2.1. DIAGNOSIS: CULTURE SIGNIFICANCE

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What are the diagnostic criteria of shoulder periprosthetic joint infection (PJI)?

RECOMMENDATION: See International Consensus Meeting (ICM) definition of shoulder PJI below. LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 88%, Disagree: 12%, Abstain: 0% (Super Majority, Strong Consensus)

DEFINITE PJI
Meeting one of the following criteria is diagnostic of definite periprosthetic shoulder infection:

- A sinus tract communicating with the prosthesis is present.
- Gross intra-articular pus
- Two positive cultures with phenotypically-identical virulent organisms

EVALUATION SCORING
Weighted values for all positive tests performed as part of the diagnostic evaluation of a failed shoulder arthroplasty are summed (Table 1).

- 6 or greater with identified organism = probable PJI
- 6 or greater without identified organism = possible PJI
- 6 or less
  - single positive culture virulent organism = possible PJI
  - two positive cultures low-virulence organism = possible PJI
  - negative cultures or only single positive culture for low virulent organism = PJI unlikely

Rationale:

The need for a consensus definition of shoulder PJI cannot be understated. A clear definition serves two purposes; to aid in clinical decision making and to provide a framework for consistent future research reporting. Furthermore, acceptance of a definition is a necessary first step in providing a well-tested diagnostic algorithm. As Hsu et al demonstrated, the shoulder research community has used disparate definitions of PJI—likely leading to variable and inconsistent conclusions about the diagnosis and management. Adoption of a uniform definition of PJI for the lower extremity quickly led to hundreds of publications evaluating prevention, diagnosis, and
treatment of PJI based upon the same consistent diagnostic criteria.\textsuperscript{9,11} This task is even more urgent in regard to shoulder arthroplasty due to the unique microbiologic and the ambiguity presented by high rates of positive intra-operative cultures in revision cases which otherwise appear aseptic\textsuperscript{1,4,6–8,10}. In order to discuss diagnosis and evaluation of shoulder PJI it is imperative that the shoulder community begin with a standardized and accepted definition of shoulder PJI.

Committee Goals
1. Define criteria that establish a diagnosis of shoulder PJI
2. Provide a common language for research reporting and clinical decision making.
3. The definition should be flexible enough to include the “obvious” suppurative, shoulder PJI as well as the subtler “stealth” infections and cases where the clinical scenario is unclear.
4. Incorporate the best available evidence in this field.
5. That the definition of shoulder PJI should generally be similar to the MSIS hip and knee definition, but differ according to specific characteristics unique to the shoulder.
   a. Less weight put on positive cultures with low-virulence organisms given the data on this phenomenon in the shoulder
   b. A larger “grey area” of “possible PJI” to recognize that there are a large number of cases where, given the current state of the field, it is not possible to define as clearly infected or uninfected.
   c. Include a scoring system in order to potentially create objective criteria for sorting these “possible PJI” cases.

Committee Process
The process undertaken to formulate this definition was a consensus effort relying upon the clinical expertise of numerous shoulder and elbow surgeons who routinely treat shoulder periprosthetic joint infection (PJI). First, a systematic review was undertaken to evaluate the definitions in use for shoulder PJI and the evidence for each (Appendix A). Second, over a year-long process, 75 separate, parallel systematic reviews evaluating aspects of prevention, diagnosis and management of shoulder PJI were performed by members of the shoulder ICM sub-section. Following a Delphi process these reviews were disseminated, discussed, and then refined in-person at the Second ICM in Philadelphia in July 2018 where delegates voted on each statement. Each of these 75 reports was used by the definition committee, in addition to their own experience, to discuss potential definition options. These were refined, voted upon and ultimately accepted at the ICM meeting in Philadelphia. The original MSIS criteria have gone through multiple iterations as the consensus definition has been refined through testing and further research. The definition of shoulder PJI is no different and we fully expect that as researchers begin to adopt this definition the criteria and weightings may change, as our knowledge and understanding of the evaluation and management of shoulder PJI evolves.

Rationale for the Definition
While there remains controversy and uncertainty about the definition and management of shoulder PJI, there are cases which are considered to be unquestionably infected. Therefore, a subgroup of “Definite PJI” shoulder PJI was defined to identify these cases. This included the presence of a sinus tract (as discussed in “Diagnosis: Diagnostic Criteria” Question 1), gross intra-articular pus, or two separate positive cultures with identical virulent pathogens (as discussed in “Diagnosis: Culture Significance” Question 1). While specific evidence for these
criteria is lacking, a strong consensus existed that if any of these criteria were met, an infection was undoubtedly present. When assessing intra-articular purulence, consideration must be given to other less common inflammatory conditions including rheumatologic disease, reactions to metal or other foreign bodies, which rarely incite a process that produces debris or aseptic purulence in shoulder arthroplasty.

As discussed in “Diagnosis: Culture Significance” Question 1 and “Diagnosis: Sampling” Question 8, the significance of a positive culture may depend upon the number of cultures sent and the degree of growth. Therefore, as discussed in “Diagnosis: Sampling” Question 8, it is recommended that “five deep tissue specimens for culture be obtained from various surgical sites (e.g. capsule, humeral canal, and peri-prosthetic membranes in the proximal humerus and glenoid)”. This should provide sufficient sensitivity for bacterial growth while minimizing the risk of false positives, as discussed in “Diagnosis: Culture Significance” Question 1. Furthermore, when reporting results we recommend that the number of positive cultures should be reported as a fraction of the total cultures sent (x/y where x=number of positive cultures and y=total number of cultures sampled) and/or the “Shoulder propi score” (“Diagnosis: Culture Significance” Question 2). Lastly, as discussed in “Diagnosis: Culture Technique” Question 1, cultures should be held for fourteen days to optimize detection of pathogens.

The lack of these defining signs certainly does not exclude the diagnosis of PJI. Therefore, in these less distinct scenarios three categories were established: “Probable PJI”, “Possible PJI”, and “PJI unlikely.” Given the lack of strong evidence defining the clinical significance of low-virulence positive cultures, this stratification allows for clinical guidance and classification of cases for research purposes without grouping heterogenous cases. For classification of these cases, minor criteria were proposed and edited by the group at large. Many of these minor criteria have been discussed in other questions answered by the shoulder ICM sub-section (Table 2). As the significance of a positive result for these minor criteria varies, each criterion was weighted. It was agreed that a threshold score of six would serve as a marker of the increased likelihood of a shoulder PJI, though the committee fully expects that as this definition is tested and refined, the weightings and the thresholds will be improved.

To apply weight for each of these minor criteria, a score was applied to each criterion independently by every member of the shoulder group in attendance. These scores were then averaged and discussed further, resulting in the weighting reported here. To further test the definition, clinical scenarios were proposed and evaluated with the definition (Table 3). In each case, the ICM diagnostic criteria gave a result which the delegates felt, with consensus, described their own clinical conclusions.

Inflammatory markers (synovial fluid white blood cell count and differential, serum erythrocyte sedimentation rate, and serum C-reactive protein) are often elevated during the early postoperative period and thus use in the diagnostic evaluation was limited to beyond six weeks from a recent surgery. There have been multiple studies in the lower extremity demonstrating the impact of surgery on these inflammatory markers. Normal thresholds for inflammatory markers in the acute post-operative period after shoulder arthroplasty have not been established.
The formation of this definition provides an important step in improving the care for patients with and understanding of shoulder PJI. Adoption of this definition by those performing research of shoulder PJI will allow for uniform evaluation of study outcomes as researchers, reviewers, and readers will all be talking the same language. Lastly, we want to emphasize this definition is a first iteration. As the understanding of shoulder PJI evolves and each diagnostic test is further evaluated, it will be necessary to revisit this definition as a community.

REFERENCES


8. McGoldrick E, McElvany MD, Butler-Wu S, Pottinger PS, Matsen FA. Substantial cultures of Propionibacterium can be found in apparently aseptic shoulders revised three years or

