Evaluation of the International Consensus Meeting (ICM) Diagnostic Categories for Shoulder Periprosthetic Joint Infection: *C. Acnes* Predominates Even in Definite Infections. Eric T. Ricchetti, Andrew P. Collins, ASES Multicenter Revision Shoulder Arthroplasty and PJI Group (Boardman, N.D., Budge, M.D., Cusick, M., Cvetanovich, G.L., Entezari, V., Fedorka, C.J., Flik, K.R., Garrigues, G.E., Ho, J., Kam, G.S., Khazzam, M.S., Kim, H.M., King, J.J., Li, X., Matsen, F.A., Namdari, S., Nicholson, G.P., Orvets, N., Smith, M.J., Tashjian, R.Z., Vanderbeck, J.L., Vap, A.R., Wright, J.O., Wright, T.W.), Anastasia J. Whitson, Jason E. Hsu.

Introduction: The diagnosis and treatment of shoulder periprosthetic joint infection (PJI) can be challenging due to the variable presentation of the most common organisms, *Cutibacterium acnes (C. acnes)*, and often benign clinical presentation without typical signs of infection. Consensus-derived diagnostic criteria for shoulder PJI were reached at the 2nd International Consensus Meeting (ICM) on Musculoskeletal Infection in 2018 to better address these challenges. Data is still limited, however, on the clinical presentation and distribution of shoulder PJI cases with regards to the ICM diagnostic categories. The purpose of this study was to utilize data from a large, multicenter cohort of consecutive revision shoulder arthroplasties to evaluate the frequency of cases meeting criteria for each of the ICM PJI categories and to examine the distribution of demographic data, microbiology, and frequency of positive criteria present in each PJI category.

Materials & Methods: Data were prospectively collected on consecutive revision shoulder arthroplasty cases from 20 institutions and 33 surgeons in the American Shoulder and Elbow Surgeons (ASES) Revision Shoulder Arthroplasty and PJI Multicenter Research Group. Intraoperative testing was standardized among participating surgeons prior to data collection. Standardized collection of data was performed for patient demographics, microbiology, major diagnostic criteria for the Definite PJI category, and minor criteria used to define the Probable, Possible, and Unlikely PJI categories in the ICM classification. The variations in demographic data, microbiology, and frequency of major and minor criteria were then evaluated within each ICM PJI category for associations and differences.

Results: 490 cases were evaluated, including 71 (14.5%) Definite PJI, 52 (10.6%) Probable PJI, 87 (17.8%) Possible PJI, and 280 (57.1%) Unlikely PJI cases. Median patient age was 66 years (IQR, 58-73), and 53% were male.

Demographic differences across groups: Male sex predominated in all but the Unlikely PJI category and was significantly more common in the Probable PJI group (80.8%) compared to Definite (63.3%), Possible (59.8%), or Unlikely PJI (43.2%) ($p<0.001$). The Probable PJI group was also more likely to be younger ($p=0.010$), on less narcotics ($p=0.014$), and of a lower ASA class ($p=0.004$) than the Definite PJI group (**Table 1**).

Definite PJI - Major Criteria and Microbiology: Gross intra-articular purulence was the most common Definite PJI criteria (64.8%), followed by ≥2 positive cultures with virulent bacteria (43.7%) and presence of sinus tract (33.8%). Of note, 28.2% of cases of Definite PJI were culture negative, and another 9.9% had only 1 positive culture. The most common bacteria were *C. acnes* (29%) followed by methicillin-sensitive *Staphylococcus aureus* (23%). The Definite PJI cases that grew *C. acnes* presented with gross purulence 71% of the time.

Non-Definite PJI - Minor Criteria and Microbiology: Mean ICM PJI score and mean number of positive intraoperative tissue cultures were significantly different across the Probable (score 9.9±3.8, cultures 3.3±1.4), Possible (score 5.8±3.4, cultures 1.7±1.8), and Unlikely PJI (score 1.3±1.6, cultures 0.1±0.3) groups ($p<0.001$). This statistically significant difference remained even after adjusting for total possible denominator (adjustment for amount of testing performed) (**Table 2**). The Probable PJI group more commonly had positive frozen sections (21.2% vs. 9.2%, $p=0.042$), a positive preoperative aspirate culture (42.3% vs. 8.0%, $p<0.001$), and cloudy intraoperative fluid (34.6% vs. 17.2%, $p=0.020$) when compared to the Possible PJI group (Table 2). None of the cases in the Probable PJI category qualified solely with ≥2 positive intraoperative tissue cultures and a positive preoperative aspirate in the absence of any other positive minor criteria. *C. acnes* was the most commonly cultured organism (91.3%) across the Non-Definite PJI groups.

Discussion: This is the first large-scale, multicenter study of consecutive revision shoulder arthroplasties to evaluate the frequency of cases meeting criteria for the 2018 ICM PJI categories and demonstrates two important findings: 1) While *C. acnes* is often labeled a "low-virulence" bacteria causing Non-Definite PJI, it was the most common bacteria in Definite PJI cases and commonly presented with gross purulence in this scenario. Classifying bacteria as "virulent" and "non-virulent" will need reconsideration in the next PJI definition. 2) Significant differences were seen in demographic characteristics, presence of minor criteria, and growth of positive cultures across Non-Definite PJI groups, even when adjusted by amount of testing performed. These findings support the usefulness of a tiered definition of shoulder PJI. Data from this multicenter effort will be used to refine ICM PJI categories and determine how they guide treatment decision-making.

Table 1: Patient demographics across groups stratified by ICM PJI definition.

ICM Classification	All Patients (n = 490)	Definite PJI (n = 71, 14.5%)	Probable PJI (n = 52, 10.6%)	Possible PJI (n = 87, 17.8%)	Unlikely PJI (n = 280, 57.1%)	p-value*	p-value†	p-value**	p-value#
Age	66.1 ± 10.2	68.2 ± 9.3	63.2 ± 12.0	65.7 ± 10.7	65.9 ± 10.3	0.064	**0.010**	0.199	0.058
Male sex	260 (53.1%)	45 (63.3%)	42 (80.8%)	52 (59.8%)	121 (43.2%)	0.062	**0.036**	**0.010**	**<0.001**
BMI	30.6 ± 7.2	29.2 ± 5.5	30.9 ± 6.1	30.5 ± 7.5	30.9 ± 7.7	0.090	0.128	0.775	0.388
History of Tobacco Use	66 (13.5%)	13 (18.3%)	6 (11.5%)	12 (13.8%)	35 (12.5%)	0.188	0.293	0.686	0.593
Current Narcotic Use	138 (28.2%)	25 (35.2%)	8 (15.4%)	20 (23.0%)	85 (30.4%)	0.193	**0.014**	0.292	**0.038**
Diabetic Status	87 (17.8%)	15 (21.1%)	10 (19.2%)	13 (14.9%)	49 (17.5%)	0.439	0.798	0.533	0.794
Inflammatory Arthropathy	32 (6.5%)	7 (9.9%)	3 (5.8%)	5 (5.7%)	17 (6.1%)	0.235	0.412	0.996	0.696
Immunosuppressant Medications	33 (6.7%)	7 (9.9%)	2 (3.8%)	3 (3.4%)	21 (7.5%)	0.339	0.197	0.986	0.334
ASA Class	2.7 ± 0.6	2.8 ± 0.5	2.5 ± 0.5	2.5 ± 0.6	2.7 ± 0.6	0.108	**0.004**	0.578	**0.003**

ICM, International Consensus Meeting; PJI, periprosthetic joint infection; BMI, body mass index; ASA, American Society of Anesthesiologists Score

* = comparing Definite and Non-Definite infections; † = comparing Definite and Probable infections; ** = comparing Probable and Possible infections; # = Analysis of Variance (ANOVA) testing for Definite, Probable, Possible, and Unlikely infections.

Table 2: Minor criteria positivity and total PJI score across groups stratified by ICM PJI definition.

Minor Criteria (ICM PJI Score Weight)	All Patients [n = 490 ± stdev (%)]	Number of Patients Assessed by Minor Criteria (%, All)	Definite PJI [(n = 71 ± stdev (14.5%)]	Number of Patients Assessed by Minor Criteria (%, Definite)	Probable PJI [(n = 52 ± stdev (10.6%)]	Number of Patients Assessed by Minor Criteria (%, Probable)	Possible PJI [(n = 87 ± stdev (17.8%)]	Number of Patients Assessed by Minor Criteria (%, Possible)	Unlikely PJI [(n = 280 ± stdev (57.1%)]	Number of Patients Assessed by Minor Criteria (%, Unlikely)	p-value*	p-value†	p-value**	p-value#
Unexpected Wound Drainage (4)	31 (6.3%)	-	22 (31.0%)	-	2 (3.8%)	-	2 (2.3%)	-	5 (1.8%)	-	**<0.001**	**<0.001**	0.601	**<0.001**
Single Positive Tissue Culture (virulent organism, 3)	73 (14.9%)	-	34 (47.9%)	-	17 (32.7%)	-	22 (25.3%)	-	0 (0.0%)	-	**<0.001**	0.092	0.351	**<0.001**
Single Positive Tissue Culture (low-virulence organism, 1)	159 (32.4%)	-	26 (36.6%)	-	52 (100.0%)	-	53 (60.9%)	-	29 (10.4%)	-	0.410	**<0.001**	**<0.001**	**<0.001**
Second Positive Tissue Culture (identical low-virulence organism, 3)	110 (22.4%)	-	18 (25.4%)	-	52 (100.0%)	-	41 (47.1%)	-	0 (0.0%)	-	0.520	**<0.001**	**<0.001**	**<0.001**
Humeral Loosening (3)	79 (16.1%)	-	17 (23.9%)	-	9 (17.3%)	-	19 (21.8%)	-	34 (12.1%)	-	0.052	0.377	0.523	**0.033**
Positive Frozen Section (5 PMN in at least 5 high-power fields, 3)	40 (8.2%)	294 (60.0%)	13 (18.3%)	31 (43.7%)	11 (21.2%)	34 (65.4%)	8 (9.2%)	56 (64.4%)	8 (2.9%)	173 (61.8%)	**<0.001**	0.432	**0.042**	**<0.001**
Positive Preoperative Aspirate Culture (low or high virulence, 3)	56 (11.4%)	332 (67.8%)	23 (32.4%)	53 (74.6%)	22 (42.3%)	43 (82.7%)	7 (8.0%)	56 (64.4%)	4 (1.4%)	180 (64.3%)	**<0.001**	0.454	**<0.001**	**<0.001**
Elevated Synovial Neutrophil Percentage (>80%, 2)	51 (10.4%)	224 (45.7%)	21 (29.6%)	35 (49.3%)	12 (23.1%)	28 (53.8%)	11 (12.6%)	45 (51.7%)	7 (2.5%)	116 (41.4%)	**<0.001**	0.181	0.102	**<0.001**
Elevated Synovial WBC (>3000 cells/microliter, 2)	42 (8.6%)	239 (48.8%)	18 (25.4%)	36 (50.7%)	8 (15.4%)	30 (57.7%)	11 (12.6%)	44 (50.6%)	5 (1.8%)	129 (46.1%)	**<0.001**	0.055	0.874	**<0.001**
Elevated ESR (>30 mm/hr, 2)	111 (22.7%)	365 (74.5%)	31 (43.7%)	54 (76.1%)	14 (26.9%)	43 (82.7%)	21 (24.1%)	68 (78.2%)	45 (16.1%)	200 (71.4%)	**<0.001**	**0.015**	0.855	**<0.001**
Elevated CRP (>10mg/L, 2)	52 (10.6%)	372 (75.9%)	20 (28.2%)	54 (76.1%)	7 (13.5%)	42 (80.8%)	12 (13.8%)	70 (80.5%)	13 (4.6%)	206 (73.6%)	**<0.001**	**0.028**	0.949	**<0.001**
Elevated Synovial Alpha-Defensin (2)	15 (3.1%)	62 (12.7%)	3 (4.2%)	5 (7.0%)	3 (5.8%)	10 (19.2%)	5 (5.7%)	13 (14.9%)	4 (1.4%)	34 (12.1%)	0.052	0.297	0.689	**0.045**
Cloudy Fluid (2)	94 (19.2%)	-	46 (64.8%)	-	18 (34.6%)	-	15 (17.2%)	-	15 (5.4%)	-	**<0.001**	**0.001**	**0.02**	**<0.001**
Average Total ICM PJI Score (percent of total 32 points)	4.3 (13.4%) ± 4.7	-	10.0 (31.3%) ± 5.2	-	9.9 (30.9%) ± 3.8	-	5.8 (18.1%) ± 3.4	-	1.3 (4.1%) ± 1.6	-	**<0.001**	0.914	**<0.001**	**<0.001**
Average Denominator ICM PJI Score	25.0	-	24.8	-	26.4	-	25.4	-	24.7	-	-	-	-	-
Average Adjusted ICM PJI Score	5.5 (17.2%)	-	13.0 (40.6%)	-	11.8 (36.9%)	-	7.5 (23.4%)	-	1.7 (5.3%)	-	-	-	-	-
Average Total Number of Deep Cultures Taken	4.9 ± 1.3	-	5.4 ± 1.5	-	5.2 ± 0.8	-	5.0 ± 1.1	-	4.7 ± 1.3	-	**0.001**	0.317	0.409	**<0.001**
Average Number of Positive Virulent Cultures	0.3 ± 1.0	-	1.7 ± 2.1	-	0.5 ± 0.9	-	0.3 ± 0.4	-	0.0 ± 0.0	-	**<0.001**	**<0.001**	0.068	**<0.001**
Average Number of Positive Non-Virulent Cultures	0.9 ± 1.5	-	1.1 ± 1.8	-	3.3 ± 1.4	-	1.7 ± 1.8	-	0.1 ± 0.3	-	0.175	**<0.001**	**<0.001**	**<0.001**