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Staphylococcus aureus versus *Staphylococcus epidermidis* in periprosthetic joint infection—Outcome analysis of methicillin-resistant versus methicillin-susceptible strains

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ABSTRACT

Periprosthetic joint infections (PJIs) are a major complication in total joint arthroplasty. *Staphylococcus aureus* and coagulase-negative staphylococci are known to cause the majority of all PJIs. This study aimed to analyze the eradication rates of *S. aureus* and *S. epidermidis* with methicillin susceptibility and methicillin resistance in a 2-stage therapy algorithm. Seventy-four patients with PJI caused by methicillin-resistant *S. aureus* (MRSA), methicillin-resistant coagulase-negative staphylococci (MRSE), methicillin-susceptible *S. aureus* (MSSA), and methicillin-susceptible coagulase-negative staphylococci (MSSE) were included, and the outcome was analyzed retrospectively. After a minimal follow-up of 2 years, $n = 56$ patients (75.7%) were definitively free of infection. The analysis revealed significant differences between the groups, with eradication rates as follows: MSSA (92.6%), MSSE (95.2%), MRSA (80%), and MRSE (54.2%). MRSE showed a significantly lower rate of patients graded as "definitively free of infection" as compared to patients with infections caused by MSSA, MSSE, and MRSA.

1. Introduction

Periprosthetic joint infections (PJIs) are a feared and potentially devastating complication after total joint arthroplasty. Despite extensive clinical and basic research in the field, treatment of PJI remains one of the most challenging complications for orthopedic surgeons and clinical microbiologists (Chen et al., 2014; Wimmer et al., 2013a, 2016; Zimmerli et al., 2004).

Several treatment strategies have been published over the last decade including debridement and retention and 1-stage exchange, as well as 2-stage exchange which is preferred by many centers. All strategies include a thorough surgical debridement and removal of all infected tissue. At the same time, the identification of a causative pathogen is essential for administering a bactericidal, specific, and focused antibiotic treatment. Identifying the pathogen is especially important in patients with infections caused by methicillin-resistant staphylococci, and it seems essential for the attending surgeon to be familiar with the main biological characteristics of the pathogens targeted.

Staphylococcus aureus is a frequently isolated opportunistic pathogen, which can produce several toxins, including alpha toxin, exfoliative toxins (ETA, ETB, ETC), enterotoxins, and Panton–Valentine leucocidin. Furthermore, there are many secreted enzymes and cell wall proteins that mediate tissue invasion, such as coagulase, DNase, hyaluronidase, collagenase, and fibronectin-binding proteins.

Most virulence factors are encoded as accessory genes that may or may not be present in an individual *S. aureus* strain. Methicillin-resistance is not decisive for virulence, but methicillin-resistant *S. aureus* (MRSA) strains often express a higher level of virulence factors that facilitate their survival and spread. The important difference from nonresistant strains is that in MRSA strains the mobile SCCmec element containing the *mec*A gene is integrated into the chromosome (Ito et al., 2001). The *mec*A gene encodes an alternative penicillin-binding protein (PBP2a) with only a poor affinity for β-lactam antibiotics. Therefore, these strains are resistant to all classical β-lactam antibiotics, except for the new fifth-generation cephalosporins. The major problem for the clinician is that, in cases of MRSA infection, there are fewer therapeutic options available. Due to the acquisition of additional resistance to quinolones, cotrimoxazole, macrolides, and lincosamides, these strains often necessitate i.v. administration of antibiotics, leaving only one oral option, i.e., bacteriostatic linezolid.

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Similarly, coagulase-negative staphylococci (CoNS) such as *S. epidermidis* can be divided into methicillin-resistant coagulase-negative staphylococci (MRSE) and methicillin-susceptible coagulase-negative staphylococci (MSSE). Methicillin resistance is also due to the chromosomal presence of the SCCmec element containing the *mec*A gene, which makes them highly resistant to β-lactam antibiotics and leaves only a limited choice of antibiotics for treatment.

In recent decades, CoNS species have emerged as causative agents in nosocomial infections, mainly due to their ability to form biofilms in foreign body associated infections. CoNS are less pathogenic than *S. aureus,* but they are able to produce several adhesion molecules—i.e., polysaccharide intercellular adhesin, biofilm-associated protein, elastin binding protein, and staphylococcal surface protein—that enable CoNS to attach to foreign bodies and produce biofilms (Cucarella et al., 2001; Gill et al., 2005; Mack et al., 1996a, 1996b; Zhang et al., 2003).

At present, there are only limited data on PJI caused by MRSA and MRSE, especially in comparison to the strains of the same species with methicillin susceptibility.

Tornero et al. describe a cohort of 106 patients suffering from PJI due to *S. aureus* and CoNS (Tornero et al., 2012). Infections with CoNS were present mainly in patients with PJI after revision surgery, whereas infections due to *S. aureus* were present in patients with infections after primary arthroplasties. The overall failure rate was 23.6%. Interestingly, in CoNS infections, the location of the prosthesis was the only factor that was associated with failure (knee 27.6% vs. hip 5%, $P = 0.045$). Another study by Tornero et al. analyzed the outcome of 96 patients with PJI due to methicillin-resistant vs. methicillin-susceptible staphylococci. The failure rate and the relapse rate of the 2 groups were not significantly different ($P = 0.62$ and $P = 1$, respectively) (Tornero et al., 2013).

An investigation by Senneville et al. compared the outcome of 98 patients with PJI caused by MSSA and MRSA. PJI due to MRSA was not associated with a worse outcome compared to PJI due to MSSA. The multivariant analysis showed that only an American Society of Anesthesiologists (ASA) score of ≤2 and rifampin–fluoroquinolone combination therapy were associated with remission (Senneville et al., 2011).

Post et al. looked for specific genes which affect the outcome of PJI and reported that PJI with isolates of *S. epidermidis* with a strong biofilm formation and aminoglycoside resistance had a poorer outcome (Post et al., 2017).

Lourtet-Hascoet et al. analyzed a group of 88 cases of PJI due to *Staphylococcus lugdunensis*, *S. aureus* and *S. epidermidis*. Interestingly, the rate of methicillin resistance was 77% in *S. epidermidis* isolates, and the use of second-line antibiotics was necessary. However, the outcome was comparable with *S. aureus* and *S. lugdunensis* with only 13% and 0% methicillin resistance, respectively ($P = 0.233$) (Lourtet-Hascoet et al., 2016).

Following this rationale, we present our cohort of PJI caused by MRSA, MRSE, MSSA, and MSSE in 74 patients treated with a 2-stage exchange strategy.

Our hypotheses were, first, that MRSA and MRSE show worse eradication rates compared to strains that are susceptible to methicillin (MSSA and MSSE) and, second, that MRSE is at least as difficult to eradicate as MRSA in a consecutive patient cohort. Our null hypothesis was that MSSA, MSSE, MRSA, and MRSE show no difference regarding infection eradication.

2. Material and methods

Routine clinical data were collected and analyzed retrospectively and anonymized. For outcome evaluation, all available data from follow-up visits to the outpatient clinic were used. A defined and structured treatment algorithm was performed as already published by our group (Kapadia et al., 2016; Wimmer et al., 2013a).

In brief, all patients underwent standardized diagnostics with physical examination and laboratory tests, as well as reviews of medical case histories. Aspiration of the affected joint was performed under strictly aseptic conditions and analyzed as published (Schafer et al., 2008; Trampuz et al., 2004; Weiss et al., 2006). Intraoperatively, at least 5 tissue specimens were taken from representative areas that showed signs of infections, and each specimen was bisected and analyzed both microbiologically and histopathologically (Krenn et al., 2014).

A PJI was considered proven according to the Musculoskeletal Infection Society definition (Parvizi et al., 2014), as already published by our group (Wimmer et al., 2013a).

All patients analyzed in this study showed chronic PJI as determined by an onset of symptoms more than 3 weeks after arthroplasty. Systemic (i.e., immunosuppression, diabetes, and ASA score) and local risk factors (soft tissue conditions) were graded preoperatively according to the classification of McPherson et al. (2002). All open surgical procedures included debridement with extensive synovectomy, intensive irrigation, removal of all foreign material, and wound drainage for 2–5 days. A spacer was used if biomechanically possible, as already published by our group (Wimmer et al., 2013b). The antibiotic therapy was chosen according to the detected pathogen and administered i.v. for at least 14 days, followed by oral therapy of 4 weeks as published (Wimmer et al., 2013a). The decision on a suitable antibiotic therapy was made in an interdisciplinary case discussion with a clinical microbiologist at the beginning of therapy, according to the detected pathogen and its susceptibility pattern.

Reimplantation was performed when no clinical and systemic signs of infection were seen (CRP < 10 mg/L, WBC < 10.2 g/L). If there was doubt or if a persisting infection was detected, further open surgical debridement was performed, and antibiotic therapy was continued for 6 weeks (14 days intravenously followed by 4 weeks of oral therapy).

The outcome evaluation was modified according to Laffer et al. (2006) and as previously published by Wimmer et al. (2016).

- *"Definitively free of infection"*: no signs of infection, CRP ≤ 10 mg/dL, follow up ≥2 years
- *"Clinical resolution of infection"*: no signs of infections, follow up ≥2 years
- *"Laboratory resolution of infection"*: CRP ≤ 10 mg/dL, follow up ≥2 years

For the data analysis, all recorded data from the patients' files were anonymized, digitized, and exported to MS Excel 2007 (Microsoft, Redmond, WA) and GraphPad Prism 5.04 (GraphPad Software, Inc., La Jolla, CA). Individual comparisons were analyzed using χ^2 cross tabulations. A P value of ≤0.05 was considered significant.

3. Results

The cohort comprised consecutive patients with 74 prostheses (43 hips, 31 knees) (male $n = 37$; 50%, female $n = 37$; 50%) with proven PJI and at least 2 deep representative intraoperative tissue samples of (1) MSSA, (2) MSSE, (3) MRSA, or (4) MRSE. The patients were treated in our institution by a 2-stage exchange as published previously (Wimmer et al., 2013a). Patients with mixed infections or more than 1 detected pathogen were excluded (Wimmer et al., 2016). No patient was excluded because of risk factors, previous infections or operations, unsuccessful past treatment attempts, or septic conditions (Wimmer et al., 2016). MSSA was found in $n = 14$ patients (18.9%), MSSE in $n = 21$ patients (28.4%), MRSA in $n = 15$ patients (20.3%), and MRSE in $n = 24$ patients (32.4%). There were no statistically significant differences in any of the groups regarding age (overall mean 67.2 ± 14.4 years), height (1.68 ± 0.09 m), weight (74.38 ± 15.09 kg), or body mass index (BMI) (25.85 ± 6.29). Neither systemic nor local risk factors varied significantly between all 4 groups analyzed with a mean McPherson score of 2.05 ± 0.81 for local risk factors and 2.36 ± 0.79 for systemic risk factors, respectively. The mean ASA score was 2.58 ± 0.72. Basic demographic data for all groups are shown in Table 1.

The mean follow-up took place 29.47 ± 10.22 months after the first surgical intervention in our hospital. The mean duration of infection was 88.3 ± 93.37 days. Overall, 1.89 ± 2.32 revisions had been performed before the patient was transferred to our hospital. After admission, 3.81 ± 3.82 revision operations were necessary to control the infection.

Table 1
Basic demographic data.

Parameter	Total	MSSA	MSSE	MRSA	MRSE
n (%)	74 (100%)	14 (18.9%)	21 (28.4%)	15 (20.3%)	24 (32.4%)
Sex	Male	Male	Male	Male	Male
n (%)	37 (50%)	5 (35.7%)	10 (47.6%)	6 (40%)	15 (62.5%)
	female	female	female	female	female
	37 (50%)	9 (64.3%)	11 (52.5%)	9 (60%)	9 (37.5%)
Age (years, SD)	67.23 ± 14.4	70.21 ± 10.25	64.95 ± 18.76	68.5 ± 11.7	65.9 ± 15.3
THA *n* (%)	43 (58.1%	7 (50%)	11 (52.4%)	7 (46.7%)	15 (62.5%)
TKA *n* (%)	31 (41.9%)	7 (50%)	10 (47.6%)	8 (53.3%)	9 (37.5%)
Left *n* (%)	33 (44.6%)	9 (64.3%)	9 (42.9%)	10 (66.7%)	10 (41.7%)
Right *n* (%)	40 (54.1%)	5 (35.7%)	12 (57.1%)	5 (33.3%)	14 (58.3%)
Height (m ± SD)	1.68 ± 0.09	1.67 ± 0.08	1.67 ± 0.09	1.67 ± 0.76	*n* = 1.66 ± 0.09
Weight (kg, SD)	74.38 ± 15.09	73.78 ± 14.49	71.52 ± 13.25	78.0 ± 11.34	*n* = 74.95 ± 18.88
BMI	25.85 ± 6.26	25.93 ± 5.81	25.29 ± 5.71	25.08 ± 7.9	26.71 ± 6.28
Local RF McPherson (mean ± SD)	2.05 ± 0.81	2.29 ± 0.83	1.57 ± 0.75	2.0 ± 2.38	2.38 ± 0.65
Local 1 *n* (%)	22 (29.7%)	3 (21.4%)	12 (57.1%)	3 (20%)	2 (8.3%)
Local 2 *n* (%)	26 (35.1%)	4 (28.6%)	6 (28.6%)	5 (33.3%)	11 (45.8%)
Local 3 *n* (%)	26 (35.1%)	7 (50%)	3 (14.3%)	7 (46.7%)	11 (45.8%)
Systemic RF McPherson (mean ± SD)	2.36 ± 0.79	2.14 ± 0.84	2.19 ± 0.75	2.67 ± 0.98	2.58 ± 0.654
Syst 1 *n* (%)	11 (14.9%)	4 (28.6%)	4 (19%)	4 (26.7%)	2 (8.3%)
Syst 2 *n* (%)	22 (29.7%)	4 (28.6%)	9 (42.9%)	5 (33.3%)	6 (25%)
Syst 3 *n* (%)	40 (54.1%)	6 (42.9%)	8 (38.1%)	6 (40%)	16 (66.7%)
ASA score	2.58 ± 0.72	2.71 ± 0.99	2.48 ± 0.6	2.67 ± 0.98	2.63 ± 0.77
1	3 (4.1%)	1 (7.1%)	0 (0%)	1 (6.7%)	2 (8.3%)
n (%)					
2	32 (43.2%)	6 (42.9%)	12 (57.1%)	7 (46.7%)	7 (29.2%)
n (%)					
3	32 (43.2%)	3 (21.4%)	8 (38.1%)	3 (20%)	13 (54.2%)
n (%)					
4	7 (9.5%)	4 (28.6%)	1 (4.8%)	4 (26.7%)	2 (8.3%)
n (%)					

Table 1 summarizes basic demographic data. SD = standard deviation; RF = risk factor.

A clinical resolution of infection was achieved with 78.4% of patients and a laboratory resolution of infection with 82.4%. After a minimum follow-up of 2 years, $n = 56$ patients (75.7%) were definitively free of infection. Results and outcome evaluations are shown in Table 2.

Regarding **laboratory resolution of infection** (Fig. 1), statistics do not show a significant difference between all groups (MSSA vs. MSSE: $P = 1$; MSSA vs. MRSA $P = 0.5977$; MSSA vs. MRSE: $P = 0.2265$, MSSE vs. MRSA: $P = 0.287$; MSSE vs. MRSE: $P = 0.1012$; MRSA vs. MRSE: $P = 1$).

Regarding **clinical resolution of infection** (Fig. 2), MSSA and MSSE showed equal eradication rates ($P = 1$). Methicillin susceptibility per se was not connected with lower clinical eradication rates. Statistics did not reveal a significant difference between MSSA vs. MRSA ($P = 1$) and MSSE and MRSA ($P = 0.5588$). Nevertheless, MRSE showed a significantly reduced clinical eradication rate compared to methicillin-susceptible strains (MRSE vs. MSSA or MSSE: $P = 0.0273$ and $P = 0.0022$, respectively). Additionally, MRSE showed a significantly lower rate of eradication of clinical infections compared to MRSA (≤0.05).

Regarding **definitively free of infection** (Fig. 3), MSSA and MSSE showed equal eradication rates ($P = 1$). Again, methicillin susceptibility per se was not connected with lower overall eradication rates. Statistics did not reveal a significant difference between MSSA and MRSA ($P = 0.3295$) and MSSE and MRSA ($P = 0.138$). Nevertheless, MRSE showed a significantly reduced overall eradication compared to methicillin-susceptible strains (MRSE vs. MSSA or MSSE: $P = 0.0273$ and $P = 0.0022$, respectively), while MRSE and MRSA showed no significant difference ($P = 0.3172$).

4. Discussion

PJI is one of the most challenging complications associated with total joint arthroplasty as it can lead to additional surgeries, revision, arthrodesis, amputation, and even death. At the same time, the common pathogens are evolving to become more resistant to conventional antimicrobial agents (Perez-Jorge et al., 2016). *Staphylococcus* species account for 50–65% of all PJI cases throughout the world and are the most common causative pathogen. CoNS (i.e., MSSE and MRSE) species have emerged as causative agents in nosocomial infections and are able to produce several adhesion molecules which improve their ability to attach to foreign bodies and produce a biofilm (Paharik and Horswill, 2016). Data on periprosthetic joint infections caused by MRSA and

Table 2
Results and outcome evaluation.

Parameter	Total	MSSA	MSSE	MRSA	MRSE
Follow-up months (mean, SD)	*n* = 29.47 ± 10.22	29.14 ± 8.57	31.9 ± 8.95	*n* = 29.47 ± 8.35	*n* = 29.44 ± 10.83
Duration of infection until treatment in days	88.3 ± 93.37	44.57 ± 18.74	73.62 ± 64.87	44.6 ± 18.06	139.29 ± 137.5
(mean, SD, range)	(13–720)	(25–100)	(13–250)	(25–100)	(40–720)
Revisions extern	1.89 ± 2.32	2.21 ± 2.72	1.38 ± 1.53	2.07 ± 2.69	1.79 ± 2.15
(mean, SD, range)	(0–9)	(0–9)	(0–5)	(0–9)	(0–6)
Revisions intern (mean, SD, range)	3.81 ± 3.82	1.86 ± 1.83	1.57 ± 1.08	1.8 ± 1.78	5 ± 3.66
	(0–15)	(1–5)	(0–4)	(0–5)	(0–15)
LRI *n* (%)	61 (82.4%)	13 (92.9)	20 (95.2)	13 (80)	18 (75)
CIR *n* (%)	58 (78.4%)	13 (92.9)	20 (95.2)	14 (86.7)	13 (54.2)
DFI *n* (%)	56 (75.7%)	13 (92.9)	20 (95.2)	13 (80)	13 (54.2)

Table 2 summarizes results and outcome evaluation. LRI = laboratory resolution of infection; CRI = clinical resolution of infection; DFI = definitively free of infection.

Fig. 1. Statistics did not show significant differences between all groups regarding laboratory resolution of infection, except between MSSE vs. MRSE (MSSA vs. MSSE: $P=1$; MSSA vs MRSA: $P=0.5977$; MSSA vs. MRSE: $P=0.2265$, MSSE vs. MRSA: $P=0.287$; MSSE vs. MRSE: $P=0.1012$; MRSA vs. MRSE: $P=1$).

MRSE are insufficient, especially in comparison with methicillin-susceptible strains of the same species.

Mittal et al. (2007) report a reinfection rate of 24% for knee arthroplasties ($n = 25$ MRSA; $n = 12$ MRSE). This is consistent with our findings since MRSE showed a frustrating overall infection eradication rate of only 54.2%, which was significantly worse than infection eradication rates for MSSA, MSSE, or MRSA. With a recurrence rate of 20%, MRSA data were comparable to the data published by Mittal et al. but failed to become statistically significant, probably due to the sample size.

Kilgus et al. (2002) found that more surgical revisions occurred when treating infections caused by methicillin-resistant ($n = 19$) vs. methicillin-susceptible bacteria ($n = 16$) (3.4 vs. 2.9 revisions). Our data partially support these findings for MRSE, with 5 ± 3.66 revisions, but not for MRSA, with 1.8 ± 1.78 revisions, which were not significantly different compared to MSSA or MSSE.

In addition to thorough surgical debridement, focused antibiotic therapy is the key to success in the therapy of PJI. Antibiotic therapy should, therefore, combine bactericidal substances with those having biofilm activity (i.e., rifampicin) (Baldoni et al., 2013; Furustrand Tafin et al., 2015; Stettler and Trampuz, 2014) even though rifampicin remains controversial for propionibacteria in the literature (Jacobs et al., 2016). The optimal procedure remains unclear if no agents are available matching these standards (e.g., rifampicin-resistant gram-positive species or ciprofloxacin-resistant gram-negative species). Other antibiotics like fosfomycin, daptomycin, moxifloxacin, and tigecycline also show activity against biofilms (Ozturk et al., 2016) and have a role in the treatment of PJI in appropriate combinations.

Empiric antibiotic therapy was chosen according to the anticipated pathogens present in our institution. After pathogen detection, adaptation of antibiotic therapy according to the susceptibility profile and individual patient's needs and considering published therapy recommendations was necessary in 31% of cases. Because of the complexity of PJI for us, it seems essential that such adjustments of antibiotic therapy are made in an interdisciplinary team based on standardized therapy algorithms (Lieb et al., 2015).

We do not have an explanation as to why MRSE infections had a poorer outcome compared to MRSA, MSSA, and MSSE. A possible reason is that small colony variants are forming and persisting in fibroblasts or osteoblasts and therefore escape from the immunological response. Moreover, persisting intracellular bacteria can outlive their host, and they can elude to extracellular compartments upon host cell death; this might be a possible explanation for the delayed onset of symptoms, for recurrent infections, and for the failure of antibiotic therapy (Perez and Patel, 2018). Generally, foreign body–associated infections due to *S. epidermidis* are low-grade infections with lower rates of growth, and so it could be that antibiotic therapy may not work as well as it does with metabolically active bacteria.

Another important fact in treating patients with multiresistant staphylococcal isolates is economics. As the occurrence of PJI due to bacteria with multidrug resistance rises, the cost of care for treatment due to methicillin-resistant staphylococci has been calculated at a mean of $107,264 per case compared to $68,053 for those infections caused by methicillin-susceptible staphylococci ($P < 0.0001$) (Parvizi et al., 2010).

We acknowledge that our study has limitations. The sample size is low for a study investigating arthroplasties, even though the number of patients is high when analyzing the treatment of PJI with MSSA, MSSE, MRSA, or MRSE in infected total knee arthroplasties (TKAs) and total hip arthroplasties (THAs) only. Additionally, the data were gathered retrospectively, limiting quality and level of evidence. The inhomogeneity of the patients investigated (i.e., duration of infection until treatment) is both a weakness and a strength of this study. Patients with PJI are complex and challenging to compare, but the inhomogeneity represents day-to-day clinical experience. Future prospective trials with a higher number of patients seem essential to confirm our findings. Overall, we are presenting one of the largest patient collectives published so far, investigating the outcome of 74 patients with prosthetic

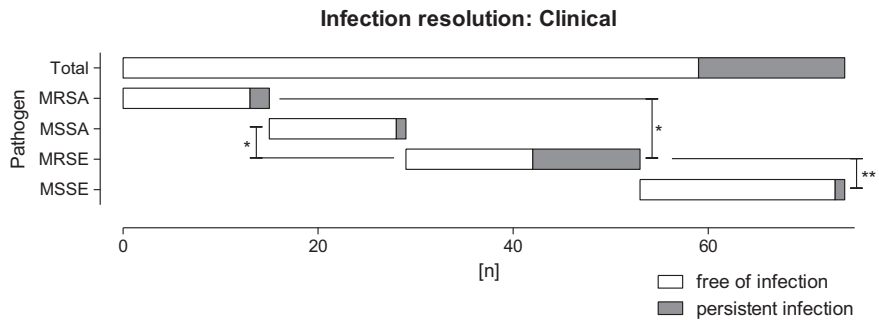

Fig. 2. Regarding clinical resolution of infection, MSSA and MSSE showed equal clinical eradication rates ($P=1$). Methicillin susceptibility per se was not connected with lower clinical resolution of infection rates. Statistics did not reveal a significant difference between MSSA vs MRSA ($P=1$) or MSSE and MRSA ($P=0.5588$). Nevertheless, MRSE showed a significantly reduced overall clinical eradication rate compared to methicillin-susceptible strains (MRSE vs. MSSA or MSSE: $P=0.0273$ and $P=0.0022$, respectively). In addition, MRSE showed a significantly lower rate of clinical resolution of infection in MRSA cases ($P \leq 0.05$); *indicates $P \leq 0.05$, **indicates $P \leq 0.01$.

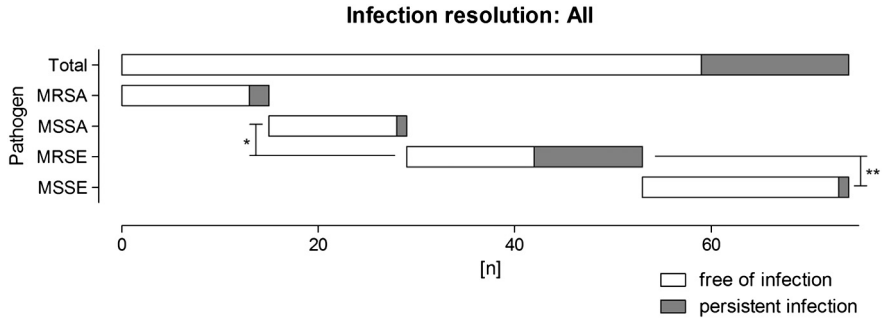

Fig. 3. Regarding definitively free of infection, MSSA and MSSE showed equal eradication rates ($P=1$). Again, methicillin susceptibility per se was not correlated (Zimmerli et al., 2004) with worse definitively free of infection rates. Statistics did not reveal a significant difference between MSSA vs. MRSA ($P=0.3295$) or MSSE and MRSA ($P=0.138$). Nevertheless, MRSE showed a significantly reduced definitively free of infection rate compared to methicillin-susceptible strains (MRSE vs. MSSA or MSSE: $P=0.0273$ and $P=0.0022$, respectively), while MRSE and MRSA showed no significant difference ($P=0.3172$); *indicates $P\leq0.05$, **indicates $P\leq0.01$.

joint infections of the hip or the knee joint caused by MSSA, MSSE, MRSA, or MRSE.

Our data suggest that methicillin resistance remains a challenge when treating PJI with *S. aureus* or *S. epidermidis*. Nevertheless, methicillin resistance seems not to be the sole relevant aspect, especially since MRSE infections show frustrating eradication rates. Future trials should focus on bioadherence capability or biofilm formation rather than on methicillin resistance alone.

5. Conclusion

The outcome of PJI due to *S. aureus* and *S. epidermidis* with different susceptibility patterns differs significantly. Our data show that infections with oxacillin-resistant *S. epidermidis* isolates have the poorest outcome regarding "definitively free of infection" and are a challenge for all 3 actors: patient, orthopedic surgeon, and microbiologist.

Conflict of interest

The authors report no conflict of interest with the data presented.

Ethics

Our survey was approved by the local ethics board according to the Declaration of Helsinki and the International Conference on Harmonization-Good Clinical Practice criteria.

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