 for intraoperative tissue culture being diagnostic of infection.

Although less accurate than tissue cultures, both ESR and CRP had better sensitivities for the diagnosis of infection. One hundred twenty-two of the 242 patients (75 septic, 167 aseptic) with preoperative ESR had an ESR > 30 mm/hour and 120 patients had preoperative ESR of ≤ 30. This represents a sensitivity of 0.63, a specificity of 0.55, a positive predictive value of 0.39, a negative predictive value of 0.77, and an accuracy of 0.57 for ESR being diagnostic of infection. Ninety-nine of the 222 patients (75 septic, 147 aseptic) with a preoperative CRP had a CRP > 10 mg/L and 123 patients had a CRP ≤ 10. This represents a sensitivity of 0.60, a specificity of 0.63, a positive predictive value of 0.45, a negative predictive value of 0.76, and an accuracy of 0.62 for CRP being diagnostic of infection.

## DISCUSSION

In revision total knee replacement surgery, it is most important to distinguish septic from aseptic failure. At our institution, the most commonly performed investigations used to make this distinction are ESR, CRP analysis, and intraoperative tissue bacterial cultures. The accuracy, sensitivity and specificity of these investigations to make a diagnosis of infection has not been clearly established.

The major limitation of this study is the use of a "gold standard" with which to compare these investigations. We used a classification described by Spangehl et al[24] which, in most, cases was not independent of the variable to which it was being compared. However, we believe that this classification, which utilizes either multiple investigation results or a clinical setting of infection, was sufficiently accurate to compare with a single investigation.

Our findings did not reflect those previously reported for ESR and CRP in TKAR,[24] in which Spangehl et al examined 202 revision hip replacements. They reported a sensitivity and specificity of 0.83 and 0.85 for the ESR, and 0.96 and 0.92 for the CRP analysis. Our respective findings for the ESR were 0.62 and 0.55, and 0.60 and 0.63 for the CRP analysis. Unlike Spangehl et al,[24] we did not exclude any patients on the basis of preexisting inflammatory conditions. Our results indicate that with such low sensitivities and specificities, ESR or CRP analysis cannot be solely relied on for an accurate diagnosis of infection. The difference between the results may indicate a difference in the inflammatory response generated in a hip compared with a knee in the presence of infection. Further work is needed to confirm this hypothesis. Our findings did agree with previous work,[5,13,18] suggesting that intraoperative tissue bacterial cultures are the single most accurate investigation to confirm the presence of infection (specificity 0.93, accuracy 0.83).

No single investigation can be relied on to diagnose TKA failure preoperatively. The diagnosis requires a thorough history, physical examination, and appropriately di-

rected investigations. A combination of routine investigations such as plain radiography, ESR, and CRP analysis are usually enough to give an adequate diagnosis to accurately plan the revision TKA surgery. In cases where this information is insufficient, more sophisticated tests such as scintigraphy and CT scanning may be required.

Relatively low sensitivity and specificity for ESR and CRP as isolated investigations were demonstrated in this series of infected total knee arthroplasties. At present they are used with plain radiography, history, and physical examination to make the vital distinction between septic and aseptic failure. While the accuracy of the investigations is acceptable, clearly there is opportunity for improvement in the preoperative evaluation of the failed total knee arthroplasty patient.

## References

1. Banit DM, Kaufer H, Hartford JM. Intraoperative frozen section analysis in revision total joint arthroplasty. *Clin Orthop Relat Res*. 2002;401:230–238.
2. Berger RA, Crosset LS, Jacobs JJ, Rubash HE. Malrotation causing patellofemoral complications after total knee arthroplasty. *Clin Orthop Relat Res*. 1998;356:144–153.
3. Brigden ML. Clinical utility of the erythrocyte sedimentation rate. *Am Fam Physician*. 1999;60:1443–1450.
4. Buchholz HW, Elson RA, Engelbrecht E. Lodenkamper H, Rottger J, Siegel A. Management of deep infection of total hip replacement. *J Bone Joint Surg Br*. 1981;63:342–353.
5. Charosky CB, Bullough PG, Wilson PD Jr. Total hip replacement failures: a histological evaluation. *J Bone Joint Surg Am*. 1973;55: 49–58.
6. Cherney DL, Amstutz HC. Total hip replacement in the previously septic hip. *J Bone Joint Surg Am*. 1983;65:1256–1265.
7. Feldman DS, Lonner JH, Desai P, Zuckerman JD. The role of intraoperative frozen sections in revision total joint arthroplasty. *J Bone Joint Surg Am*. 1995;77:1807–1813.
8. Gaine WJ, Ramamohan NA, Hussein NA, Hullin MG, McCreath SW. Wound infection in hip and knee arthroplasty. *J Bone Joint Surg Br*. 2000;82:561–565.
9. Garvin KL, Evans BG, Salvati EA, Brause BD. Palacos gentamicin for the treatment of deep periprosthetic hip infections. *Clin Orthop Relat Res*. 1994;298:97–105.
10. Huberti HH, Hayes WC. Patellofemoral contact pressures. The influence of q-angle and tibiofemoral contact. *J Bone Joint Surg Am*. 1984;66:715–724.
11. Hunter GA. Results of reinsertion of a total hip prosthesis after sepsis. *J Bone Joint Surg Br*. 1979;61:422–423.
12. Larsson S, Thelander U, Friberg S. C-reactive protein (CRP) levels after elective orthopedic surgery. *Clin Orthop Relat Res*. 1992;275: 237–242.
13. Lonner JH, Desai P, Dicesare PE. Steiner G, Zuckerman JD. The reliability of analysis of intraoperative frozen sections for identifying active infection during revision hip or knee arthroplasty. *J Bone Joint Surg Am*. 1996;78:1553–1558.
14. Love C, Tomas MB, Marwin SE, Pugliese PV, Palestro CJ. Role of nuclear medicine in diagnosis of the infected joint replacement. *Radiographics*. 2001;21:1229–1238.
15. McDonald DJ, Fitzgerald RH Jr, Ilstrup DM. Two stage reconstruction of a total hip arthroplasty because of infection. *J Bone Joint Surg Am*. 1989;71:828–834.
16. Mason JB, Fehring TK, Odum SM, Griffin WL, Nussman DS. The value of white blood cell counts before revision total knee arthroplasty. *J Arthroplasty*. 2003;18:1038–1043.
17. Mirra JM, Amstutz HC, Matos M, Gold R. The pathology of joint tissue and its clinical relevance in prosthesis failure. *Clin Orthop Relat Res*. 1976;117:221–240.
18. Mirra JM, Marder RA, Amstutz HC. Pathology of failed Total Joint Arthroplasty. *Clin Orthop Relat Res*. 1982;170:175–183.
19. Musso AD, Mohanty K, Spencer-Jones R. Role of frozen section histology in diagnosis of infection during revision arthroplasty. *Postgrad Med J*. 2003;79:590–593.
20. Pace TB, Jeray KJ, Latham JT Jr. Synovial tissue examination by frozen section as an indicator of infection in hip and knee arthroplasty in community hospitals. *J Arthroplasty*. 1997;12:64–69.
21. Rand JA, Bryan RS, Morrey BF, Westholm F. Management of infected total knee arthroplasty. *Clin Orthop Relat Res*. 1986;205: 75–85.
22. Sanzen L, Carlsson AS, Josefsson G, Lindberg LT. Revision operations on infected total hip arthroplasties: Two to nine year follow up study. *Clin Orthop Relat Res*. 1988;229:165–172.
23. Shih LY, Wu JJ, Yang DJ. Erythrocyte sedimentation rate and C-reactive protein value in patients with total hip arthroplasty. *Clin Orthop Relat Res*. 1987;225:238–246.
24. Spangehl MJ, Masri BA, O'Connell JX, Duncan CP. Prospective analysis of preoperative and intraoperative investigations for the diagnosis of infection at the sites of two hundred and two revision total hip arthroplasties. *J Bone Joint Surg Am*. 1999;81:672–683.
25. Syahrizal AB, Kareem BA, Anbanadan S, Harwant S. Risk factors for infection in total knee replacement surgery at hospital Kuala Lumpur. *Med J Malaysia*. 2001;56(Suppl):5–8.
26. Vince KG, Long W. Revision knee arthroplasty: the limits of medullary fixation. *Clin Orthop Relat Res*. 1995;317:172–177.