



# The evaluation, classification, and management of septic arthritis of the shoulder: the comprehensive shoulder sepsis system

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**Background:** Septic arthritis of the shoulder is distinctly challenging to diagnose and treat. Guidelines for appropriate workup and management are limited and do not account for the variations in clinical presentation. The purpose of this study was to present a comprehensive and anatomically based classification system and treatment algorithm for septic arthritis of the native shoulder joint.

**Methods:** A multicenter, retrospective analysis of all patients treated surgically for septic arthritis of the native shoulder joint was performed at 2 tertiary care academic institutions. Preoperative magnetic resonance imaging and operative reports were used to classify patients as having 1 of 3 infection subtypes: type I, confined to the glenohumeral joint; type II, extra-articular extension; or type III, concomitant osteomyelitis. On the basis of these clinical groupings of patients, the comorbidities, types of surgical management, and outcomes were analyzed.

**Results:** Sixty-five shoulders in 64 patients met the inclusion criteria for the study. Of these infected shoulders, 9.2% had type I infections, 47.7% had type II, and 43.1% had type III. Age and the time between symptom onset and diagnosis were the only significant risk factors for the development of a more severe infection. Fifty-seven percent of shoulder aspirates revealed cell counts below the standard surgical cutoff of 50,000 cells/mL. On average, each patient required 2.2 surgical débridements to eradicate the infection. Infections recurred in 8 shoulders (12.3%). Body mass index was the only risk factor for recurrence of infection. Of the 64 patients, 1 (1.6%) died acutely of sepsis and multi-organ system failure.

**Conclusion:** We propose a comprehensive system for the classification and management of spontaneous shoulder sepsis based on stage and anatomy. Preoperative magnetic resonance imaging can help determine the severity of disease and aid in surgical decision making. A systematic approach to septic arthritis of the shoulder as a unique entity from septic arthritis of other large peripheral joints may lead to more timely diagnosis and treatment and improve the overall prognosis.

**Level of evidence:** Level III; Retrospective Cohort Comparison; Prognosis Study

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**Keywords:** Septic arthritis; glenohumeral joint; shoulder; native; MRI; classification

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Septic arthritis of the native shoulder accounts for 3%-15% of joint infections.<sup>9,22,24</sup> Sepsis involving the shoulder complex is primarily thought to arise hematogenously<sup>10</sup>; however, infections can also arise via direct inoculation, such as a corticosteroid injection, or by contiguous spread.<sup>1</sup> Most commonly, the infectious pathogen is *Staphylococcus aureus*,<sup>2,9,13,14</sup> and the overall prognosis is dependent on early diagnosis and treatment to eradicate the infection and preserve articular cartilage.

The classic presenting symptoms of septic arthritis are often not present in cases of shoulder sepsis or are vague and difficult to differentiate from the symptoms of more common shoulder pathologies.<sup>7,24</sup> Native shoulder sepsis may also present with nonspecific serologic markers and/or joint aspiration results.<sup>20,27,29,31</sup> As a consequence, a delay in diagnosis of up to 6 months can occur in such patients, which correlates with adverse outcomes and substantial morbidity.<sup>1,13</sup>

Magnetic resonance imaging (MRI) represents the most sensitive and specific imaging modality not only for identifying the location of infection but also for determining the coexistence of osteomyelitis.<sup>13</sup> The latter finding is critical for surgical decision making.<sup>28</sup> Favorable outcomes have been reported in 80% of shoulders promptly treated within 1 month of symptom onset, regardless of the method of surgical management (ie, open vs. arthroscopic),<sup>3,9,19,31</sup> with up to 30%-40% of patients requiring multiple surgical procedures to successfully manage the infection.<sup>10,12,18,31</sup> The overall mortality rate is 2.6%-17%.<sup>1,18</sup>

Currently, there is no universally accepted standard of care for the diagnostic workup, classification, or surgical management of patients with septic arthritis of the shoulder. Therefore, the purpose of this study was to present a comprehensive and anatomically based classification system and treatment algorithm for septic arthritis of the native shoulder joint. The secondary objective was to report the demographic characteristics, clinical and laboratory findings, and comorbidities of a large cohort of patients presenting with spontaneous shoulder sepsis. We hypothesized that diagnostic delays, patient comorbidities, and the organism(s) cultured would represent independent risk factors for worse clinical disease, an increased number of surgical washouts required to eradicate the infection, and an increased rate of recurrent infection.

## Materials and methods

A multicenter, retrospective analysis of patients treated surgically for septic arthritis of the native shoulder joint at 2 tertiary care academic institutions (University of Texas Health Science Center at San Antonio and University of Calgary) from 2008 to 2021 was performed. The inclusion criteria included adult patients (age  $\geq$  18 years) undergoing either arthroscopic and/or

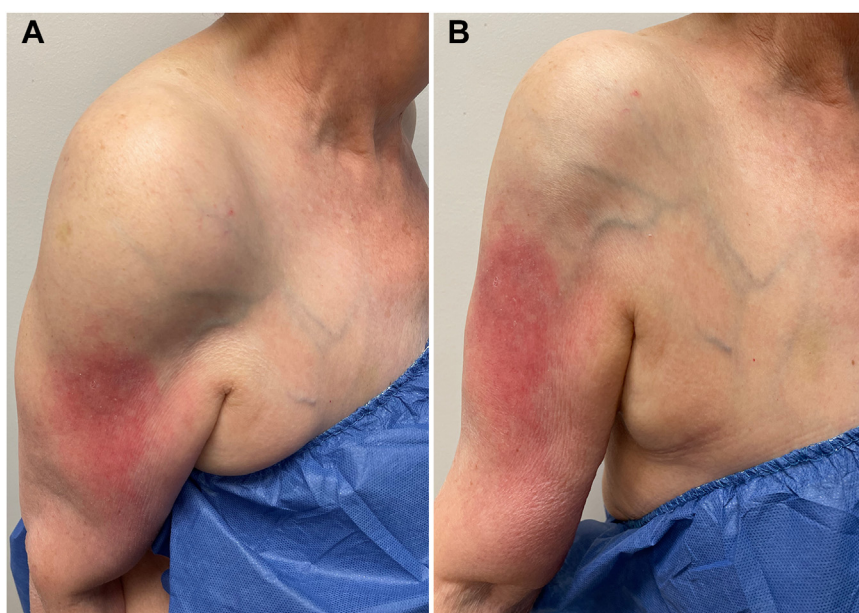
open débridement of the native shoulder joint for septic arthritis. *International Classification of Diseases, Tenth Revision* (ICD-10) codes for shoulder sepsis and septic arthritis were combined with the Current Procedural Terminology (CPT) code for irrigation and débridement of the shoulder to identify eligible patients for this study. The diagnosis of septic arthritis was made by combining all available clinical (Fig. 1), laboratory, and advanced imaging data<sup>8,21</sup> and only included patients with surgically confirmed shoulder sepsis with evidence of one or more of the following: (1) purulent fluid and/or material, (2) devitalized tissue, (3) bony destruction such as osteomyelitis, and (4) soft-tissue abscess and/or pyomyositis. Patients were excluded if the clinical and/or diagnostic workup was consistent with other shoulder problems that may present with shoulder pain and/or effusion, such as rotator cuff tear arthropathy or rheumatic disease (eg, rheumatoid arthritis) without concomitant infection. Patients with a history of a surgical intervention on the ipsilateral shoulder were also excluded. The diagnostic protocol used to identify eligible patients was the same at each study site.

Secondary outcomes of interest including patient demographic characteristics, presenting symptomatology, comorbidities, serologic findings, microbiological findings, preoperative advanced imaging, antibiotic treatment, surgical details, and recurrence of infection were recorded within a Research Electronic Data Capture (REDCap) database. Recurrence of infection was defined as a subsequent hospital admission requiring further surgical débridement of the same shoulder joint.<sup>31</sup> Of note, we have previously published 1 patient's clinical outcome as this case represented a unique form of shoulder sepsis.<sup>11</sup>

## Zones of the shoulder girdle and infection classification

The "zones of infection" have been previously defined and described by the senior authors (C.A.R., A.J.B., and A.K.D.) (Fig. 2).<sup>4</sup> Ogul et al<sup>25</sup> have described in detail the extra-articular areas within the shoulder girdle that fluid can easily extravasate, providing pathways for infection to spread, and their description supports our anatomic-based classification. By use of MRI and/or CT, the 7 zones were subcategorized into 1 of 3 subtypes: type I, confined to the glenohumeral joint (zone 1); type II, extra-articular extension, excluding the acromioclavicular joint (zones 2-6) (Fig. 3); or type III, osteomyelitis of the humeral head and/or metaphysis (zone 7A) and/or glenoid vault (zone 7B).

Preoperative advanced imaging (ie, MRI or CT) was reviewed by 2 of the senior authors (A.J.B. and A.K.D.) to determine the infection classification for each patient; each senior author only reviewed the imaging studies of the patients who were recruited from their respective institution (ie, not the entire study cohort). These authors were blinded to the operative reports during imaging review, maintaining objectivity. For patients in whom preoperative imaging was unavailable, operative reports were reviewed to determine the zone or zones of involvement. For the purpose of this study, preoperative MRI or CT findings were not assessed for interobserver and intraobserver reliability statistics nor were the findings correlated to the intraoperative findings as such analyses will form the basis of subsequent prospective studies.



**Figure 1** (A and B) Photographs of a 74-year-old female patient with pre-existing rotator cuff tear arthropathy presenting with chronic right shoulder sepsis due to methicillin-resistant *Staphylococcus aureus*. There was clinical evidence of a large joint effusion, erythema extending down the upper arm to the elbow, and a large palpable axillary lymph node (not shown). The patient was found to have an ipsilateral deep venous thrombosis of the upper arm with secondary venous congestion and lymphedema.

## Operative technique

All procedures were performed with patients in the beach-chair position. When open procedures were performed, a deltopectoral approach was used. For arthroscopic cases, standard arthroscopic portals were used (Fig. 4). All anatomic zones were systematically explored, followed by débridement of nonviable and/or infected tissue. Additional care was taken in patients with zone 3 involvement (distal extension into the anterior brachium), zone 6 involvement (distal extension into the posterior brachium), zone 4 involvement with proximal (ie, brachial plexus)<sup>11</sup> or distal-medial (ie, anterior chest wall) extension (Fig. 5), or severe zone 5 involvement, which may have required separate open approaches to manage the infection burden in each respective region. Multiple culture and tissue biopsy specimens (ie, minimum of 3) were obtained. Focal or contained type III infections (zones 7A and 7B) were treated with osseous débridement, subchondral drilling, and/or curettage with or without placement of antibiotic-impregnated beads. In cases with more severe and/or diffuse humeral involvement, resection arthroplasty (Fig. 6) with or without insertion of an antibiotic humeral spacer was performed (Fig. 7). The administration of broad-spectrum intravenous antibiotics was started after joint aspiration and/or tissue specimens were obtained; this was adjusted based on the final culture results. All patients underwent infectious disease consultation postoperatively to facilitate antibiotic management. Serum markers were followed by both the treating surgeon and infectious disease consultant postoperatively to assess each patient's response to surgical and medical treatment.

## Statistical analysis

All statistical analyses were conducted using SAS software (version 9.4; SAS Institute, Cary, NC, USA), with the assistance of a

statistician (L.P.G.). Categorical variables are presented as counts and percentages. Continuous variables that are normally distributed are presented as means and standard deviations or medians and ranges. Comparisons between infection types I, II, and III were completed with  $\chi^2$  tests for categorical variables and generalized linear regressions for continuous variables. All statistical comparisons were performed using a *P* value of .05 to denote significance.

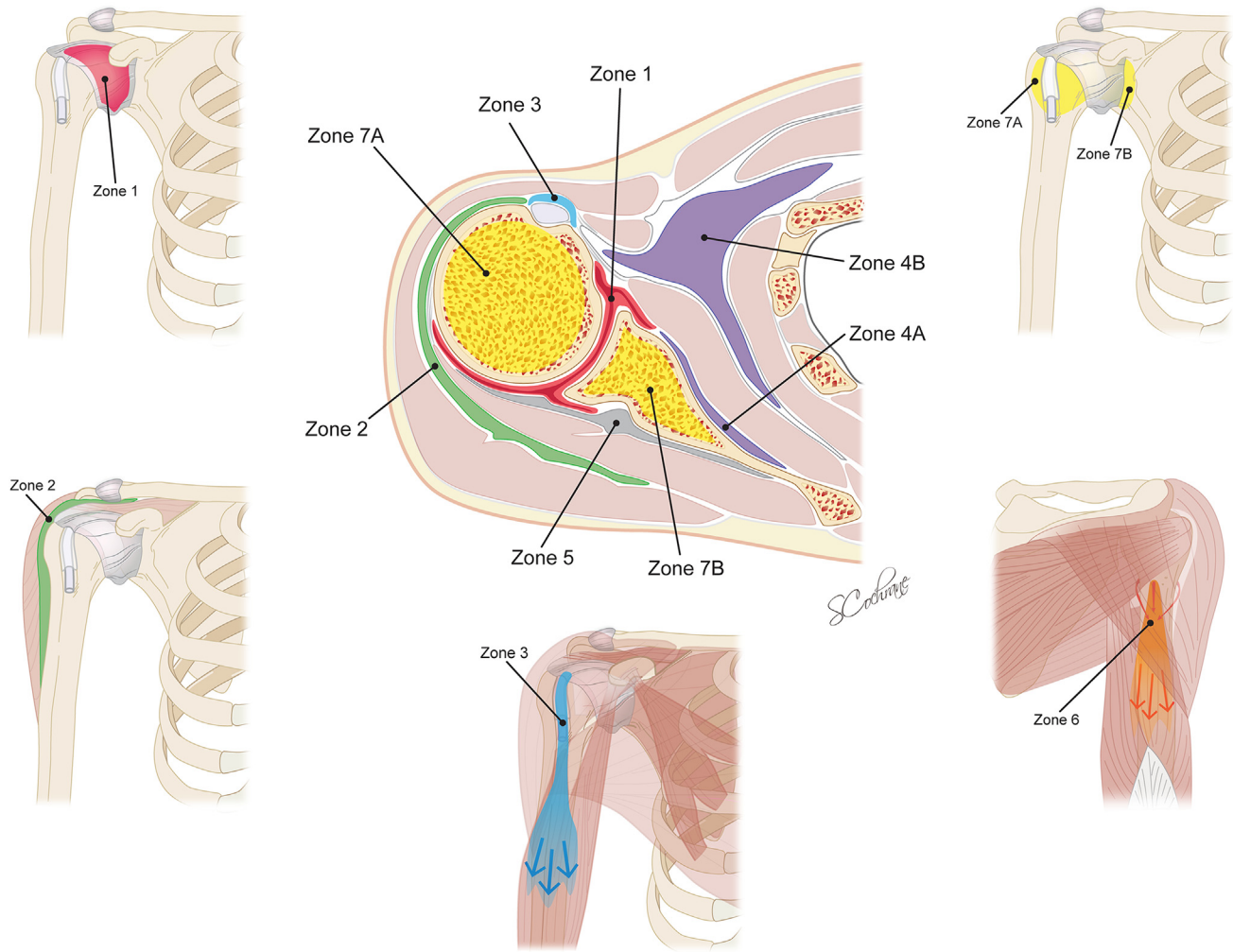
## Results

Sixty-five shoulders in 64 patients were included in the final analysis. We recruited 52 patients (53 shoulders) from the University of Texas at San Antonio and 12 patients (12 shoulders) from a single surgeon's practice (A.J.B.) at the University of Calgary. Patient demographic characteristics, disease timelines (time to diagnosis and time to surgery), and infection classifications are described in Tables I and II. Of the infected shoulders, 9.2% (*n* = 6) had type I infections, 47.7% (*n* = 31) had type II, and 43.1% (*n* = 28) had type III.

## Demographic characteristics

The average age of the cohort at the time of surgery was 50.7 years (range, 20-84 years). Sixty-five percent of patients were men, and 46% had  $\geq 2$  significant comorbidities at presentation. The most common comorbidities included a history of intravenous drug use and diabetes (Fig. 8).

There was a positive association between the duration from symptom onset to diagnosis and the 3 types of



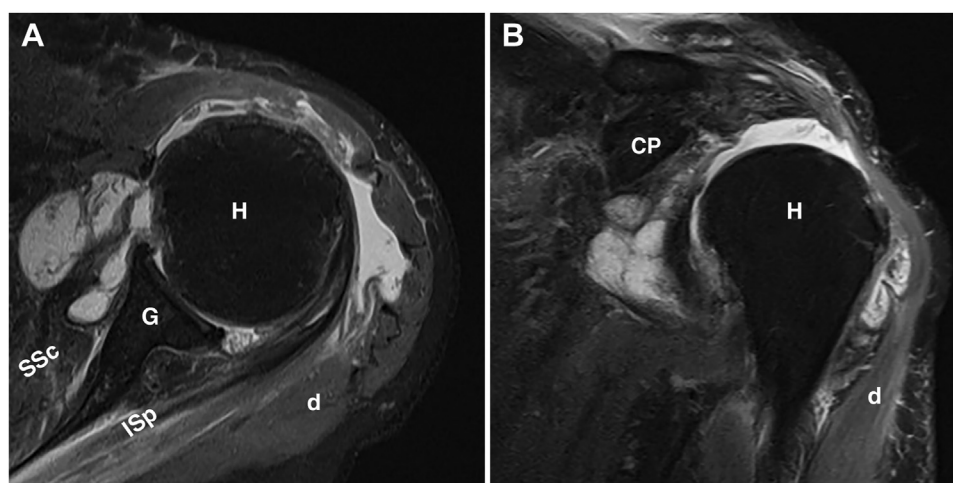
**Figure 2** Comprehensive classification of shoulder sepsis with shoulder in axial plane (*central image*) and coronal plane (*peripheral images*) outlining 7 zones of infection. Zone 1 is confined to the glenohumeral joint. Zone 2 extends into the subacromial and subdeltoid spaces. Zone 3 extends down the biceps tendon sheath with or without extension into the soft tissues of the anterior compartment of the brachium. Zone 4A extends deep to the subscapularis muscle (ie, between the muscle and the subscapular fossa), whereas zone 4B extends via the rotator interval along the bursal surface of the subscapularis muscle and subcoracoid space. Zone 4B may further extend distally into the anterior chest wall (deep and/or superficial to the pectoralis major muscle) or proximally surrounding the brachial plexus. Zone 5 extends posteriorly, deep to the infraspinatus muscle (ie, between the muscle and the infraspinous fossa). Zone 6 extends distally into the soft tissues of the posterior compartment of the brachium. It should be noted that in zones 2-6, there may be concomitant pyomyositis of the surrounding muscles within each respective zone. Zone 7A includes osteomyelitis involving the humeral head and/or metaphysis; and zone 7B, the glenoid vault. In some severe and/or chronic cases with osseous involvement, one should note that there may be distal meta-diaphyseal or intramedullary extension within the proximal humerus or there may be medial extension beyond the glenoid vault into any 1 of the following locations (or a combination thereof): coracoid process, lateral pillar of the scapula, scapular spine or acromion, and scapular body.

infection, with the average period ranging from 1.5 days for type I infections to 26.5 days for type III infections (Table I). Prior to the index hospitalization, 23 patients (36%) had been seen by a physician at an outside center (ie, primary care or other physician) for their initial shoulder complaints. Unfortunately, septic arthritis was correctly diagnosed in only 8 of these patients (35%). Increasing age ( $P = .0481$ ) and time from symptom onset to diagnosis ( $P < .001$ ) were the only significant risk factors for the development of a more severe infection (ie, type II or III infection) based on a

multivariate regression analysis. Other factors such as patient comorbidities and organisms cultured (eg, methicillin-resistant *S aureus*) were not identified as independent risk factors for worsening disease severity.

### Clinical presentation and laboratory analysis

At presentation, most patients were afebrile with an average maximum body temperature of 37.5°C. Clinically, 43.1% of the cohort (28 of 65 shoulders) met the systemic



**Figure 3** Type II infection in left shoulder. T2-weighted axial (A) and coronal (B) magnetic resonance imaging demonstrates a large joint effusion with extra-articular extension into the subacromial and subdeltoid spaces (zone 2), as well as tracks along both sides of the subscapularis (SSC) muscle and subcoracoid space (zones 4A and 4B). H, humeral head; G, glenoid; d, deltoid muscle; ISp, infraspinatus; CP, coracoid process.

inflammatory response syndrome (SIRS) criteria at presentation, which was inversely related to infection type (Table I).<sup>16</sup> Serum white blood cell (WBC) counts for type I, II, and III infections revealed minimal evidence of leukocytosis and measured 12,600 cells/ $\mu$ L, 13,100 cells/ $\mu$ L, and 10,500 cells/ $\mu$ L, respectively. The C-reactive protein (CRP) level decreased across type I and II infections and type III infections (type I, 151.4 mg/L; type II, 151.9 mg/L; and type III, 78.4 mg/L), whereas the erythrocyte sedimentation rate increased as a function of disease severity (type I, 62.5 mm/h; type II, 90.7 mm/h; and type III, 89.2 mm/h) (Table II).

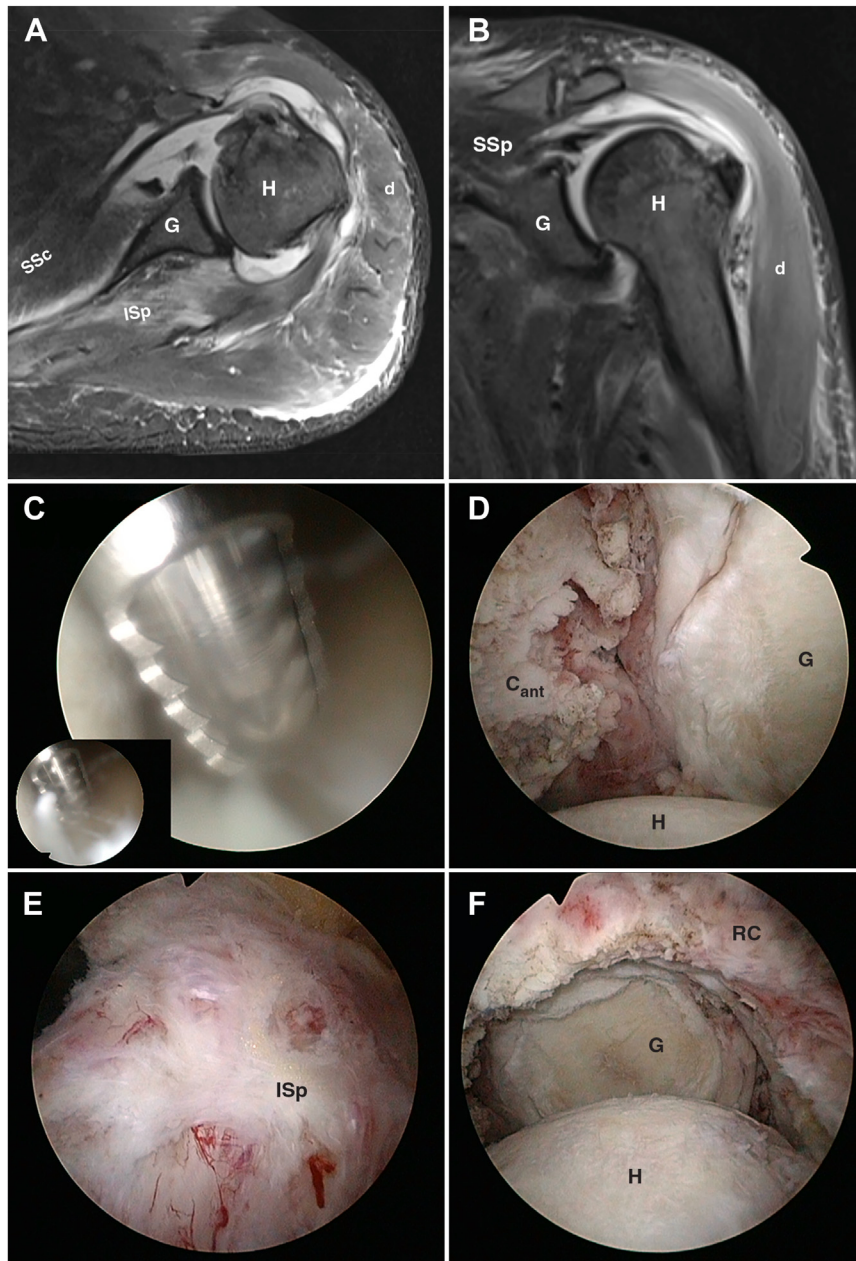
Preoperative aspiration was performed in 39 shoulders (60%). Of these shoulders, 28 (71.8%) had cytologic data available for analysis. Across the cohort, joint aspirate WBC counts ranged from 10 to 327,600 cells/mL. Fifty-seven percent of aspirates revealed cell counts <50,000 cells/mL. Additionally, 64.1% of aspirated shoulders showed positive microbial culture results. Blood cultures were obtained at presentation in 52 patients (81.3%), and positive results were found in 65.4% of these patients. Intraoperative cultures from either joint fluid or tissue specimens showed positive findings in 62.6% of available specimens (Table III). Positive blood culture findings matched intraoperative specimen culture findings 58.8% of the time. Positive shoulder aspiration findings matched intraoperative specimen findings 88% of the time. Staphylococcus aureus was cultured in 73.6% of specimens that underwent microbiological analysis (Table III). Preoperative antibiotics were administered in 46 patients (71.9%), and of these patients, 32.6% had positive preoperative blood culture findings or positive shoulder aspiration findings with negative intraoperative culture findings. In most cases, antibiotic administration was performed prior to

orthopedic surgery consultation and there was no consistent indication or protocol for when antibiotics were provided. In addition, owing to the retrospective nature of data collection, the exact timing of preoperative antibiotic administration and arthrocentesis and/or blood cultures was not consistently documented; therefore, further statistical analysis could not be performed.

### Preoperative imaging, surgical treatment, and recurrence of infection

Immediate preoperative advanced imaging was available prior to the index surgical intervention in 53 shoulders (81.5%) (46 MRI and 7 CT studies). Of these 53 shoulders, 4 (7.5%) had type I infections; 26 (49.1%), type II infections; and 23 (43.4%), type III infections. In the remaining shoulders without advanced imaging (12 of 65, 18.5%), the anatomic zones of involvement and infection types were determined based on the intraoperative findings alone.

On average, each patient required 2.2 operations (range, 1-7 operations) to eradicate the infection. The decision to perform an additional surgical washout was made based on (1) intraoperative findings of disease burden (ie, infection) at the time of the index irrigation and débridement procedure and at each subsequent washout and/or (2) the combination of all available clinical findings, laboratory findings (eg, failure of serum markers to normalize or trend downward), and/or advanced imaging findings that revealed evidence of persistent infection. The aforementioned criteria were used during both the initial hospitalization and readmission to hospital for patients with recurrent infection. Patients in whom a type I infection was diagnosed required



**Figure 4** Type II infection in an immunocompromised 65-year-old male patient presenting with acute left shoulder sepsis. Short tau inversion recovery (fat-suppressed) axial (A) and coronal (B) magnetic resonance imaging demonstrates a joint effusion with extra-articular extension into the subacromial and subdeltoid spaces (zone 2), extension down the long head of the biceps tendon sheath distally (zone 3), and tracks along both sides of the subscapularis (SSc) muscle (zones 4A and 4B). The initial infection burden is shown while viewing from a standard posterior portal (C) and following arthroscopic débridement of zone 4 (D) and the subacromial and subdeltoid spaces (E and F) while viewing from a lateral subacromial portal. This patient's infection was managed successfully with 1 arthroscopic irrigation and débridement followed by parenteral antibiotic therapy. H, humeral head; d, deltoid muscle; G, glenoid; ISp, infraspinatus; SSp, supraspinatus; C<sub>ant</sub>, anterior capsule; RC, posterosuperior rotator cuff.

a median of 1.5 surgical washouts (range, 1-2 washouts) to successfully eradicate the infection, whereas patients with type II infections required 1.6 washouts (range, 1-5 washouts) and those with type III infections required 2 washouts (range, 1-7 washouts) ( $P = .057$ ). A single operation successfully treated 57% of shoulder infections; however, 14%

of patients required  $\geq 4$  débridements during their index hospitalization. Of note, there were no cases of acromioclavicular joint involvement. A regression analysis failed to identify potential risk factors for failure of a single surgical washout. Specifically, patient comorbidities and the organisms cultured (eg, methicillin-resistant *S aureus*) were

not identified as independent risk factors for failure of a single washout.

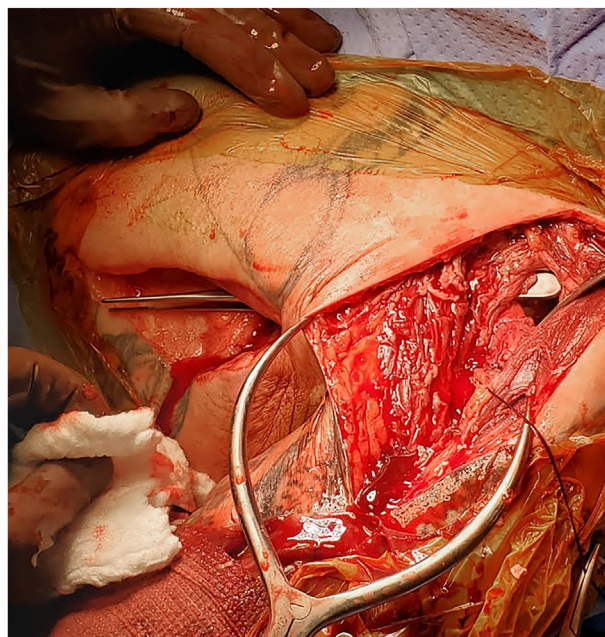
During the 14-year study period (ie, between 2008 and 2021), 8 shoulders (12.3%) in 7 patients had a recurrence of infection (ie, readmission to the hospital for the purpose of undergoing further surgical débridement). This group included 5 male and 2 female patients, and the mean age was 54.1 years (range, 27-75 years). Type III infections had the highest recurrence rate, at 17.9% (5 of 28). The recurrence rates for type I and type II infections were 16.7% (1 of 6) and 6.5% (2 of 31), respectively. All 3 patients who started with either type I or type II infections at the time of their initial hospitalization advanced to type III infections at the time of readmission to hospital (Table IV). A regression analysis identified increased body mass index as the only identifiable risk factor for the recurrence of septic arthritis ( $P = .029$ ). Of the 64 patients, 1 patient (1.6%)—with multiple-joint involvement and medical comorbidities—died acutely of sepsis and multiorgan system failure during the initial hospitalization.

On the basis of the surgical experience presented in this study, a comprehensive treatment algorithm (ie, comprehensive shoulder sepsis system) was developed by 2 of the senior authors (A.J.B. and A.K.D.) (Fig. 9). This algorithm is prognostically based and takes into consideration both the disease location and severity (ie, zone and type) and the surgeon's skill set for treatment planning.

## Discussion

In this study, we have developed a simple but comprehensive staging system and treatment algorithm (ie, comprehensive shoulder sepsis system) that include an emphasis on preoperative advanced imaging to classify infection “type” and guide the surgical decision-making process for patients presenting with septic arthritis of the native shoulder joint. On the basis of the zones of involvement, we have identified 3 major types of infection that were found to correlate with 3 distinct clinical entities. Early diagnosis and management of shoulder sepsis are crucial as we have determined that diagnostic delays lead to worse clinical disease and devastating sequelae (ie, osteomyelitis). Treatment guidelines are proposed for each group to decrease the risk of treatment failure and infection recurrence.

Previous studies have attempted to address the need for a septic arthritis–related staging system specific to the shoulder. The Gächter staging system, traditionally used for knee sepsis, has often been applied in the context of arthroscopic management of shoulder infections.<sup>10,19,28</sup> Pfeiffenberger and Meiss<sup>27</sup> and Kirchoff et al<sup>18</sup> described the use of the Classification of Exogenous Bacterial Infections (CEBI) to stage infections into minor (stage I), moderate (stage II), and severe (stage III) and

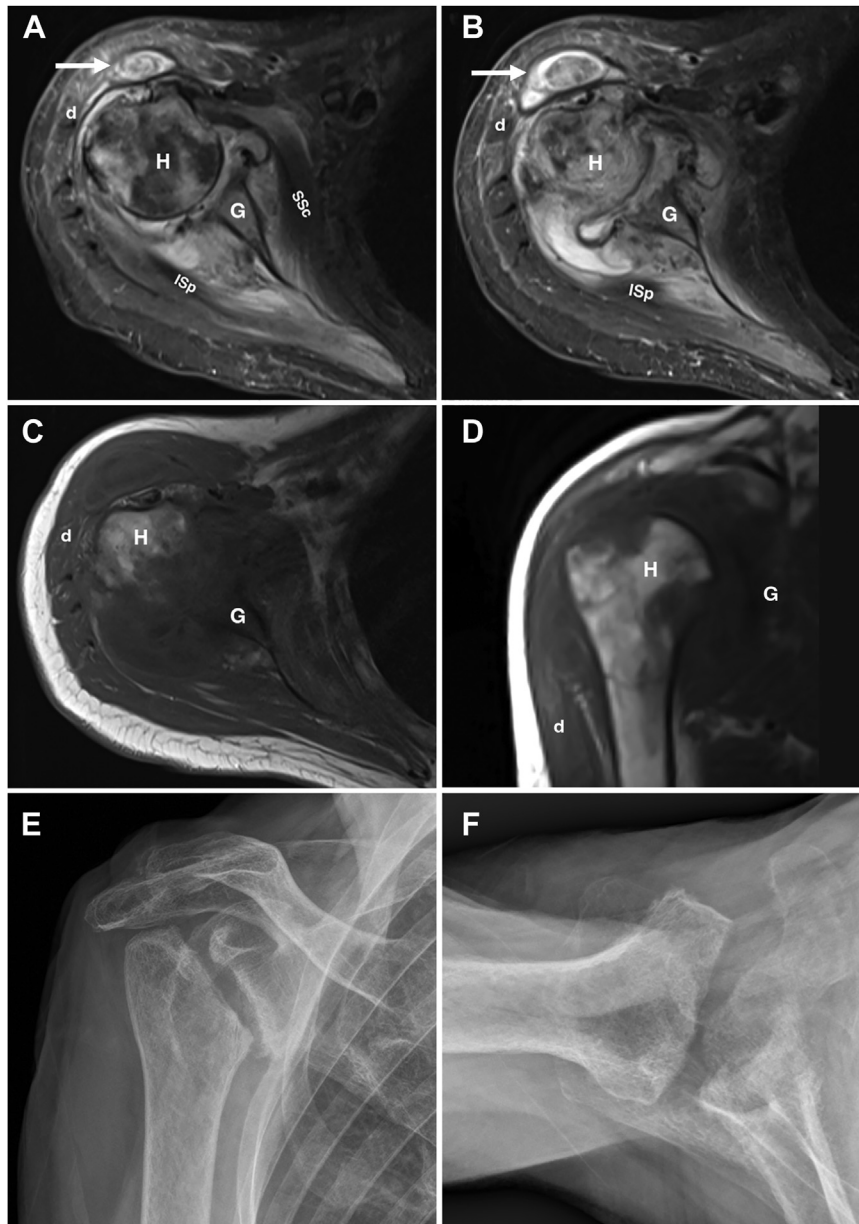


**Figure 5** Type II infection in a left shoulder with distal-medial extension of zone 4B involvement requiring exploration and débridement of the anterior chest wall (forceps are shown, passed between deltopectoral interval and axillary surgical wound).

provided treatment recommendations based on these stages. Rhee et al<sup>28</sup> proposed an MRI-based staging system that focuses exclusively on the glenohumeral joint and divides infections into 5 stages based on progressive signal changes in soft tissue and bone. In the staging system described in this study, there is an emphasis on progressive anatomic zone involvement as a simplified means of determining type akin to oncologic staging. Our proposed system accounts for the different patterns of chronicity of infection described by the Classification of Exogenous Bacterial Infections (CEBI) and the value of advanced imaging in treatment planning.

As one of the largest multicenter studies, our study found similar epidemiologic patterns to other studies reported in the literature. Regarding the bacterial spectrum, *S aureus* was the most common organism (73.6%) isolated from cultured specimens (Table III).<sup>2,9,13,14,31</sup> In addition, our study included a high number of patients with medical comorbidities and an immunocompromised state, with 46.2% of patients having  $\geq 2$  major comorbidities (Table I), which aligns with other recent reports.<sup>31</sup> Although not a statistically significant finding in our study cohort, a high index of suspicion for worse clinical disease (ie, type II or III infection) and recurrence of infection should exist in this patient population.<sup>5,13,31</sup>

A delay in diagnosis is a specific prognostic feature of shoulder sepsis and has been reported in some series.<sup>6,10,17,30</sup> This delay in presentation and management may be explained by key anatomic differences between the shoulder joint and other joints. Capsular failure to contain

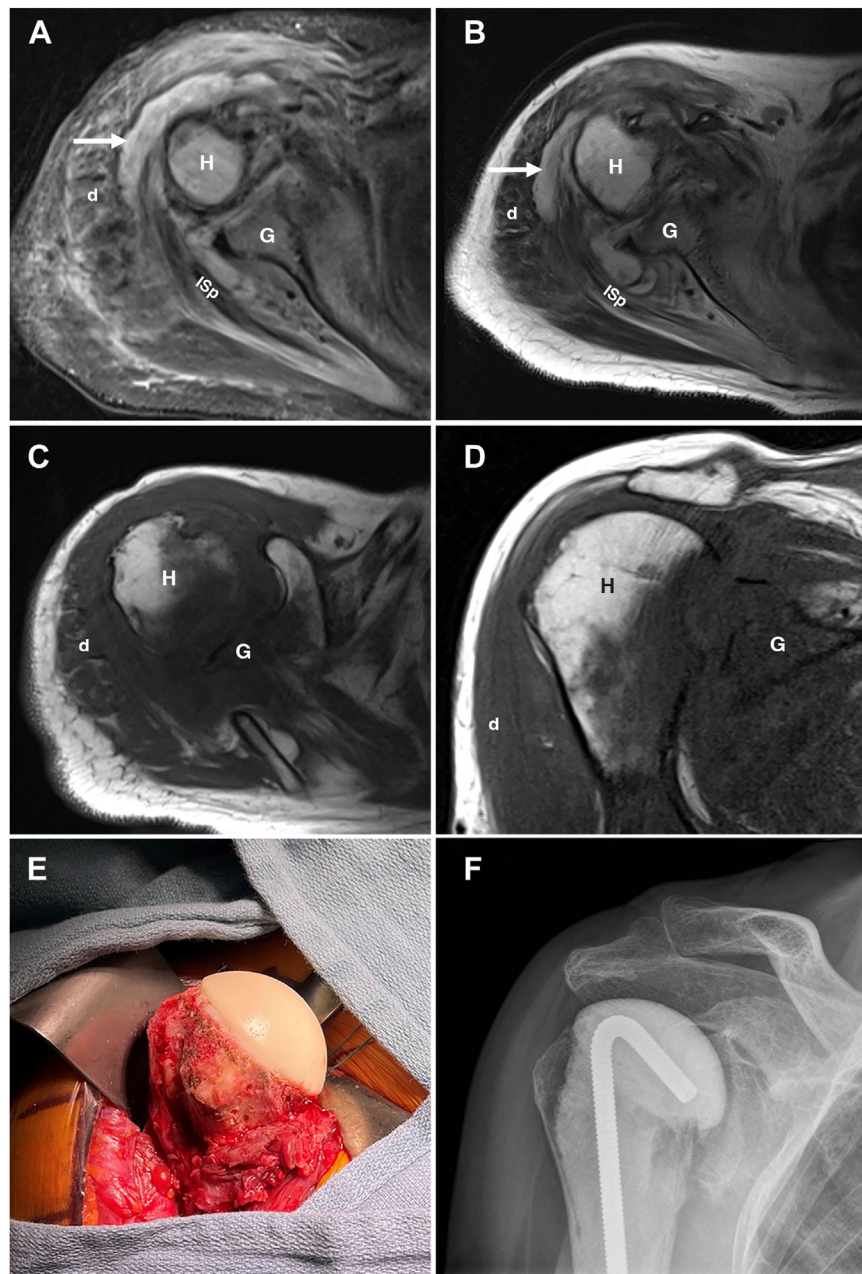


**Figure 6** Type III infection in an 83-year-old female patient with pre-existing dementia presenting with chronic right shoulder sepsis. (**A** and **B**) Short tau inversion recovery (fat-suppressed) axial magnetic resonance images demonstrate a joint effusion and synovitis with extra-articular extension into the subdeltoid space (zone 2), biceps tendon sheath (zone 3), subscapular fossa (deep to the subscapularis muscle [zone 4A]), and infraspinous fossa (deep to the infraspinatus muscle [zone 5]). There is also evidence of articular destruction, most notably involving the glenoid fossa (zone 7B). In addition, pyomyositis of the anterior deltoid (*arrows*) is evident. T1-weighted axial (**C**) and coronal (**D**) imaging demonstrates widespread articular destruction on both sides of the joint and osteomyelitis involving the humeral head (zone 7A) with metadiaphyseal extension, as well as the entire glenoid vault (zone 7B), extending into the scapular body. Anteroposterior (**E**) and axillary (**F**) radiographs obtained at the 12-month follow-up visit reveal resection arthroplasty as the primary and definitive method of treatment. Although the patient continued to experience functional limitations with her shoulder, her pain was minimal and there was no documented recurrence of infection. *d*, deltoid muscle; *H*, humeral head; *G*, glenoid; *SSc*, subscapularis; *ISp*, infraspinatus.

infection is common in the shoulder, leads to diffuse peri-articular spread of infection into potential spaces (ie, zones), and may contribute to a delay in presentation. In this study, two-thirds of patients who had previously undergone evaluations of their shoulder pathology received incorrect diagnoses and were not referred for appropriate management.

Furthermore, the period between symptom onset and definitive diagnosis was the only identifiable risk factor contributing to a type III infection, reinforcing the need to include shoulder sepsis in the differential diagnosis in patients presenting with chronic shoulder pain and vague symptoms not explained by other pathologies.





**Figure 7** Type III infection in a 74-year-old female patient with pre-existing rotator cuff tear arthropathy presenting with chronic right shoulder sepsis (same patient shown in Fig. 1). Short tau inversion recovery (fat-suppressed) axial (A) and T2-weighted axial (B) magnetic resonance imaging demonstrates a joint effusion and synovitis with extra-articular extension into the subdeltoid space (*arrows*, zone 2), biceps tendon sheath (zone 3), and infraspinous fossa (deep to the infraspinatus muscle [zone 5]). T1-weighted axial (C) and coronal (D) imaging demonstrates widespread articular destruction on both sides of the joint and osteomyelitis involving the humeral head (zone 7A) with metadiaphyseal extension, as well as the entire glenoid vault (zone 7B) with extension into the scapular body and base of the coracoid. An intraoperative photograph (E) and an anteroposterior radiograph obtained at the 12-month follow-up visit (F) reveal placement of an articulating antibiotic spacer as the primary and definitive method of treatment. Although the patient continued to experience functional limitations with her shoulder, her pain was minimal and there was no documented recurrence of infection. *H*, humeral head; *d*, deltoid muscle; *G*, glenoid; *ISp*, infraspinatus.

In the literature, controversy regarding the optimal surgical treatment (ie, technique) for shoulder sepsis remains. Multiple studies have shown good results with arthroscopic debridement or equivalent results when comparing arthroscopic and

open methods<sup>7,9,14,15,23,26</sup>; however, Level I comparative studies comparing open and arthroscopic management of shoulder sepsis are lacking, and recent studies have suggested that open methods remain the optimal treatment especially in

**Table I** Demographic data

	Type I	Type II	Type III	Total	P value
Shoulders	6 (9.2)	31 (47.7)	28 (43.1)	65	
Age, mean (SD), yr	40.3 (14.0)	49.4 (15.9)	54.4 (14.3)	50.7 (15.4)	.048 <sup>†</sup>
Sex					.211
Male	2 (33.3)	22 (71.0)	18 (64.3)	42 (64.6)	
Female	4 (66.6)	9 (29.0)	10 (35.7)	23 (35.4)	
BMI, mean (SD)	22.5 (3.5)	30.7 (7.0)	28.2 (7.9)	29.0 (7.5)	.964
≥2 Comorbidities	2 (33.3)	18 (58.1)	10 (35.7)	30 (46.2)	.183
Time from symptom onset to diagnosis, d	1.5 (0, 3)	6 (0, 30)	26.5 (0, 146)	7 (0, 146)	<.001 <sup>†</sup>
Time from symptom onset to surgery, d	3.5 (2, 8)	6 (0, 661)	30.5 (1, 191)	8 (0, 661)	.432
Positive finding of SIRS*	4 (66.7)	15 (48.4)	9 (32.1)	28 (43.1)	.082

SD, standard deviation; BMI, body mass index; SIRS, systemic inflammatory response syndrome.

Data are presented as mean (minimum, maximum) or count (percentage) unless otherwise indicated.

\* Patients with ≥2 SIRS criteria at presentation.<sup>16</sup>

<sup>†</sup> Statistically significant.

**Table II** Serologic and joint aspiration data

	Type I (n = 6, 9.2%)	Type II (n = 31, 47.7%)	Type III (n = 28, 43.1%)	Total (N = 65)	P value
WBC count, cells/μL					
Serum	12,600 (820,019,300)	13,100 (3400, 33,200)	10,500 (3300, 24,900)	11,900 (3400, 33,200)	.331
Aspirate (n = 28)	121,200 (22,600, 219,700)	85,200 (10, 327,600)	80,900 (1600, 204,600)	86,300 (10, 327,600)	.873
ESR (mm/hr)	62.5 (4.0, 120.0)	90.7 (18.0, 120.0)	89.2 (34.0, 120.0)	87.6 (4.0, 120.0)	.204
CRP level (mg/L)	151.4 (48.0, 263.0)	151.9 (1.4, 240.0)	78.4 (0.8, 391.0)	120.5 (0.8, 391.0)	.011*

WBC, white blood cell; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein.

Data are presented as mean (minimum, maximum).

\* Statistically significant.

cases with bony involvement (ie, osteomyelitis).<sup>3,10,19,23,27,28</sup>

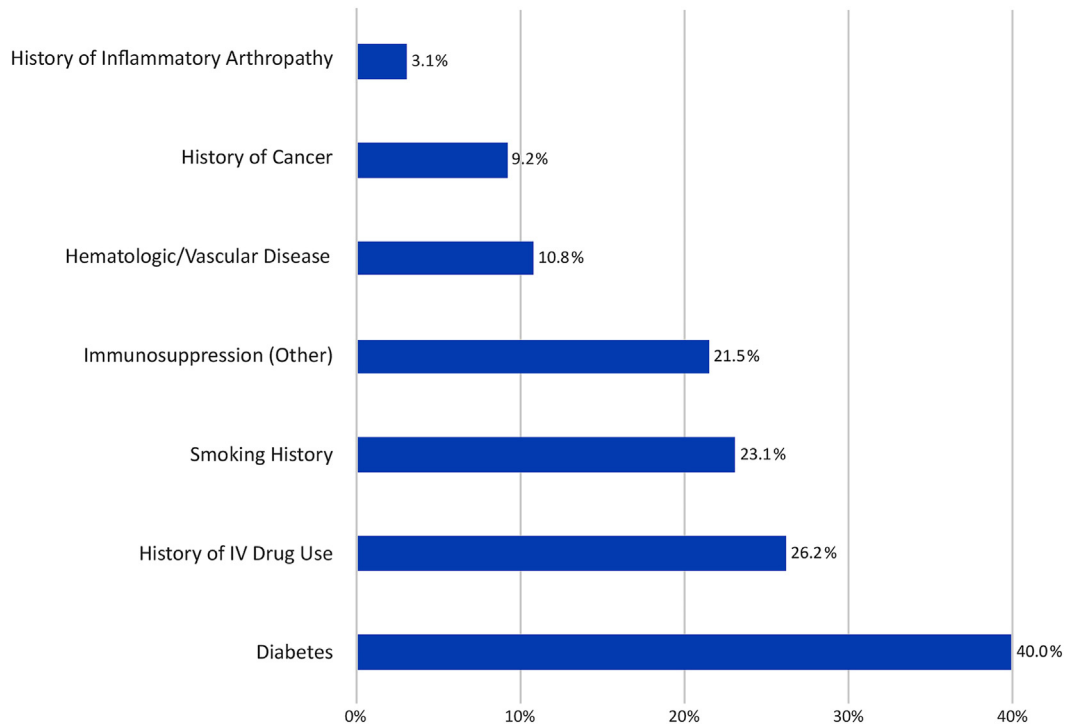
Our study attempts to address this discrepancy in the literature by stratifying treatment based on disease severity and pathoanatomy.

This study proposes a standardized pathway for patients presenting with septic arthritis of the shoulder (Fig. 9). Patients in whom septic arthritis is suspected should undergo an initial laboratory workup (serum complete blood count, erythrocyte sedimentation rate, and CRP level) followed by joint aspiration with analysis of cell count and differential, crystal analysis, and culture analysis. Blood cultures are obtained in patients with documented fever or other signs of systemic sepsis.<sup>16</sup> Of note, we found elevated serum WBC counts and CRP levels in patients with type I and II infections; however, there was a significant decrease in CRP levels in patients with type III infections, consistent with more chronic infections. Treating physicians should also be aware that a lower WBC count on joint aspiration may represent a false-negative test result when there is an otherwise high index of suspicion for septic arthritis using other clinical and radiographic parameters.<sup>29</sup> Of the patients with positive preoperative culture findings who were administered preoperative antibiotics, one-third were found

to have negative intraoperative culture findings in our study. In such circumstances, we recommend either providing broad-spectrum antibiotic coverage or using the preoperative culture results to guide antibiotic therapy under the guidance of an infectious disease specialist.

A key component of the classification system described in this study is recognition of the value of preoperative advanced imaging. This is especially true in cases of delayed presentation as serum inflammatory markers and joint aspiration results become less reliable.<sup>29</sup> MRI can be used as a preoperative diagnostic test to determine infection stage (ie, type) by providing a detailed assessment of areas of sequestered infection and osseous involvement, and its use in our study is in alignment with other studies that found additional value of MRI in surgical decision making.<sup>28</sup> In this study, preoperative imaging was used in the majority of cases (81.5%). However, if advanced imaging is unattainable preoperatively, the classification can still be determined intraoperatively with a systematic evaluation of each anatomic zone.

We recommend open débridement in cases in which substantial osseous lesions (osteomyelitis) are present on preoperative MRI (type III) and in most type II infections



**Figure 8** Patient comorbidities documented in our cohort of 64 patients. IV, intravenous.

**Table III** Preoperative and intraoperative microbiological data

	Cultures obtained	Positive culture findings
Blood	52	34 (65.4)
Joint aspirate	39	25 (64.1)
Intraoperative*	99	62 (62.6)
Organism cultured		n = 129 <sup>†</sup>
MSSA		65 (50.4)
MRSA		30 (23.3)
GBS		8 (6.2)
<i>Cutibacterium acnes</i>		5 (3.9)
<i>Staphylococcus</i> (coagulase negative)		5 (3.9)
<i>Pseudomonas aeruginosa</i>		4 (3.1)
<i>Staphylococcus lugdunensis</i>		3 (2.3)
Diphtheroids		2 (1.6)
<i>Enterococcus</i>		2 (1.6)
<i>Streptococcus viridans</i>		2 (1.6)
<i>Arcanobacterium haemolyticum</i>		1 (0.8)
<i>Fusobacterium necrophorum</i> <sup>11</sup>		1 (0.8)
GCS		1 (0.8)

MSSA, methicillin-sensitive *Staphylococcus aureus*; MRSA, methicillin-resistant *S aureus*; GBS, group B streptococcus; GCS, group C streptococcus.

Data are presented as count (percentage).

\* Includes both exudate and tissue specimens.

<sup>†</sup> Some specimens were polymicrobial, and the frequency of each pathogen was counted.

that involve any zone not amenable to standard arthroscopic techniques (eg, when there is extension distally into the anterior brachium or chest wall or in cases with pyomyositis). Many patients in our study were treated with a staged washout due to substantial infection burden encountered during the index operation; therefore, reinfection was defined as a return to the operating room as part of a separate admission to the hospital when a repeated surgical débridement procedure was required. This study had a low overall rate of infection recurrence (12.3%) compared with the literature. This finding helps reinforce the prognostic value of the proposed classification system.

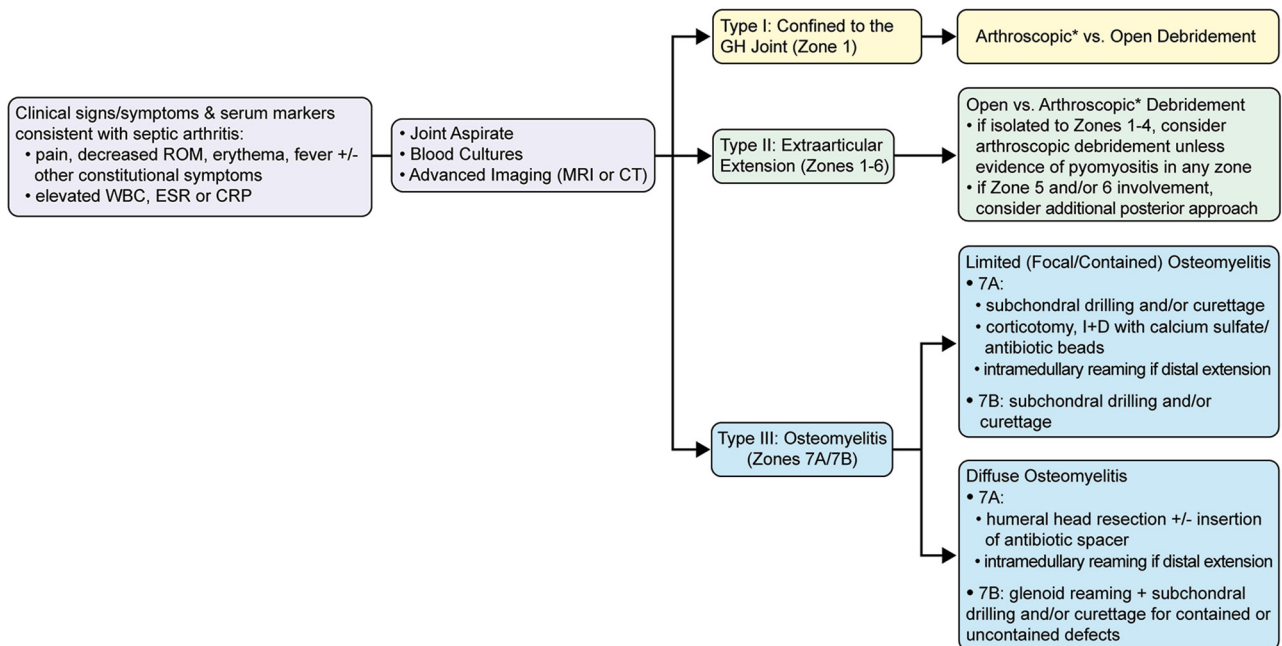
There are several study limitations that should be discussed. As this was a retrospective review, we were limited by the available documentation and data. Our study included only 6 patients with early infections (6 of 65 shoulders, 9.2%). This may reflect referral bias at some tertiary care referral centers; future studies will aim to include more patients with type I infections to improve our understanding of early disease and help prevent delays in the diagnosis and management of shoulder sepsis. Postoperative follow-up was inconsistent, and patient-reported outcome scores were not available; however, our main postoperative outcome of interest was the rate of infection recurrence (ie, treatment failure). Furthermore, the operative reports and/or techniques may have been inconsistent owing to different operating surgeons. Despite these limitations, many strengths support this study's findings. The authors were blinded to the operative findings during

**Table IV** Recurrent infection cases

Case	Age, yr/sex	Comorbid conditions	ESR (mm/hr)	CRP level (mg/L)	Time from symptom onset to diagnosis/surgery, d	Organisms cultured	Infection type at initial presentation (No. of washouts)	Duration between discharge and readmission, mo	Infection type at readmission (No. of washouts)
1	45/M	Elevated BMI	56	63	0/0	Group B streptococcus	II (1)	6	III (4)
2	57/F	Elevated BMI	60	1	2/4	—	III (3)	4	III (1)
3	58/M	Elevated BMI	105	47	9/14	MSSA	III (4)	2	III (2)
4	57/M	Hepatitis C with cirrhosis, IVDU, smoking	98	79	21/22	MSSA	III (4)	2	III (2)
5*	60/M	Elevated BMI, cardiac sarcoidosis, CKD, inguinal abscess	84	50	53/54	MSSA, <i>Enterococcus</i> , <i>Pseudomonas aeruginosa</i>	III (1)	3	III (4)
6*	60/M	Elevated BMI, cardiac sarcoidosis, CKD, inguinal abscess	84	50	53/54	MSSA, <i>Enterococcus</i> , <i>Pseudomonas aeruginosa</i>	III (1)	3	II (3)
7	75/M	RA, smoking	—	64	5/6	MSSA	II (1)	9	III (1)
8	27/F	SCD with pre-existing humeral head osteonecrosis	—	48	5/8	<i>Staphylococcus lugdunensis</i> , <i>Cutibacterium acnes</i>	I (1)	10	III (1)

ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; BMI, body mass index; IVDU, intravenous drug use; CKD, chronic kidney disease; RA, rheumatoid arthritis; SCD, sickle cell disease; MSSA, methicillin-sensitive *S aureus*.

\* Cases 5 and 6 comprised infections in both shoulders of a single patient in whom primary treatment of both joints failed.



**Figure 9** Treatment algorithm proposed to manage septic arthritis of the native shoulder joint: comprehensive shoulder sepsis system. ROM, range of motion; WBC, white blood cell count; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein level; MRI, magnetic resonance imaging; CT, computed tomography; GH, glenohumeral; I+D, irrigation and débridement. \*, dependent on surgeon skill set.

review of preoperative advanced imaging to reduce observer bias. In addition, this study contains one of the largest series of patients with native septic arthritis of the shoulder, and the inclusion of data from 2 geographically independent academic institutions increases the generalizability of the reported results. Finally, this study proposes the use of an anatomically based classification system to manage shoulder sepsis that is prognostically valuable and currently does not exist in the literature.

## Conclusion

Septic arthritis of the shoulder lacks a consistent etiology, clinical presentation, and natural history, and its treatment must be approached in a thorough and individualized manner. The comprehensive shoulder sepsis system presented in this study is intended to assist all orthopedic surgeons in the characterization and management of patients with septic arthritis of the shoulder. Future work is required to evaluate the reliability and validity of this classification system and proposed treatment algorithm and to determine optimal synovial fluid diagnostic thresholds for immunocompetent and immunocompromised patient groups.

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