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The MusculoSkeletal Infection Society Diagnostic Criteria are Insufficient to Diagnose Shoulder Periprosthetic Infection: a retrospective study case and literature review

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Periprosthetic shoulder infection (PSI) management is very complicated because of its unique microbiology and due to the heterogeneity of studies published about it. Nowadays, there isn't a strict consensus on the diagnosis. Nevertheless, the criteria established by the musculoskeletal infection society (MSIS) are generally used by the scientific community. The objective of this retrospective study case and literature review is to establish that the MSIS criteria are insufficient to diagnose PSI.

We did a retrospective monocentric analysis concerning PSI. Out of the 25 shoulder arthroplasty revisions conducted in our institution from January 2010 till January 2022 (including primary implants placed in other facilities), 10 had a positive periprosthetic culture from samples taken during surgery.

In 60% of cases, the diagnosis of PSI has been made because of 2 positive periprosthetic cultures (major criterion). In 10% of cases, the diagnosis of prosthetic shoulder infection was recognized from the presence of a cutaneous fistula in communication with the joint implants (major criterion). In no case was the diagnosis of PSI determined by the presence of 4 out of 6 minor MSIS criteria. In 30% of cases, the MSIS criteria were insufficient to establish the PSI diagnosis.

The MSIS criteria are insufficient to establish the diagnosis of PSI and should be considered as a methodological bias in published studies on this subject.

Keywords: Shoulder Replacement Arthroplasty, Prosthesis-Related Infections, Propionibacterium acnes.

INTRODUCTION

The management of periprosthetic shoulder infection (PSI), from diagnosis to treatment poses of great challenge. PSI incidence is estimated between 0,08 to 5% after primary shoulder replacement. It should be noted that the incidence is higher after total reverse arthroplasty compared to regular arthroplasty[1]. In arthroplasty revision surgery, the incidence of infection can go up to 32%[2]. This complication is responsible for morbidity, mortality and health care costs[3].

The scientific literature offers a variety of diagnostic and therapeutic tools to tackle PSI because of the heterogeneity of clinical and para-clinical presentations. Furthermore, for many years, the management of PSI was based on lower limb periprosthetic infection. Nonetheless, the shoulder is a different joint, with its own biomechanics, microbiology and thus management needs to be adapted.

Moreover, there is an important diversity of the methodology used in studies concerning PSI rendering systematization more complex[4]. PSI management is therefore an intricate process requiring a multidisciplinary approach and relies on approximate diagnostic criteria laidout by the scientific literature and expert opinions.

The MSIS criteria were established in 2011 as an attempt to standardize the diagnosis of periprosthetic infection[5] (Table I). These criteria were established using data obtained from lower limb periprosthetic infection and then later, applied to the whole of periprosthetic infection. They have been widely adopted by the international scientific community for the diagnosis of PSI[6]. Our hypothesis is that these criteria, used by default as there isn't any alternative to

Table I. — The 2011 Musculoskeletal Infection Society (MSIS) diagnostic criteria for periprosthetic infection.

The 2011 Musculoskeletal Infection Society (MSIS) diagnostic criteria for periprosthetic infection.
Major criteria (min. 1 out of 2 necessary).
- The presence of a fistula communicating through the skin to the joint implant.
- 2 positive cultures with the same organism. Tissue or liquid samples should be obtained from the suspected periprosthetic infected joint.
Minor criteria (min. 4 out of 6 necessary).
- Elevated erythrocyte sedimentation rate (ESR) or elevated C-Reactive Protein (CRP).
- Elevated synovial fluid white blood count.
- Elevated synovial fluid neutrophil count.
- Presence of purulence in the affected joint.
- 1 positive culture obtained from periprosthetic tissue or liquid sample.
- > 5 neutrophils per field in 5 anatomopathological samples obtained from the suspected infected joint, according to the results established by Mirra and al. In 1976[6].

diagnose PSI, are insufficient in view of the evidence provided by the scientific international literature and present a methodological bias to systematize studies on the management of this complex pathology.

It should be noted that the modifications made during the 2018 revision of the MSIS criteria only bring minor clarifications as a result of newly gathered data solely on periprosthetic lower limb infections[7].

Throughout the series of PSI managed in our institution, we will apply and contrast these criteria with iconographic evidence before shedding light on elements found in the scientific literature pointing out to their limitations concerning PSI diagnosis.

MATERIAL AND METHODS

Study design and patient cohort

We designed a retrospective monocentric study on PSI including 328 shoulder joint replacements conducted in our institution during the period from January 2010 to January 2022 (including shoulder hemiarthroplasty, anatomic total shoulder arthroplasty and reverse total shoulder arthroplasty).

The criterion for inclusion is the presence of a germ in one periprosthetic sample obtained during surgical washout or during surgical revision for chronic pain, independently of patient age, initial cause of joint replacement, and institution of the first arthroplasty.

Fourteen out of the 328 shoulder replacements conducted in our institution from January 2010 to January 2020 have undergone surgical revision. In 6 of these patients, a germ was isolated from perioperative samples (1,8% of periprosthetic infection).

Including primary shoulder replacement surgery undergone in other institutions, we did a total of 25 surgical redos, 10 of which had an isolated germ from perioperative samples. Our study, therefore, includes 10 patients based on our criterion mentioned above.

RESULTS

Ten patients were included in our study based on the established criterion above (Table II). The mean age was 62,4 years old (40-79 years old) and the delay between primary shoulder replacement and germ identification was 99,6 weeks (variable 6-223 weeks). The reasons for shoulder replacement were comminuted humeral head fracture (4 patients), rotator cuff rupture (2 patients), avascular osteonecrosis of the humeral head (1 patient) and advanced omarthrosis (1 patient). 6 of these patients underwent their shoulder replacement surgery in our institution. The 4 others were carried out in a different hospital. Concerning the 4 patients operated in a different institution, the cause of the primary arthroplasty was unknown for 2 of them. It should also be specified that 2 of these 4 external patients already underwent PSI management before contacting our orthopedic department.

Concerning the 10 patients included in our study, 3 had a positive Cutibacterium acnes culture, Staphylococcus aureus was identified in 2 cases whereas Staphylococcus caprae was detected in one case. Finally, in the 3 remaining cases, a polymicrobia was found.

The diagnostic criterion established by our hypothesis was then correlated with clinical and paraclinical findings (Table III). In 6 cases (60%), the diagnosis of PSI was in accordance with the identification of 2 positive periprosthetic cultures with the same organism (major MSIS criterion).

Table II. — Summary table of our 10 cases of periprosthetic shoulder infection (PSI), identified during the period from January 2010 to January 2022 in our institution's database.

Patient	Sex	Age	Date of first prosthetic implantation	Cause for shoulder replacement	Date of germ isolation	Delay ***	Identified germ
1	F	76	03/03/11	Humeral head fracture	20/04/12	59	St. epidermidis + C. acnes
2	F	64	05/02/09*	Massive rotator cuff rupture	13/01/12	153	St. epidermidis
3	M	40	28/01/13	Humeral Head osteonecrosis	26/11/13	43	C. acnes
4	M	79	01/11/14*	?**	13/04/16	196	C. acnes
5	F	67	25/04/14	Advanced omarthrosis	03/08/18	223	St. caprae
6	M	64	05/10/16	Massive rotator cuff rupture	13/11/16	6	C. acnes
7	M	68	2006*	?**	27/04/16	x****	St. epidermidis + C. acnes + E. coli
8	M	40	2010*	Humeral head fracture	24/01/18	x****	St. aureus
9	M	61	11/04/18	Humeral head fracture	12/12/19	87	C. acnes + St. capitis
10	F	65	08/06/21	Humeral head fracture	01/01/22	30	St. aureus

* Primary shoulder replacement conducted in another institution; ** Unavailable information; *** Delay between primary arthroplasty and germ indentification (weeks); **** History of surgical revision for PSI.

In one case (10%), the patient had a skin fistula in communication with the joint implants (major MSIS criterion).

When using the minor MSIS criteria, no patient has been identified as having PSI. It should be mentioned that the use of these criteria in our institution remains variable and case dependent and should be considered a limitation of our study. For instance, the histobiochemical analysis of synovial fluid was not conducted.

In 30% of cases, the diagnosis of PSI has not been made using the MSIS criteria: it is the correlation between the clinical findings and the detection of a single positive perioperative culture that leads to PSI diagnosis.

In 6 cases (60%), there was iconographical evidence of PSI such as radiographic findings of a periprosthetic osteolytic border in contact with the humeral stem or glenoid implant. In 5 cases, this data was correlated with a diagnosis of PSI according to the MSIS criteria.

DISCUSSION

Our retrospective case series only includes 10 patients and thus has little weight to be statistically significant. Inconsistent histological analysis and the absence of histobiochemical analysis of synovial fluid in our institution during the management of these patients should also be mentioned. This can be subsequently regarded as a methodological negligence and a bias towards the MSIS criteria. Multiple hypothesis may explain the lack of diligence put into the study of minor criteria:

- Blood draw samples may have been overlooked before revision surgery because of the presumption of a mechanical issue causing joint pain.
- The presence of a small quantity of liquid joint produced by the low growth bacteria usually involved in PSI might have seemed counterintuitive on the part of our surgeons to gather synovial joint liquid samples during surgery.

Nonetheless, the aim of this series is to highlight the issues regarding the interpretation and relevance of the MSIS criteria currently used as a base methodology to cope with this threatening complication.

PSI management, from diagnosis to treatment, is difficult due to the heterogeneity of methodology applied in the literature, the small number of patients included in cohort studies and lastly as it is often handled similarly to lower limb periprosthetic infection.

Currently there is not a consensus on a clear definition of PSI. Often, the MSIS criteria, submitted in 2011, are used as a diagnostic tool to address PSI; however, these criteria were established from data obtained essentially on lower limb periprosthetic infection studies. Furthermore, the authors responsible for

Table III. — Application of the 2011 Musculoskeletal Infection Society (MSIS) diagnostic crite-ria to our proven PSI cases.

	MSIS criteria									
	Major criteria		Minor criteria							
Patient	Skin fistula	2 + cultures	Biological infla. Syndro.	Elev. synovial WBC	Elev. synovial neutro.	Joint purulence	+ peri-prosthe. culture	+ Histology	Diagnosis according to MSIS	Icono-graphic evidence
1	-	+	-	Not studied	Not studied	+	+	Not studied	Yes	Yes
2	-	+	+	Not studied	Not studied	-	+	Not studied	Yes	Yes
3	-	-	Not studied	Not studied	Not studied	-	+	Not studied	No	No
4	-	-	Not studied	Not studied	Not studied	-	+	-	No	Yes
5	-	+	+	Not studied	Not studied	-	+	-	Yes	No
6	-	+	-	Not studied	Not studied	-	+	+	Yes	No
7	-	-	Not studied	Not studied	Not studied	-	+	Not studied	No	Yes
8	+	-	+	Not studied	Not studied	+	+	Not studied	Yes	Yes
9	-	+	+	Not studied	Not studied	-	+		Yes	Yes
10	-	+	+	Not studied	Not studied	+	+	-	Yes	No

publishing these materials explicitly specified that "in certain lowgrade infections (ie, Propionibacterium acnes), several of these criteria may not be routinely met despite the presence of periprosthetic joint infection"[5]. The same caution was applied regarding the 2018 revised criterion.

Cutibacterium acnes (formerly known as Propionibacterium acnes) is an anaerobic Gram positive bacterium naturally found in the commensal flora of humans, especially in the hair follicles of the axillary region. Relatively slowgrowing and less virulent than coagulase-negative staphylococci such as Staphylococcus aureus, this germ produces a biofilm in contact with prosthetic implants, making it difficult for the immune system and systemic antibiotic therapy to reach it[8]. According to the systematic review of Egglestone and al.[2], it is regarded as the most implicated bacterium in PSI with an incidence of 39%. Moreover, this germ is rarely the cause of an expressive osteoarticular infection symptomatology despite disastrous consequences for the patient[6]. Cutibacterium acnes is hence viewed as the primary difficulty of PSI diagnosis: subsequently, these elements cannot be ignored when formulating PSI diagnostic criteria.

Concerning each MSIS criteria:

- As intuitive as it may sound that a joint implant exposed to air is considered infected, the distinction between a scar dehiscence limited to the subcutaneous tissue and a fistulous pathway with visual or palpatory joint contact is hazy and relies on surgical investigation rather than clinical examination. In addition to what have been said, the relationship between superficial plane infection and deep prosthetic infection has not been researched to our knowledge, nor has the incidence of the development of a fistula pathway communicating with the prosthesis in confirmed PSI[9].
- In view of its high susceptibility to PSI, the high risk of false-negative bacteriological specimen due to the required number of samples, the difficulties of transportation and a period of culture beyond 5 days, a positive culture for Cutibacterium acnes at the time of revision shoulder arthroplasty cannot be casually dismissed as just a contaminant. In the series of Pottinger and al. in which 193 cases of prosthetic revisions were conducted for pain, stiffness and/or loosening, 108 (56%) were associated with an unexpectedly positive intraoperative culture, 70% of which were Cutibacterium acnes[10].
- Elevation of biological inflammatory markers is rarely found in PSI cases. In the series conducted by Pottinger and al., elevated CRP was present in 13%, ESR in 17% and elevated white blood count in only 9% of cases[10]. The same is true in the series by Fortune and al. reporting elevated CRP and ESR in 12% and 5% respectively of unexpectedly positive intraoperative samples[11]. In terms of validity, the sensitivity of CRP for the diagnosis of PSI is evaluated between 0 and 46%, and that of ESR between 16 and 42%[9].
- The anatomopathological diagnosis of PSI has not been well studied and current available results have been rather disappointing; in the study conducted by Topolski and al., positive extemporaneous analysis was present in only 7 of their 93 cases of proven PSI12. There is thus a 92% rate of negative analysis for proven PSI. Grosso and al. found a sensitivity

of 50% for a specificity of 100% when the MSIS pathology criterion was applied. However, when the minimum threshold value of neutrophils was increased to 10 per field in 5 pathological analyses of periprosthetic samples, an increase in sensitivity to 72% was observed[13].

There is no iconographic criterion for PSI within the MSIS criteria despite the fact that radiographic evidence of humeral osteolysis or prosthetic loosening is considered significant in Pottinger's series[10]. This published series was the only one to study iconographic diagnostic criteria for PSI. Our series reports 60% radiographic or scannographic evidence, such as the presence of a humeral or glenoid border in confirmed PSI cases. Further studies are thereupon needed to determine the intrinsic validity of an iconographic diagnostic criterion for the diagnosis of PSI.

The MSIS criteria do not include risk factors associated with PSI that could increase the diagnostic probability of PSI. Indeed, although evidence is lacking in the literature due to the heterogeneity of methodologies used in case series, several risk factors for PSI have been suggested, such as male gender (associated with a denser hair territory and therefore richer in C. acnes), age below 65 years, history of surgery, and comorbidities specific to the affected patient[9]. Further studies are necessary to investigate the validity of comorbidity scores that could be integrated in the diagnostic procedure of PSI, such as the Charlson index14 and the Elixhauser index[15].

Finally, the definition of PIJ proposed by the European Bone and Joint Infection Society (EBJIS) in 2021 proposed a "three-level approach to the diagnostic continuum", allowing to define any suspicious arthroplasty as "likely" or "confirmed" infection in a simple matter by any clinician, regardless of the "complexity, geographical variations in practice, use of expensive tests, and disagreement over the accuracy of some of the included tests"[16]. Even though non-binary as a definition, we encouraged the use of the new method of diagnostic in the methodology of future publication regarding PSI instead of the MSIS criteria, allowing a better sensibility of diagnostic, as it has been demonstrated by Huard et al., and thus a better standardization of further results as it has been demonstrated by Huard et al.[17].

CONCLUSION

Our retrospective case series, statistically insignificant, serves as a basis for the necessary debate regarding the use of periprosthetic infection criteria established by the Musculoskeletal Infection Society in 2011 to define PSI. Indeed, the management of this pathology is very complex due to its specific microbiology and a great heterogeneity in the methodology of published studies on this subject. The handling of this troublesome complication must be based on a consensus diagnosis of PSI as must its treatment. We encouraged the use of the EBJIS definition of periprosthetic infection joint in the methodology of future publication regarding the management of PSI.

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