Perioperative Testing for Joint Infection in Patients Undergoing Revision Total Hip Arthroplasty

Mark F. Schinsky, Craig J. Della Valle, Scott M. Sporer and Wayne G. Paprosky
J Bone Joint Surg Am. 2008;90:1869-1875. doi:10.2106/JBJS.G.01255

Perioperative Testing for Joint Infection in Patients Undergoing Revision Total Hip Arthroplasty

By Mark F. Schinsky, MD, Craig J. Della Valle, MD, Scott M. Sporer, MD, and Wayne G. Paprosky, MD

Investigation performed at Midwest Orthopaedics at Rush, Rush University Medical Center, and Central DuPage Hospital, Chicago, Illinois

Background: While multiple tests are used to determine the presence of infection at the site of a total hip arthroplasty, few studies have applied a consistent algorithm to determine the utility of the various tests that are available. The purpose of the present study was to evaluate the utility of commonly available tests for determining the presence of periprosthetic infection in patients undergoing revision total hip arthroplasty.

Methods: Two hundred and thirty-five consecutive total hip arthroplasties in 220 patients were evaluated by one of two surgeons using a consistent algorithm to identify infection and were treated with reoperation. Receiver-operating-characteristic curve analysis was used to determine the optimal cut-point values for the white blood-cell count and the percentage of polymorphonuclear cells of intraoperatively aspirated hip synovial fluid. Sensitivity, specificity, negative predictive value, positive predictive value, and accuracy were determined. Patients were considered to have an infection if two of three criteria were met; the three criteria were a positive intraoperative culture, gross purulence at the time of reoperation, and positive histopathological findings.

Results: Thirty-four arthroplasties were excluded because of the presence of a draining sinus, incomplete data, or a preoperative diagnosis of inflammatory arthritis, leaving 201 total hip arthroplasties available for evaluation. Fifty-five hips were judged to be infected. No hip in a patient with a preoperative erythrocyte sedimentation rate of <30 mm/hr and a C-reactive protein level of <10 mg/dL was determined to be infected. Receiver-operating-characteristic curve analysis of the synovial fluid illustrated optimal cut-points to be >4200 white blood cells/mL for the white blood-cell count and >80% polymorphonuclear cells for the differential count. However, when combined with an elevated erythrocyte sedimentation rate and C-reactive protein level, the optimal cut-point for the synovial fluid cell count was >3000 white blood cells/mL, which yielded the highest combined sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the tests studied.

Discussion: A synovial fluid cell count of >3000 white blood cells/mL was the most predictive perioperative testing modality in our study for determining the presence of periprosthetic infection when combined with an elevated preoperative erythrocyte sedimentation rate and C-reactive protein level in patients undergoing revision total hip arthroplasty.

Level of Evidence: Diagnostic Level I. See Instructions to Authors for a complete description of levels of evidence.

The evaluation of pain at the site of a total hip arthroplasty is often complex. Etiologies can include aseptic loosening, trochanteric bursitis, heterotopic ossification, component failure, synovitis, infection, or pain extrinsic to the hip joint. An accurate diagnosis is essential for formulating an appropriate preoperative plan, for counseling the patient with regard to expected treatment and outcomes, and for ensuring a successful result. Distinguishing between aseptic failure and infection remains difficult.

Periprosthetic infection presents a challenging complication to both the patient and the surgeon. Several studies have demonstrated a 1% to 2% rate of infection after primary total

Disclosure: In support of their research for or preparation of this work, one or more of the authors received, in any one year, outside funding or grants of less than $10,000 from Zimmer in the form of statistical analysis. In addition, one or more of the authors or a member of his or her immediate family received, in any one year, payments or other benefits or a commitment or agreement to provide such benefits from commercial entities in excess of $10,000 (Zimmer) and less than $10,000 (Stryker, Smith and Nephew). Also, a commercial entity (Zimmer) paid or directed in any one year, or agreed to pay or direct, benefits in excess of $10,000 to a research fund, foundation, division, center, clinical practice, or other charitable or nonprofit organization with which one or more of the authors, or a member of his or her immediate family, is affiliated or associated.

TABLE I Reason for Revision Procedures

Preoperative Diagnosis	Number of Procedures
Aseptic loosening	79
Chronic infection	35
Instability	34
Acute* infection	
Acute hematogenous	11
Acute postoperative	7
Periprosthetic fracture	14
Implant fracture	10
Polyethylene wear	10
Limb-length discrepancy	1

*Diagnosed less than six weeks after the onset of symptoms.

hip arthroplasty and even higher rates after revision hip arthroplasty[1,2]. Given the increasing number of total hip arthroplasties being performed each year, this rate equates to a large number of patients with periprosthetic hip infections who utilize a substantial amount of health-care resources. Multiple tests are used in an attempt to determine the presence of periprosthetic infection in patients managed with total joint arthroplasty, including preoperative laboratory testing (determination of the erythrocyte sedimentation rate and C-reactive protein level), imaging studies, intraoperative Gram staining, intraoperative frozen-section analysis, and preoperative or intraoperative joint aspiration with determination of the synovial fluid white blood-cell count and culture of specimens[2-16]. However, no completely reliable diagnostic test is currently available for establishing the presence of infection at the site of a total hip arthroplasty. The purpose of the present study was to evaluate the utility of commonly available tests for determining the presence of periprosthetic infection in patients undergoing revision total hip arthroplasty by applying a consistent algorithm with a specific focus on the intraoperative use of the synovial fluid white blood-cell count.

TABLE II Organisms Isolated in the Fifty-five Infected Hips

Organism	Number of Hips
Staphylococcus aureus	24
Staphylococcus epidermidis	11
Streptococcus species	4
Enterococcus species	2
Haemophilus parainfluenzae	1
Mycobacterium malmoense	1
Proteus mirabilis	1
Pseudomonas aeruginosa	1
Veillonella species	1
Anaerobic Gram-positive cocci*	1
Multiple organisms	1
No organism identified	7

*Unable to be further identified.

TABLE III Summary Results for Perioperative Testing in Infected and Noninfected Hips

Test*	Infected (N = 55)	Noninfected (N = 146)	P Value†
Erythrocyte sedimentation rate *(mm/hr)*			
Mean	55.4	26.2	<0.001
Range	5 to 124	1 to 103	
Standard deviation	24.5	17.0	
C-reactive protein *(mg/dL)*			
Mean	52.4	7.8	<0.001
Range	0.5 to 393	0.1 to 157	
Standard deviation	86.1	21.2	
Synovial fluid WBC/mL			
Mean	61,336.0	1721.8	<0.001
Range	470 to 407,000	0 to 53,200	
Standard deviation	84,268.0	4722.9	
Percent PMN in synovial fluid *(%)*			
Mean	86.1	51.3	<0.001
Range	5 to 100	0 to 98	
Standard deviation	20.3	29.3	
Years from primary surgery to revision			
Mean	4.5	8.0	<0.001
Range	0 to 20	0 to 27	
Standard deviation	4.4	6.8	

*WBC = white blood cells, and PMN = polymorphonuclear cells.
†Significance levels correspond to two-sided p values and were not adjusted for multiplicity.

Materials and Methods

Two hundred and thirty-five painful total hip arthroplasties in 220 patients were prospectively evaluated and underwent reoperation by one of two surgeons (C.J.D.V. and S.M.S.) from August 2003 to March 2007. A preoperative and intraoperative protocol for assessing the painful hips for infection was utilized. Five patients underwent revision of both hips, and ten additional patients had more than one revision of the same hip during the study period (five because of infection, three because of instability, and two because of fracture). To control for the possibility of intercorrelated events, the data set was analyzed both with the inclusion of these fifteen secondary arthroplasties in nonunique patients and a second time with the exclusion of all but the first revision for these fifteen patients. Patients who had a previous resection arthroplasty with or without an antibiotic spacer present were not included in

TABLE IV Diagnostic Test Characteristics for All Patients*

Test†‡	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value	Accuracy
Elevated erythrocyte sedimentation rate >30 mm/hr	97% (93% to 100%)	39% (31% to 47%)	42% (34% to 50%)	96% (92% to 100%)	57% (50% to 64%)
Elevated C-reactive protein >10 mg/dL	94% (87% to 100%)	71% (64% to 79%)	59% (49% to 69%)	96% (92% to 100%)	78% (72% to 84%)
Synovial fluid WBC count >4200 WBC/mL	84% (74% to 94%)	93% (88% to 98%)	81% (71% to 91%)	93% (89% to 97%)	90% (86% to 94%)
Synovial fluid WBC differential >80% PMN†	84% (74% to 93%)	82% (76% to 89%)	65% (54% to 76%)	93% (88% to 97%)	83% (77% to 88%)
Positive frozen section	73% (63% to 86%)	94% (83% to 94%)	82% (60% to 84%)	90% (85% to 95%)	88% (80% to 90%)
Positive culture	87% (79% to 95%)	92% (89% to 95%)	80% (71% to 89%)	95% (91% to 99%)	91% (87% to 95%)

*The 95% confidence intervals are shown in parentheses. †N = 201 for all tests. ‡WBC = white blood cell, and PMN = polymorphonuclear cell.

the present study, nor were patients who had been receiving antibiotics preoperatively.

The protocol that was used to evaluate these total hip arthroplasties included determination of the preoperative erythrocyte sedimentation rate and C-reactive protein level, intraoperative hip aspiration prior to arthrotomy after exposure of the hip capsule (for determination of the synovial fluid white blood-cell count with differential), three full sets of intraoperative cultures taken from deep within the hip joint (for determination of the presence of aerobic and anaerobic bacteria, fungi, and acid-fast bacilli), intraoperative frozen-section analysis of specimens taken from the synovial tissue adjacent to the prostheses, and permanent histopathological examination of this tissue. As this protocol is our standard of care, patient informed consent was not required by our institutional review board, which approved the present study.

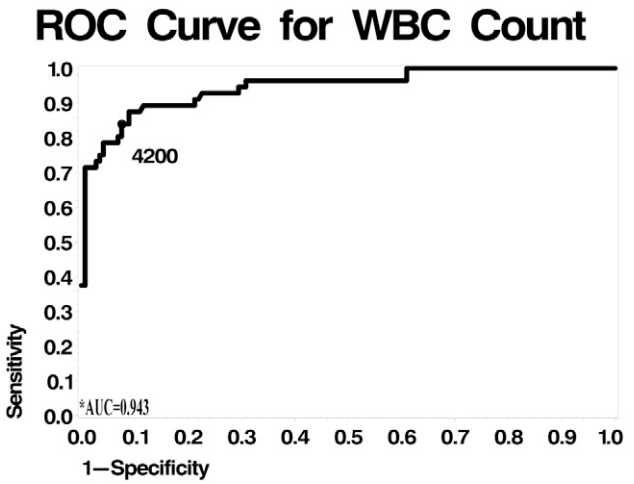

Fig. 1

Receiver-operating-characteristic (ROC) curve demonstrating the hip aspirate white blood-cell (WBC) count cut-point of 4200 white blood cells/mL for all patients in the cohort. *AUC = area under the curve.

On the basis of previous studies, the values that were considered to be abnormal and potentially consistent with infection included an erythrocyte sedimentation rate of >30 mm/hr, a C-reactive protein level of >10 mg/dL, and an average of more than ten polymorphonuclear cells seen within the tissue in the five most cellular high-power fields on frozen-section and/or permanent histopathological analysis[2,3,7,15]. As the practicing orthopaedic surgeon may come across different suggested normal ranges for the erythrocyte sedimentation rate and C-reactive protein level, results were also graded as normal or elevated on the basis of the normal reference ranges for the laboratory where the testing was performed. The optimal cut-point value for the white blood-cell count and for the percentage of polymorphonuclear cells on the differential count were obtained with use of receiver-operating-characteristic curve analysis. Cultures were considered to be positive if the organisms grew on solid media. Intraoperative Gram stains were not performed because previous studies have failed to show the utility of this diagnostic test[2,16,17]. The routine preoperative evaluation did not include nuclear medicine imaging. Antibiotics were withheld until after intraoperative culture specimens were acquired.

The final diagnosis of infection at the site of an individual total hip arthroplasty required two of the following three criteria to be met: a positive intraoperative culture, gross purulence, or a final histopathological result consistent with infection. Hips that were diagnosed as infected were further analyzed to determine if a difference existed between those with positive cultures and those that demonstrated no growth of an organism on solid media.

Data Analysis

Categorical variables were summarized as frequencies and percentages with use of the SAS (SAS Institute, Cary, North Carolina) FREQ procedure, and frequencies were compared with use of either the Fisher exact test (dichotomous) or the likelihood ratio chi-square test (polychotomous). Continuous

TABLE V Diagnostic Test Combination Characteristics Relating Erythrocyte Sedimentation Rate and C-Reactive Protein Level to Receiver-Operating-Characteristic-Curve-Optimized Synovial Fluid White Blood-Cell Count Cut-Points

Test Combination*	Sensitivity†	Specificity†	Positive Predictive Value†	Negative Predictive Value†	Accuracy†
Elevated ESR and CRP, >3000 WBC/mL (n = 79)	90% (82% to 98%)	91% (85% to 97%)	95% (89% to 100%)	82% (74% to 90%)	90% (85% to 95%)
Elevated ESR and CRP, >9000 WBC/mL (n = 79)	81% (72% to 99%)	90% (83% to 97%)	94% (91% to 97%)	77% (66% to 88%)	85% (77% to 93%)
Elevated ESR or CRP, >3000 WBC/mL (n = 60)	83% (54% to 100%)	87% (78% to 96%)	67% (47% to 87%)	91% (87% to 95%)	87% (79% to 95%)
Elevated ESR or CRP, >9000 WBC/mL (n = 60)	83% (54% to 100%)	100% (100% to 100%)	100% (100% to 100%)	98% (95% to 100%)	98% (92% to 100%)

*The categories are given as the combination of diagnostic tests with or without elevated results, followed by the synovial fluid white blood-cell (WBC) count cut-point. An elevated erythrocyte sedimentation rate (ESR) is defined as >30 mm/hr, and an elevated C-reactive protein (CRP) level is defined as >10 mg/dL. †The 95% confidence intervals are shown in parentheses.

variables were summarized with use of the UNIVARIATE procedure, and averages were compared between groups with use of a Student t test with pooled variance by means of the TTEST procedure. Odds ratios were used for associating outcomes. The assumption of equal sample variances between comparison groups was assessed with use of a (folded) F test. If variances were found to differ significantly, distributions of continuous variables were compared nonparametrically with use of the NPAR1WAY procedure by means of a Wilcoxon rank-sum test. Significance was inferred at an alpha (type-I) error level of 0.05, and significance levels were not adjusted for multiplicity.

Sensitivity, specificity, positive predictive value, negative predictive value, and test accuracy as measured with Youden's J statistic were calculated in a SAS computer program that was developed for the study. Statistics were calculated at each unique value of a variable or composite under evaluation, and a grid search method was used to identify the cut-point that resulted in the maximum test accuracy (Youden's J statistic) at an acceptable level of sensitivity, specificity, negative predictive value, and positive predictive value. Ninety-five percent confidence limits were computed for sensitivity, specificity, positive predictive value, negative predictive value, and test accuracy with use of standard errors calculated under a binomial assumption, with widths determined with use of a normal approximation to the binomial distribution.

Receiver-operating-characteristic curves were used to examine the relationship between sensitivity and the false positive rate (1 − specificity) on the basis of attributes of assignment into infected and noninfected groups from a predictive model fit by logistic regression. Estimates of sensitivity and specificity were created with use of the LOGISTIC procedure in SAS, and receiver-operating-characteristic curves were plotted with use of the SAS GPLOT procedure.

Results

Of the 235 revision total hip arthroplasties that were performed, thirty-four were excluded because of the presence of a draining sinus, incomplete data, or a preoperative diagnosis of inflammatory arthritis, leaving 201 total hip arthroplasties available for evaluation. The average age of the patients at the time of revision surgery was 64.9 years (range, thirty to ninety-four years). One hundred and twenty-seven (63%) of the revision arthroplasties were performed in women. The average interval between the index procedure and revision surgery was 7.2 years for all hips, 4.5 years for infected hips, and 8.0 years for noninfected hips. Table I summarizes the reasons for the revision procedures.

Fifty-five hips (27.4%) were deemed to be infected. *Staphylococcus aureus* and *Staphylococcus epidermidis* represented the majority of the infecting organisms. No organism could be identified in seven of the infected hips. Table II

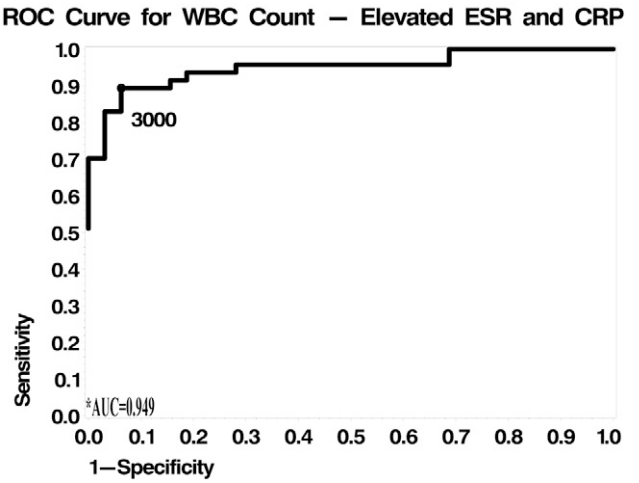

Fig. 2

Receiver-operating-characteristic (ROC) curve demonstrating the hip aspirate white blood-cell (WBC) count cut-point of 3000 white blood cells/mL for patients with an elevated erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) level. *AUC = area under the curve.

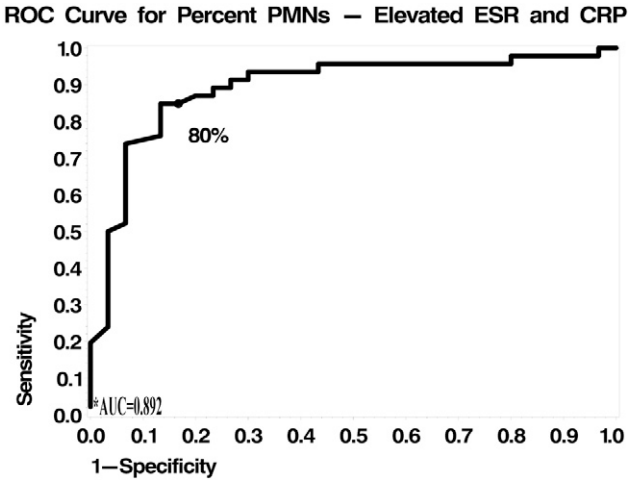

Fig. 3

Receiver-operating-characteristic (ROC) curve demonstrating the hip aspirate white blood-cell count differential cut-point of 80% polymorphonuclear (PMN) cells for patients with an elevated erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) level.
*AUC = area under the curve.

summarizes the organisms that were identified in the hips that were judged to be infected.

Table III provides a summary of the mean, range, and standard deviation of the preoperative erythrocyte sedimentation rate and C-reactive protein level, the white blood-cell count and the percentage of polymorphonuclear cells in the synovial fluid aspirated from the hip, and the time from the primary procedure to revision for both the infected and noninfected hips. All values were significantly different between the two groups ($p < 0.001$). The gross appearance, results of frozen-section analysis, and final histopathological results were also significantly different between the infected and noninfected groups ($p < 0.001$ for all comparisons).

The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for the erythrocyte sedimentation rate, C-reactive protein level, synovial fluid white blood-cell count and differential, frozen-section analysis, and culture are given in Table IV. The receiver-operating-characteristic curve analysis for all patients confirmed the white blood-cell count in synovial fluid aspirated from the hip as a high-quality diagnostic test (Fig. 1). The optimal white blood-cell count cut-point from our entire patient cohort was 4200 white blood cells/mL. At this cut-point, the hip aspirate white blood-cell count had a sensitivity of 84%, a specificity of 93%, a positive predictive value of 81%, a negative predictive value of 93%, and an accuracy of 90%. When multiple perioperative diagnostic tests were combined, the strength of the test battery as a whole improved. When an elevated preoperative erythrocyte sedimentation rate and C-reactive protein level were combined with the hip aspirate white blood-cell count, the receiver-operating-characteristic curve analysis demonstrated an optimal white blood-cell count cut-point of 3000 white blood cells/mL (Fig. 2). Furthermore, when either the erythrocyte sedimentation rate or the C-reactive protein level was elevated, but not both, the receiver-operating-characteristic curve analysis demonstrated an optimal white blood-cell count cut-point of 9000 white blood cells/mL. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for these test batteries are summarized in Table V. Receiver-operating-characteristic curve analysis additionally demonstrated an optimal hip aspirate white blood-cell count differential of >80% polymorphonuclear cells when both the erythrocyte sedimentation rate and the C-reactive protein level were elevated (Fig. 3). When the preoperative erythrocyte sedimentation rate and C-reactive protein status were combined with the hip aspirate white blood-cell count differential, the strength and accuracy of the predictive tests improved (Table VI). When the data were reanalyzed with the exclusion of the fifteen secondary procedures on nonunique patients, the optimum cut-point for the white blood-cell count on aspirated fluid when both the erythrocyte sedimentation rate and the C-reactive protein level were elevated remained at 3000 white blood cells/mL, with a sensitivity of 91%, a specificity of 86%, a positive predictive value of 95%, a negative predictive value of 77%, and an accuracy of 88%. No difference in patient demographics could be established between hips that were determined to be infected on the basis of positive cultures and hips with negative cultures. The optimum white blood-cell count cut-point for these patients also remained at 3000 white blood cells/mL when both the erythrocyte sedimentation rate and the C-reactive protein level were elevated, with a sensitivity

TABLE VI Diagnostic Test Characteristics for Hip Aspirate Synovial Fluid White Blood-Cell Count Differential of >80% Polymorphonuclear Cells as Related to Elevated Erythrocyte Sedimentation Rate and C-Reactive Protein Level

ESR and CRP Status*	Sensitivity†	Specificity†	Positive Predictive Value†	Negative Predictive Value†	Accuracy†
All patients (n = 201)	82% (73% to 91%)	83% (76% to 90%)	69% (54% to 84%)	90% (85% to 95%)	83% (77% to 88%)
Elevated ESR and CRP (n = 79)	87% (66% to 100%)	90% (84% to 96%)	93% (86% to 100%)	82% (71% to 93%)	88% (78% to 98%)

*ESR = erythrocyte sedimentation rate, and CRP = C-reactive protein. †The 95% confidence intervals are shown in parentheses.

of 92%, a specificity of 86%, a positive predictive value of 80%, a negative predictive value of 94%, and an accuracy of 90%. The data were further analyzed with elevations of the erythrocyte sedimentation rate and C-reactive protein being defined as values above the reference ranges given by the laboratory performing the test. With this definition, when the erythrocyte sedimentation rate and C-reactive protein level were both elevated above their respective reference ranges, the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were 91%, 91%, 95%, 83%, and 91%, respectively, at the cut-point of 3000 white blood cells/mL, as compared with 90%, 91%, 95%, 82%, and 90%, respectively, when the erythrocyte sedimentation rate and C-reactive protein level elevations were defined as >30 mm/hr and >10 mg/dL, respectively.

Our data also demonstrated a 100% specificity for a hip not to be infected when both the preoperative erythrocyte sedimentation rate and C-reactive protein level were <30 mm/hr and <10 mg/dL, respectively.

Discussion

Successful evaluation of pain at the site of a total hip arthroplasty must rule out infection because the treatment for an infected hip is fundamentally different from the treatment for a noninfected hip. Occasionally, an infection is obvious on the basis of a thorough history, physical examination, and review of plain radiographs. Often, however, infection cannot be ruled out without adjunctive laboratory tests and imaging modalities. In such cases, tests are necessary that are readily available to the majority of surgeons in a variety of practice settings. Advanced nuclear imaging and molecular biologic techniques require increased resource utilization and the expertise of radiologists and specialized laboratory personnel. We present diagnostic criteria that are easily accessible to the majority of surgeons and are useful for preoperative decision-making.

Several studies have examined the utility of the preoperative erythrocyte sedimentation rate and C-reactive protein level in diagnosing periprosthetic hip infections[2,11,18]. As nonspecific inflammatory markers, the erythrocyte sedimentation rate and the C-reactive protein level must be used in conjunction with a careful history and physical examination. Recent surgery and active systemic inflammatory conditions can raise the levels without being indicative of infection. We excluded patients from the present study who had a preoperative diagnosis of inflammatory arthritis. Previous studies on the diagnosis of infection prior to revision total joint arthroplasty demonstrated similar sensitivity and specificity for the erythrocyte sedimentation rate and the C-reactive protein level to those in the present study, although Spangehl et al. reported a higher specificity for the erythrocyte sedimentation rate[2,6,18]. As none of our patients who had a normal erythrocyte sedimentation rate and C-reactive protein level had an infection, we found that this combination of preoperative tests had 100% specificity for ruling out infection at the site of a total hip arthroplasty. This finding concurs with those of the study by Spangehl et al., who found no periprosthetic infections associated with both a normal erythrocyte sedimentation rate and a normal level of C-reactive protein[2]. We recommend the use of a combination of the history, the physical examination, and a normal erythrocyte sedimentation rate and C-reactive protein level as an effective, low-cost method of screening to rule out infection.

Much has been written about the utility of intraoperative frozen-section analysis in the diagnosis of infection at the site of a total joint arthroplasty[3,5,7,9,13,19-21]. We used the criteria established by Lonner et al.[7] and supported by Banit et al.[3] of at least ten polymorphonuclear cells per high-power field as suggesting the presence of infection. Had the criteria established by Mirra et al.[20,21] of five polymorphonuclear cells per high-power field been utilized, the sensitivity of the frozen-section analysis may have been higher; however, the specificity may have been reduced. Our results for sensitivity, specificity, predictive value, and accuracy were consistent with the wide ranges reported in other studies[2,3,5,7,9,13,19-21]. While this testing modality was useful in our practice, the variable nature of the test limited its role. Obtaining an appropriate sample of tissue from the most infected-appearing area without frank necrosis is important in order to minimize sampling errors. Also, a dedicated and interested pathologist is necessary to interpret the results. These conditions are not always available to every orthopaedic surgeon. We have primarily used the results of frozen-section analysis when other, more objective, perioperative tests have proved equivocal.

The so-called gold standard for diagnosing infection at the site of a total hip arthroplasty has long been intraoperative cultures[1]. However, intraoperative cultures have also been fraught with sampling errors and substantial false-positive rates[1,2,10,22-26]. Padgett et al. found that with the development of infection as an end point, the positive predictive value of a positive intraoperative culture was only 2.4% and represented an unreliable predictor of infection at the time of revision surgery[10]. Our culture results, with an 8% false-positive rate (twelve of 146 hips), were more consistent with the results of other large studies that have demonstrated false-positive rates of 2.4% to 31.5%[2,24-26]. Intraoperative cultures are subject to errors in technique, the potential for antibiotics to have been placed in the irrigant or to have been given preoperatively without the surgeon's awareness, and potential contaminants. An obvious difficulty with intraoperative cultures is the time required to obtain useful results. This delay prevents intraoperative cultures from being useful in decision-making during an equivocal procedure.

Hip aspiration for determination of the white blood-cell count and differential as a perioperative diagnostic test has several advantages. It can be performed either preoperatively or intraoperatively; when performed intraoperatively, the results in our hospital are typically returned within forty-five minutes. Hip aspiration for determination of the synovial fluid white blood-cell count is also low-cost, does not require specialized equipment, and was the most predictive perioperative testing modality in our study when combined with the preoperative

erythrocyte sedimentation rate and C-reactive protein level. On the basis of our analysis, we propose using a cut-point of 3000 white blood cells/mL when the erythrocyte sedimentation rate and C-reactive protein level are both elevated, and a cut-point of 9000 white blood cells/mL when either the erythrocyte sedimentation rate or the C-reactive protein level (but not both) is elevated, as being consistent with a diagnosis of infection. These cut-points are markedly lower than those in several previous reports on lower extremity periprosthetic infection, which have ranged from 25,000 to 80,000 white blood cells/mL[1,2,27,28]. In a recent report on revision total knee arthroplasty, Della Valle et al.[14] found an optimal cut-point of 3000 white blood cells/mL in aspirated synovial fluid. We also found the white blood-cell count differential to be useful with high accuracy when the preoperative erythrocyte sedimentation rate and C-reactive protein level are both elevated. We use the percent polymorphonuclear count in the white blood-cell differential as a useful adjunct in the diagnosis of infection. ■

NOTE: The authors thank Daniel P. Reyner, DrPH, MS, Director, Corporate Biostatistics and Data Management, Department of Clinical Affairs, Zimmer, Inc., for his assistance with the statistical analysis on this project.

Mark F. Schinsky, MD
Castle Orthopaedics and Sports Medicine, S.C., 2111 Ogden Avenue, Aurora, IL 60504., E-mail address: mfs@castleortho.com

Craig J. Della Valle, MD
Scott M. Sporer, MD
Wayne G. Paprosky, MD
Midwest Orthopaedics at Rush, Rush University Medical Center, 1725 West Harrison Street, Suite 1063, Chicago, IL 60612

References

1. Salvati EA, González Della Valle A, Masri BA, Duncan CP. The infected total hip arthroplasty. Instr Course Lect. 2003;52:223-45.

2. 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;81:672-83.

3. Banit DM, Kaufer H, Hartford JM. Intraoperative frozen section analysis in revision total joint arthroplasty. Clin Orthop Relat Res. 2002;401:230-8.

4. Gould ES, Potter HG, Bober SE. Role of routine percutaneous hip aspirations prior to prosthesis revision. Skeletal Radiol. 1990;19:427-30.

5. Ko PS, Ip D, Chow KP, Cheung F, Lee OB, Lam JJ. The role of intraoperative frozen section in decision making in revision hip and knee arthroplasties in a local community hospital. J Arthroplasty. 2005;20:189-95.

6. Levitsky KA, Hozack WJ, Balderston RA, Rothman RH, Gluckman SJ, Maslack MM, Booth RE Jr. Evaluation of the painful prosthetic joint. Relative value of bone scan, sedimentation rate, and joint aspiration. J Arthroplasty. 1991;6:237-44.

7. 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;78:1553-8.

8. Marculescu CE, Berbari EF, Hanssen AD, Steckelberg JM, Osmon DR. Prosthetic joint infection diagnosed postoperatively by intraoperative culture. Clin Orthop Relat Res. 2005;439:38-42.

9. Nuñez LV, Buttaro MA, Morandi A, Pusso R, Piccaluga F. Frozen sections of samples taken intraoperatively for diagnosis of infection in revision hip surgery. Acta Orthop. 2007;78:226-30.

10. Padgett DE, Silverman A, Sachjowicz F, Simpson RB, Rosenberg AG, Galante JO. Efficacy of intraoperative cultures obtained during revision total hip arthroplasty. J Arthroplasty. 1995;10:420-6.

11. Rosas MH, Leclercq S, Pégoix M, Darlas Y, Aubriot JH, Rousselot P, Marcelli C. Contribution of laboratory tests, scintigraphy, and histology to the diagnosis of lower limb joint replacement infection. Rev Rhum Engl Ed. 1998;65:477-82.

12. Williams JL, Norman P, Stockley I. The value of hip aspiration versus tissue biopsy in diagnosing infection before exchange hip arthroplasty surgery. J Arthroplasty. 2004;19:582-6.

13. Wong YC, Lee QJ, Wai YL, Ng WF. Intraoperative frozen section for detecting active infection in failed hip and knee arthroplasties. J Arthroplasty. 2005;20:1015-20.

14. Della Valle CJ, Sporer SM, Jacobs JJ, Berger RA, Rosenberg AG, Paprosky WG. Preoperative testing for sepsis before revision total knee arthroplasty. J Arthroplasty. 2007;22(6 Suppl 2):90-3.

15. Trampuz A, Hanssen AD, Osmon DR, Mandrekar J, Steckelberg JM, Patel R. Synovial fluid leukocyte count and differential for the diagnosis of prosthetic knee infection. Am J Med. 2004;117:556-62.

16. Della Valle CJ, Scher DM, Kim YH, Oxley CM, Desai P, Zuckerman JD, Di Cesare PE. The role of intraoperative Gram stain in revision total joint arthroplasty. J Arthroplasty. 1999;14:500-4.

17. Chimento GF, Finger S, Barrack RL. Gram stain detection of infection during revision arthroplasty. J Bone Joint Surg Br. 1996;78:838-9.

18. Itasaka T, Kawai A, Sato T, Mitani S, Inoue H. Diagnosis of infection after total hip arthroplasty. J Orthop Sci. 2001;6:320-6.

19. Musso AD, Mohanty K, Spencer-Jones R. Role of frozen section histology in diagnosis of infection during revision arthroplasty. Postgrad Med J. 2003;79:590-3.

20. Mirra JM, Amstutz HC, Matos M, Gold R. The pathology of the joint tissues and its clinical relevance in prosthesis failure. Clin Orthop Relat Res. 1976;117:221-40.

21. Mirra JM, Marder RA, Amstutz HC. The pathology of failed total joint arthroplasty. Clin Orthop Relat Res. 1982;170:175-83.

22. Barrack RL, Harris WH. The value of aspiration of the hip joint before revision total hip arthroplasty. J Bone Joint Surg Am. 1993;75:66-76.

23. Fehring TK, Cohen B. Aspiration as a guide to sepsis in revision total hip arthroplasty. J Arthroplasty. 1996;11:543-7.

24. Fitzgerald RH Jr, Peterson LF, Washington JA 2nd, Van Scoy RE, Coventry MB. Bacterial colonization of wounds and sepsis in total hip arthroplasty. J Bone Joint Surg Am. 1973;55:1242-50.

25. Murray WR. Results in patients with total hip replacement arthroplasty. Clin Orthop Relat Res. 1973;95:80-90.

26. Tietjen R, Stinchfield FE, Michelsen CB. The significance of intracapsular cultures in total hip operations. Surg Gynecol Obstet. 1977;144:699-702.

27. Eftekhar NS. Total hip arthroplasty. Vol 2. St. Louis: C. V. Mosby; 1993. Postoperative wound infection; p 1457-504.

28. Windsor RE, Insall JN. Management of the infected total knee arthroplasty. In: Insall JN, Windsor RE, Scott WN, Kelly MA, Aglietti P, editors. Surgery of the knee. New York: Churchill Livingstone; 1993. p 962.