

Tertiary care centre adherence to unified guidelines for management of periprosthetic joint infections: a gap analysis

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Background: The success rate of surgical treatment for periprosthetic joint infection (PJI) remains inconsistent in the literature. Variability in PJI clinical guidelines and surgeon adherence to guidelines could affect treatment success. The objectives of this study were to appraise current recommendations for PJI management and develop a unified clinical standard of care, to perform a gap analysis of PJI cases in a tertiary institution to determine the rate of guideline adherence, and to determine if adherence to unified PJI guidelines affected 2-year treatment outcomes.

Methods: We appraised the PJI guidelines from 3 academic medical societies, and consistent statements were aggregated. We retrospectively reviewed all PJI cases in a tertiary care institution. We defined PJI based on Musculoskeletal Infection Society PJI criteria. Surgeon adherence to preoperative, intraoperative, surgical and medical management guidelines was calculated, and we evaluated the association between guideline adherence and 2-year treatment outcomes.

Results: The institutional rate of PJI was 1.13% (38 of 3368). Treatment success was 57.8% at 2 years. Unified guideline adherence percentages varied substantially: 92% of patients had preoperative erythrocyte sedimentation rate and C-reactive protein, 97% had intraoperative tissue cultures, 42% had appropriate preoperative arthrocentesis, and 74% underwent guideline-appropriate surgery. Performing appropriate preoperative arthrocentesis significantly correlated with positive treatment outcomes at 2 years ($p = 0.028$).

Conclusion: Adherence to PJI guidelines varies considerably, indicating that clinicians are either unaware of them or do not recognize their value for PJI treatment. This study shows the need for institution-based PJI treatment pathways that are consistent with published guidelines and the need to monitor adherence.

Contexte : Les études ne concordent pas quant au taux de réussite du traitement chirurgical des infections de prothèses articulaires (IPA). Une certaine variabilité dans les lignes directrices sur ces infections et dans l'adhésion des chirurgiens à celles-ci pourrait nuire à la réussite du traitement. La présente étude visait à évaluer les recommandations actuelles sur la prise en charge des IPA afin d'élaborer une norme de soins uniforme, à effectuer une analyse des lacunes entourant les cas d'IPA dans un établissement de soins tertiaires pour déterminer le taux d'adhésion aux lignes directrices, et à déterminer si l'adhésion à des lignes directrices uniformes influençait les issues de traitement après 2 ans.

Méthodes : Nous avons évalué les lignes directrices sur les IPA de 3 sociétés médicales universitaires, et agrégé des énoncés cohérents. Nous avons également examiné de façon rétrospective tous les cas d'IPA dans un établissement de soins tertiaires. Aux fins de notre étude, l'IPA était définie selon les critères de la Musculoskeletal Infection Society. Nous avons calculé l'adhésion des chirurgiens aux lignes directrices de prise en charge préopératoire, peropératoire, chirurgicale et médicale, puis nous avons évalué l'association entre ce paramètre et les issues de traitement après 2 ans.

Résultats : Le taux d'IPA dans l'établissement était de 1,13 % (38 sur 3368), et le taux de réussite du traitement était de 57,8 % après 2 ans. Les pourcentages d'adhésion aux lignes directrices variaient considérablement : 92 % des patients avaient eu une analyse préopératoire de la vitesse de sédimentation érythrocytaire et de la protéine C-réactive, 97 % avaient eu des cultures tissulaires peropératoires, 42 % avaient eu une arthrocentèse préopératoire appropriée, et 74 % avaient subi une intervention chirurgicale conforme aux lignes directrices. Il y avait une corrélation significative entre l'arthrocentèse préopératoire et les issues favorables après 2 ans ($p = 0,028$).

Conclusion : L'adhésion aux lignes directrices sur les IPA varie considérablement, ce qui indique que les cliniciens ne les connaissent pas ou n'en reconnaissent pas la valeur pour le traitement des IPA. La présente étude montre qu'il faut dans les établissements des protocoles de traitement conformes aux lignes directrices publiées, et qu'il est nécessaire de surveiller l'adhésion des chirurgiens à celles-ci.

Periprosthetic joint infection (PJI) is a devastating complication that can occur following total joint arthroplasty. The treatment of PJI often involves multiple surgical procedures and a prolonged recovery period. Consequently, patients with PJI report greater dissatisfaction and significantly poorer health-related quality of life than patients without PJI.¹ Furthermore, the development of PJI is associated with a dramatically increased risk of death, with reported 5-year mortality ranging from 25.9%² to 45%.³ Although the incidence of PJI following primary joint arthroplasty is commonly reported to be around 1%, recent reports suggest that the incidence of PJI is increasing, with a predicted incidence of 4 million cases per year in the United States by 2030.^{4,5} This rising incidence coupled with the increasing demand for joint arthroplasty has led to a financial burden for treating PJI that is projected to be in excess of \$1.6 billion per year in the United States by 2020.⁵

Despite the rising prevalence and cost associated with PJI, reported treatment outcomes remain inconsistent in the literature. Surgical irrigation and débridement, a recommended treatment for early PJI, has a reported success rate of 8%–71%.^{6–9} Meanwhile, the gold standard treatment for chronic PJI, the “2-stage” revision arthroplasty, has a reported failure rate of 5%–23%.^{10–12} This variability in treatment efficacy makes clinical decision-making difficult for the treating physician, who wishes to balance the morbidity of invasive surgery with the probability of treatment success. Properly prognosticating treatment success is further compounded when the diagnosis of PJI is not straightforward, such as in the setting of culture-negative PJI¹³ or infection due to *Propionibacterium acnes*.¹⁴

In response to challenges with the diagnosis and treatment of PJI, several medical associations have developed evidence-based clinical practice guidelines^{15–17} over the last decade. Although such guidelines were established to help standardize PJI management, to date no assessment of congruity among these guidelines or physician adherence to them in clinical practice has been performed. Exploring guideline heterogeneity and variation in physician practices could help explain local variation in PJI outcomes and identify opportunities to improve outcomes through standardization of both diagnostic and management strategies.

The objectives of the present study were to appraise the current literature recommendations for PJI diagnosis and management and organize them into a unified PJI clinical standard of care, to perform a gap analysis of qualifying PJI cases in a tertiary institution to quantify the rate of guideline adherence by treating surgeons, and to report if any association between guideline adherence and treatment outcome was observed. To our knowledge, no previous studies have examined institutional adherence rates for PJI management.

METHODS

We obtained institutional review board approval before study commencement.

Currently, there are a variety of clinical practice guidelines available for the diagnosis and management of PJI. These guidelines have been developed by groups of clinicians who rigorously reviewed the literature and achieved agreement in working groups using accepted consensus-building techniques. To develop a unified clinical standard of care for which PJI management in our institution could be compared, we reviewed the clinical practice guidelines produced by 3 major academic societies: the American Academy of Orthopaedic Surgeons (AAOS),¹⁵ the Infectious Disease Society of North America (IDSNA)¹⁶ and the Musculoskeletal Infection Society (MSIS).¹⁷ Clinical practice guidelines that received a “strong” recommendation from both the AAOS and IDSNA were incorporated into the current clinical standard of PJI management. Two clinicians experienced in PJI management (A.C. and H.A.) independently reviewed the 207 consensus statements outlined in the 2014 MSIS international consensus proceedings and identified statements that were identical to or consistent with AAOS/IDSNA “strong” recommendations or those that involved direct recommendations for how to diagnose and manage PJI and were supported by at least 85% of participating MSIS members. The resulting consensus statements and clinical practice guidelines agreed upon by the 2 reviewers were collapsed into a unified clinical standard of care.

All primary total knee (TKA), hip (THA) and shoulder (TSA) arthroplasty procedures performed at a tertiary referral centre between Jan. 1, 2011, and Dec. 31, 2013, were retrospectively reviewed. The centre performs an average of 1400 primary joint replacement surgeries per year and has on-call access to arthroplasty-specialized surgeons. To identify patients with PJI, we used a 2-step search process. First, the digital charts and laboratory values of all patients were screened to identify patients with 1 or more of the following results: elevated erythrocyte sedimentation rate (ESR), elevated C-reactive protein (CRP), positive joint fluid culture, positive joint tissue culture, surgical reoperation for any reason, and/or an ICD-9 diagnostic code of PJI. Second, one of us (M.D.A.) manually reviewed the electronic and physical charts from all patients with 1 or more positive findings from the first screening. Patients were identified as having PJI if they had either a final ICD-9 diagnosis of PJI or fulfilled MSIS criteria for PJI¹⁷ and had at least a 2-year follow-up.¹⁸

We collected the following data on patients with PJI: age, sex, body mass index, smoking status, American Society of Anesthesiologists (ASA) classification, Charlson Comorbidity Index score and interval between initial arthroplasty and onset of PJI. We then categorized PJI as early, delayed or late according to the Zimmerli/Trampuz classification.¹⁹ Furthermore, we recorded details regarding the method of PJI workup (radiography, blood tests, aspiration/biopsy,

number of intraoperative cultures, gram stain), culture results, PJI treatment (antibiotic suppression, irrigation and débridement, 1-stage revision, 2-stage revision, type of antibiotics spacer), antibiotic duration and criteria for proceeding to a second stage revision. The initial data collection was verified by a second reviewer for accuracy.

Treatment success was defined as cessation of antibiotic therapy with a prosthesis or antibiotic spacer implanted, normalized laboratory markers, and no further infectious symptoms for a period of at least 2 years following surgery. After the first surgical treatment and conclusion of antibiotic therapy, we considered treatment to have failed if patients required subsequent surgery and/or acute or chronic antibiotic therapy.

Upon collection of the aforementioned variables, we performed a gap analysis,²⁰ whereby we compared the management of previous PJI cases (actual clinical performance) with a conceptually desired performance (unified clinical standard). This form of analysis has been used previously to evaluate medical institutional performance²¹ and improve dissemination of best health care practices across institutions.²² For each PJI case, specific features of the preoperative PJI workup, intraoperative workup and surgical treatment, and postoperative PJI management were compared with recommendations from the unified clinical standard to determine the rate of physician adherence. We tabulated the number of guideline statements fulfilled for each case. Owing to the use of an ordinal rank scale (no. of guidelines followed out of a possible 11), we calculated a Spearman correlational coefficient to determine if a significant association existed between guideline adherence and clinical treatment success. We conducted χ^2 tests to assess fulfillment of specific guidelines and determine if any of these were significantly more prevalent in cases of successful (i.e., no recurrence of PJI 2 yr after initial treatment) or unsuccessful PJI treatment. All statistical tests assumed 95% confidence intervals (CIs), and we considered results to be significant at $p < 0.05$.

RESULTS

We identified 7 “strong” recommendations from the AAOS guidelines and 8 “level A” recommendations identified from IDSNA guidelines. Twelve consensus statements from the MSIS met selection criteria and were incorporated into 10 recommendations, making up the unified clinical standard for diagnosis and management of PJI (Box 1).

Over the 3-year study period, a total of 3368 primary knee, hip, and shoulder arthroplasty procedures were performed. Chart review and application of the 2-step search process identified a total of 38 cases (1.13%) that met MSIS criteria for PJI. Of these cases, 17 patients (1.02%) had THAs, 19 (1.3%) had TKAs and 2 (2.02%) had TSAs. Regarding the timing of PJI, 23 were early, 12 were delayed and 3 were late. Patient demographic and baseline clinical characteristics are described in Table 1.

Of the 38 cases of PJI, 22 (57.8%) met criteria for successful treatment (Table 2) after a single surgical procedure at an average follow-up of 2.11 (range 2.0–3.4) years. The 16 patients in whom initial management failed underwent an average of 2.9 ± 1.24 surgical procedures in total. After 2 years (Table 3), 3 of these 16 patients had undergone multiple irrigation and débridements, with no infectious symptoms at the most recent follow-up. Eight patients had undergone at least 1 implant revision and had no infectious

Box 1. Unified periprosthetic joint infections (PJI) guidelines

Preoperative evaluation (performed before the initiation of oral or intravenous antibiotic treatment)

1. Serum erythrocyte sedimentation rate/C-reactive protein
2. Anteroposterior and lateral radiographs of the affected joint
3. Diagnostic arthrocentesis with fluid sent for the following:
 - a. Cell count and differential
 - b. Culture and sensitivity

Intraoperative evaluation and management

1. Intraoperative collection of at least 3 tissue cultures
2. Débridement with exchange of modular components and implant retention is indicated if:
 - a. PJI diagnosed within 30 days of the index arthroplasty procedure
 - b. PJI diagnosed within 3 weeks of symptoms
3. A revision arthroplasty (1-stage/2-stage) with implant removal is indicated if:
 - a. PJI is diagnosed after 30 days since the index arthroplasty procedure and/or symptoms have been greater than 3 weeks.
 - b. PJI has recurred following previous débridement and modular component exchange.
4. Resection arthroplasty and/or chronic antibiotic suppression is indicated for PJI recurrence following multiple 1-stage/2-stage surgery failures.

Medical management

1. Empiric, broad-spectrum antibiotics are administered immediately after surgical management and continued until final culture results are obtained.
2. Following débridement and implant retention, treatment consists of pathogen-specific intravenous antibiotics for 2–6 weeks in combination with rifampin.
3. Following resection arthroplasty or 1-stage/2-stage revision arthroplasty, treatment consists of pathogen-specific intravenous antibiotics for 2–6 weeks in combination with rifampin.
4. For chronic suppression of PJI, pathogen-specific antibiotics are administered (orally or intravenously) for at least 3 months.

Table 1. Demographic and clinical characteristics of study participants (n = 38)

Characteristic	Mean [range], or no. (%)*
Age, yr	68.5 [27–85]
BMI	30.8 [19.4–54.4]
American Society of Anesthesiology classification	2.8 [2–4]
Charlson Comorbidity Index score	3.5 [1–7]
Sex, male:female	16:22
Smoker	6 (15)
Concurrent/recent infection	4 (10)
Immunocompromised	8 (20)
Drug resistant bacteria	15 (39.5)

BMI = body mass index.
*Unless indicated otherwise.

Table 2. Success rate of treatments for all patients with PJI

Treatment	No. (%) of successful cases
Irrigation, débridement and bearing exchange	18/28 (64.3)
Revision arthroplasty	
1-stage revision	0/2 (0)
2-stage revision	3/8 (37.5)

PJI = periprosthetic joint infections.

Table 3. Cases of periprosthetic joint infections in which initial treatment failed (n = 16)

Outcome	No. of cases
One or more irrigation, débridement and bearing exchanges, free of infection	8
One or more implant revisions, free of infection	3
Failure after multiple surgeries, on chronic antibiotic suppression	3
Joint arthrodesis	1
Deceased	1

symptoms at the most recent follow-up. Three patients were placed on long-term oral antibiotic suppression, 1 patient underwent implant resection and arthrodesis, and 1 patient died within 2 years of the initial surgery.

Gap analysis

For the preoperative workup for PJI, 33 (86.4%) patients had serum ESR and CRP levels measured, 20 (52.6%) had joint-specific plain radiographs completed, and 25 (65.8%) underwent diagnostic arthrocentesis (Fig. 1). Of the cases with completed arthrocentesis, only 16 (64%) included a cell count, manual differential and bacterial culture.

With respect to intraoperative diagnosis and management, intraoperative culture and gram stains were acquired in 100% of cases. Specifically, fluid cultures were obtained in 92.1% of cases and tissue cultures were obtained in 97.4%. Only 42.1% of cases had 3 or more tissue cultures acquired at the time of surgery. For operative management, irrigation with débridement and modular component

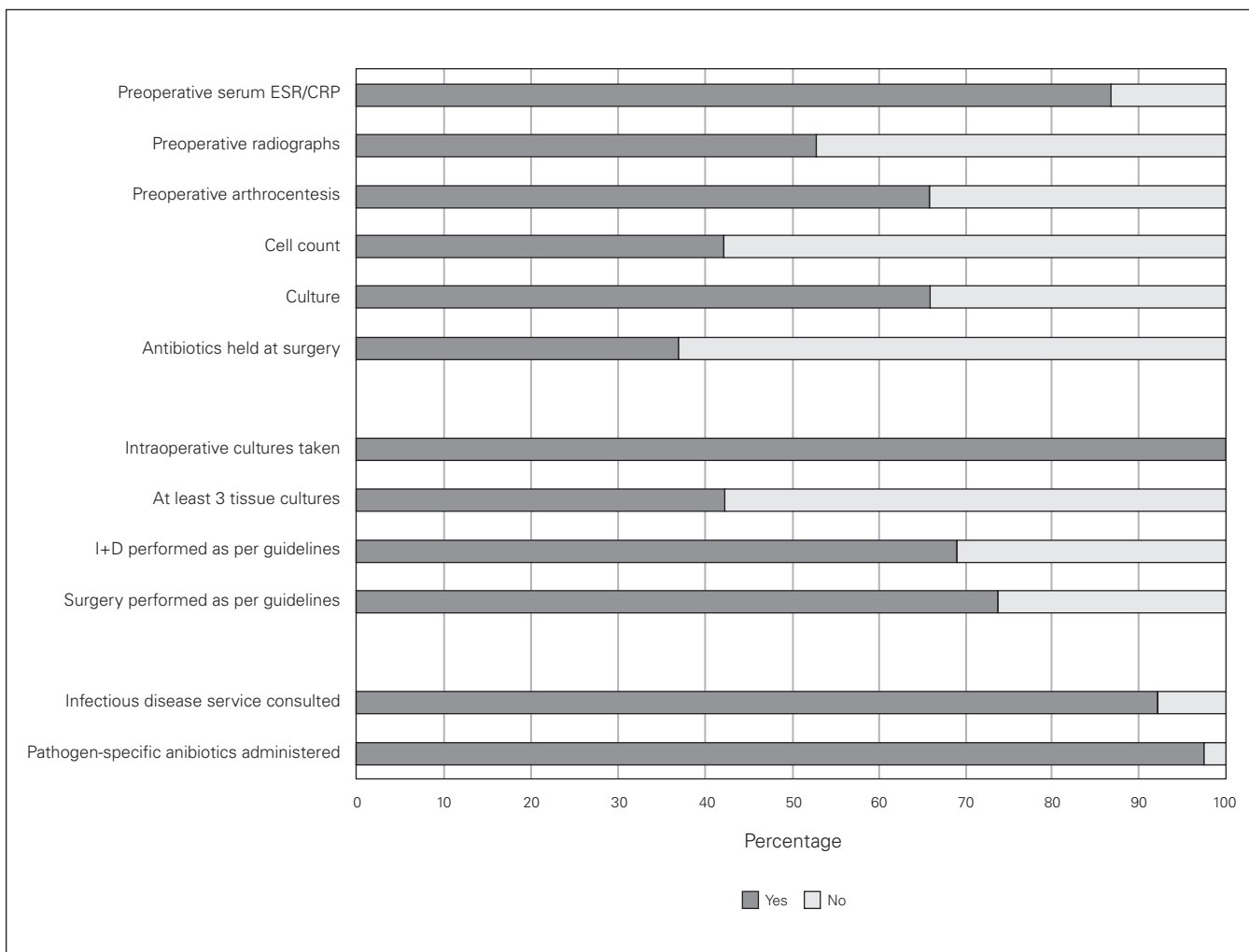


Fig. 1. Percentage of guideline adherence among study cases. CRP = C-reactive protein; ESR = erythrocyte sedimentation rate; I+D = irrigation and débridement.

exchange was the most common procedure performed, occurring in 28 (73.7%) patients with a success rate of 64.2%. For 10 of the 38 (26.3%) patients with PJI, the operative procedure performed was not consistent with the unified PJI guidelines. In 9 of these patients, irrigation with débridement and modular component exchange was performed instead of implant revision.

With respect to postoperative medical management, consultation with infectious disease specialists occurred in 35 (92.1%) cases. Organism-specific intravenous antibiotics were administered for at least 4–6 weeks in 37 (97.3%) patients.

Association between guideline adherence and treatment outcome

Of the 4 preoperative measures identified in the unified guidelines, an average of 2.23 ± 0.97 were completed, with 4 cases achieving all 4 measures and 9 cases achieving only 1 measure (serum CRP and ESR levels). For treatment success, performing a diagnostic arthrocentesis and appropriately ascertaining cell count and bacterial culture was significantly correlated with a positive PJI treatment outcome at 2 years (Spearman correlation coefficient = 0.357, $p = 0.028$). Undergoing a diagnostic arthrocentesis significantly correlated with better preoperative guideline adherence (ESR/CRP, radiographs, diagnostic arthrocentesis and antibiotics withheld; Spearman correlation coefficient = 0.722, $p < 0.001$), but was otherwise not associated with any other treatment variable.

For intraoperative culture requirements or surgical management, only 14 of 38 cases (36.8%) fulfilled both requirements according to the unified guidelines. In 8 cases (21.1%), neither the correct number of cultures nor appropriate surgical management were performed. No significant correlations were found for fulfilling culture requirements, appropriate use of irrigation and débridement or appropriate surgical management with overall PJI treatment outcome. Furthermore, postopera-

tive infectious disease consultation and use of antibiotics was not correlated with PJI treatment outcome. A complete list of variables and correlational coefficients is provided in Table 4.

Overall, of the 8 PJI management guidelines, an average of 5.3 ± 1.27 (range 3–8) were followed per case. There was no significant correlation between overall PJI guideline adherence rate and treatment outcomes. The timing of PJI (early/delayed/late) was significantly associated with the surgical procedure chosen (Spearman correlation coefficient = -0.642 , $p < 0.001$), with the negative number reflecting the large number of irrigation and débridements performed. Body mass index, history of diabetes, smoking and Charlson Comorbidity Index score did not correlate with PJI treatment outcomes.

DISCUSSION

To our knowledge, this study is the first to compare and unify current PJI guidelines and then investigate how often orthopedic surgeons adhere to these guidelines when managing PJI. Although involving only a single tertiary care institution, the study results are generalizable, given that the PJI rate of 1.13% following primary arthroplasty is similar to the rates reported in the literature,^{23,24} as is the 63% treatment success with irrigation and débridement.²⁵ Furthermore, the management of patients with PJI was not limited to arthroplasty surgeons, but rather consisted of a multispecialty group, further increasing the generalizability of the results. In this reported series of 38 cases, we identified great variability in the way surgeons diagnose and manage PJI. Although 92% of patients with suspected PJI did undergo initial serological screening and 100% were treated with some form of operative management, the inconsistent use of diagnostic modalities and surgical procedures suggest that orthopedic surgeons do not recognize their value or are conflicted regarding the various PJI guidelines currently available. We advocate that the development of a simple,

Table 4. Associations between patient, diagnostic and treatment variables with outcomes		
Variable	Spearman correlation coefficient	p value
Charlson Comorbidity Index	-0.207	0.21
Timing of PJI (early, delayed, late)	-0.043	0.80
Antibiotic resistant bacteria	-0.171	0.33
Correct preoperative diagnostic arthrocentesis*	0.357	0.028
Correct number of intraoperative cultures taken*	-0.233	0.16
Correct operative procedure performed*	0.039	0.82
Correct use of irrigation, débridement and modular component retention*	-0.233	0.16
Perioperative infectious disease service consultation	-0.016	0.93
Correct use of antibiotic therapy postoperatively*	0.186	0.26

PJI = periprosthetic joint infection.
 *According to the unified PJI guidelines.

unified set of clinical practice guidelines published under the collective banner of both orthopedic and infectious disease societies would substantially improve and clarify how best to diagnose and manage PJI. Application of this unified guideline within an institution could then reduce treatment inconsistencies and optimize outcomes.

Limitations

We acknowledge several limitations to this study. First, we recognize that the diagnosis and management of PJI is complex, and that the unified guidelines proposed in this study do not cover all diagnostic tests, do not evaluate criteria for 1-stage versus 2-stage revision and instead simplify the subtypes of surgical management. However, these guidelines were created using objective, unbiased criteria that identified the strongest recommendations from 3 of the largest academic bodies to guide PJI care. We decided to reconcile these strong recommendations to avoid preferential treatment to 1 specific academic body and to quantify physician adherence to clinical rules that are generally known among orthopedic surgeons. A second limitation is the relatively small number of PJI cases included and the even smaller number of cases that underwent initial full implant revision, which limits the statistical power of the study. Such small numbers are explained by the stringent criteria for study inclusion: specifically, meeting MSIS criteria and a minimum 2-year follow-up in order to define treatment success consistent with recommendations in the literature.¹⁸ A final limitation is that we were unable to explicitly retrieve reasons for why surgeons did or did not follow PJI guidelines for each case. Although presenting symptoms (draining sinus, septic shock, previous history of PJI) and surgeon expertise (fellowship-trained or not) are observable factors that could affect diagnostic and surgical management, other influences, such as diagnostic test availability, access to the operating room, physician attitudes toward the effectiveness of PJI guidelines and physician-specific differences in technique (method of arthrocentesis, quality of surgical débridement, amount of irrigation used), are not easy to collect in a retrospective fashion. Moving forward, we plan to engage these surgeons in reviewing the current guidelines, promote comparative data-sharing and evaluate how patient-based and facility-based factors affect PJI care as part of our continuous quality improvement initiatives.²⁶ Such efforts have been shown to improve physician guideline adherence^{27,28} and encourage the building of multidisciplinary teams within single institutions.²⁹

Despite not being properly performed in more than half of the cases in our series, a preoperative diagnostic arthrocentesis is an important tool in the management of PJI. Although the precise technique of arthrocentesis has been scrutinized in the recent PJI literature,³⁰ its use has

been described as mandatory in the context of chronic PJI, as bacterial identification can help determine if a 1-stage or 2-stage revision is indicated.^{31,32} Yet, apart from sending aspirated fluid for culture, the PJI literature offers a wide array of other assays to diagnose PJI. Although synovial leukocyte counts and neutrophil percentages are widely recommended for PJI diagnosis, the thresholds vary according to the type of joint infected, acute versus chronic infection, and infection of a primary versus a revised joint. Synovial CRP and a variety of inflammatory cytokines have been lauded as being superior to serum testing,^{33,34} but these tests are not widely available, they are expensive, and they are not consistently reproduced.^{35,36} For our study series, the use of preoperative arthrocentesis with both culture and leukocyte cell count was the only diagnostic tool significantly associated with a positive PJI treatment outcome. Although it is unclear if the treating surgeons used similar leukocyte count thresholds to diagnose PJI, it is logical to assume that arthrocentesis-based bacterial culture permits proper identification of the offending organism and permits expedient perioperative use of appropriate antibiotics, which can eradicate infection. Choosing the appropriate surgical management is the next step.

Irrigation, débridement and modular component exchange was the most common surgical protocol used in our series; with a 64% success rate it is an appealing, yet somewhat controversial treatment for PJI. In addition to being technically easier than a full implant revision, the procedure can be better tolerated by a large percentage of patients with PJI, who are generally fragile and have multiple comorbidities. The above features as well as the observation that patients with PJI operated on by nonarthroplasty surgeons were included in the study series could explain why irrigation and débridement was the most common surgical procedure performed. Unfortunately, the contemporary outcomes for irrigation and débridement in patients with PJI vary substantially in the literature, with 2-year cure rates ranging from 29% to 92%.⁹⁻¹² Furthermore, results from several large case series suggest that a failed irrigation and débridement is associated with even poorer outcomes following a subsequent 2-stage revision.^{37,38} In the last 2 years, very poor results, even in the context of acute infection, have led several PJI experts to recommend against the routine use of irrigation and débridement, with the sole exception being a specifically immunologically competent patient who has a non-Staphylococcal, low-virulence infection.^{39,40} Although our correlational findings suggest that surgeons factor in the timing of PJI with the type of surgical procedure offered, further investigations are needed to determine what patient and institutional factors influence surgeons to perform irrigation and débridement as well as what, if any, intraoperative techniques influence the outcome of the procedure.

CONCLUSION

The present investigation suggests that unified, simplified PJI guidelines and efforts to improve adherence to such guidelines are seriously needed. Although previous efforts to improve guideline adherence among orthopedic surgeons have not always been successful,^{41,42} the rising incidence and dramatic care costs associated with PJI mandate an earnest effort at both the institutional and national levels. It is hoped that these efforts as well as published attempts for consensus among experts^{43,44} will help clarify what features of PJI diagnosis and management are the most effective.

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Contributors: All authors designed the study. M. Armstrong acquired and analyzed the data, which A. Carli, H. Abdelbary, S. Poitras and P. Beaulé also analyzed. M. Armstrong, A. Carli and P. Beaulé wrote the article, which all authors reviewed and approved for publication.

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