Original

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Prosthetic joint infections due to methicillin-resistant and methicillin-susceptible staphylococci treated with open debridement and retention of the prosthesis

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ABSTRACT

Objectives. To compare the specific characteristics, the outcome and the predictors of failure of prosthetic joint infections (PJI) due to methicillin-resistant (MRS) and methicillin-susceptible staphylococci (MSS) treated with open debridement and retention of the implant.

Material and methods. PJI due to MRS or MRS prospectively registered in a database from 1999 to 2009 were retrospectively reviewed.

Results. During the study period, 96 patients met the inclusion criteria of the study. The mean follow-up period was 3.9 years and at least 2 years in all patients. The failure rate was 25%. The only variable significantly associated with failure in the global cohort was polymicrobial infection (59.3% vs. 40.7%, p=0.036). Thirty-four (35.4%) patients had an infection due to MRS and 62 (63.6%) due to MSS. Among MSS infections, 95.2% corresponded to primary arthroplasties while 29.4% of PJI due to MRS were after revision arthroplasties (p=0.001). CRP was significantly higher in PJI due to MSS (5.2 mg/dl vs 9.1 mg/dL, p=0.02).The failure rate (20% vs 27%, p=0.62) was very similar in MSS and MRS groups.

Conclusion. PJI due to MRS were mainly coagulase-negative staphylococci, more frequent after revision arthroplasties, had a lower inflammatory response, and had a similar failure rate than MSS infections.

Keywords: prosthetic joint infection, debridement, methicillin-resistant, *Staphylococcus aureus*, coagulase-negative staphylococci.

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Infecciones protésicas articulares por estafilococos meticilin-resistentes y meticilin-sensibles tratadas mediante desbridamiento y retención de la prótesis

RESUMEN

Objetivo. Comparar las características específicas, los resultados y los factores predictivos de mal pronóstico de las infecciones de prótesis articulares (IPA) por estafilococos meticilin-resistentes (EMR) y meticilin-sensibles (EMS) tratadas mediante desbridamiento, retención del implante y tratamiento antibiótico.

Material y métodos. Se realizó una revisión retrospectiva de todas las IPA's por EMR o EMS registradas en nuestra base datos desde 1999 a 2009.

Resultados. Durante el periodo del estudio, 96 pacientes cumplieron los criterios de inclusión en el estudio. El seguimiento medio de los pacientes fue de 3,9 años y todos los pacientes tenían al menos 2 años de seguimiento. La tasa de fracaso fue del 25%. La única variable asociada significativamente a fracaso terapéutico en el total de pacientes fue la infección polimicrobiana (59,3% vs. 40,7%, p=0,036). Treinta y cuatro (35,4%) pacientes tuvieron una infección por EMR y 62 (63,6%) por EMS. Respecto las infecciones por EMS, el 95,2% correspondían a cirugías primarias mientras que el 29,4% de las IPA's por EMR ocurrieron tras cirugías de revision (p=0,001). El valor de la PCR fue significativamente superior en las IPA's por EMS (5,2 mg/dl vs 9,1 mg/dL, p=0,02). La tasa de fracaso fue similar en las infecciones por EMS y EMR (20% vs 27%, p=0,62).

Conclusión. Las IPA's por EMR fueron causadas principalmente por estafilococos coagulase-negativo, ocurrieron más frecuentemente tras cirugías de revisión, tenían una reacción inflamatoria menor y obtuvieron una tasa de fracaso similar a las infecciones por EMS.

Palabras clave: Infección protésica, desbridamiento, meticilin-resistente. *Staphylococcus aureus*, estafilococo coagulase-negativo

INTRODUCTION

Early prosthetic joint infections (PJIs) are associated with substantial morbidity, increased medical costs and reduced quality of life[1,2]. Debridement and prosthesis retention combined with a prolonged antibiotic regimen including rifampin is an accepted therapeutic approach when the duration of symptoms is less than 4 weeks and there are no radiological signs of loosening. The outcome of patients with a PJI has been previously assessed in several articles with success rates between 60% to 90%[3-6]. Articles describing outcome predictors in patients treated with an open debridement combined with a rifampin-based regimen are scarce and mainly focused on PJIs due to *Staphylococcus aureus*[4,7-9]. During recent years, the prevalence of coagulase-negative staphylococci (CNS) as an etiological agent of PJI is increasing[10] and frequently associated with methicillin and fluoroquinolone resistance, thereby reducing the antibiotic options for combining with rifampin.

The aim of the present study was to compare specific characteristics, outcome and predictors of failure of infections due to methicillin-resistant and methicillin-susceptible staphylococci, including *S. aureus* and CNS, treated with open debridement without removing the implant and prolonged antibiotic treatment.

METHODS

Since January 1999 patients with a PJI (hip or knee arthroplasties) were prospectively registered in a database. Relevant information about demographics, co-morbidity, type of implant, clinical manifestations, leukocyte count, and C-reactive protein (CRP) concentration at the time of admission for infection, surgical treatment, microorganism isolated, antimicrobial therapy, and outcome were recorded. For the present study, cases with a mono- or polymicrobial prosthetic joint infection due to staphylococcal microorganism (*S. aureus* or CNS) registered from 1999 to 2009 were retrospectively reviewed.

Prosthetic joint infection was defined by the presence of local inflammation, macroscopic evidence of extension of the infection through the capsule during open debridement, and isolation of significant microorganisms from deep samples. In case of CNS, ≥2 positive deep samples were required for considering this microorganism a true pathogen. All patients were treated in the bone and joint infection unit of our hospital, which includes orthopaedic surgeons, infectious disease specialists and microbiologists. For debridement, pre-existing incisions were always used, necrotic tissue was excised, and the joint was washed out with 7 liters of sterile water. The components of the prosthesis were left in situ after it was confirmed during surgery that there were no signs of loosening. In knee arthroplasties, the polyethylene component was removed and replaced with a new one, while in total hip arthroplasties, the polyethylene as well as the femoral head were replaced whenever possible. The patients were taken back to the operating room to repeat the irrigation only when systemic or local signs of infection persisted after debridement. Six deep samples of synovial fluid or periprosthetic tissue were submitted to the microbiology laboratory. An antibiogram for all significant isolates was performed by microdilution method.

After debridement, a broad-spectrum intravenous antibiotic regimen including vancomycin (1 g/12 h) plus ceftazidime (2 g/8 h) was started and maintained until definitive microbiological results were obtained. When the microorganism was susceptible to methicillin, vancomycin was switched to intravenous cloxacillin (2 g/4 h). The definitive oral antibiotic treatment was levofloxacin (500 mg/24 h) plus rifampin (600 mg/24 h), except in those cases with resistant strains or polymicrobial infection, in which an alternative was selected according to the antibiogram. The protocol of our hospital recommends 10 days of intravenous antibiotics, and the duration of oral antibiotics was decided by a member of the team (A.S) in each case according to the clinical manifestations and the CRP value.

After being discharged, patients were followed up monthly while they were receiving treatment and every 6 to 12 months after finishing the therapy. Outcome was classified according to the following definitions: (i) remission, when the patient had no symptoms of infection, the prosthesis was retained, and CRP was <1 mg/dl after at least 2 years of follow-up; or (ii) failure, when inflammatory signs and high CRP remained during treatment and the patient needed a second surgery (second debridement or prosthesis removal) or when symptoms re-appeared after completing treatment. Relapsed or re-infection was considered to have occurred depending on the microorganism that was isolated. It was not considered failure when the patient developed an aseptic loosening that required the prosthesis to be exchanged and deep samples taken during surgery were found to be negative.

Statistical analysis

Variables analyzed were age, sex, co-morbidity (having or not having one or more of the following conditions: diabetes mellitus, liver cirrhosis, chronic renal failure, rheumatoid arthritis, or chronic obstructive pulmonary disease), type of prosthesis (hip or knee), age of implant, duration of symptoms, presence of fever, leukocyte count, CRP value, positive blood cultures, the need for a second debridement, resistance to methicillin or fluoroquinolones, and polymicrobial infection. For the statistical analysis, continuous variables were explored and categorized. Categorical variables were compared by Chi-square test or Fisher's exact test when necessary and continuous variables by Student's t test. Kaplan-Meier survival method was used to estimate the cumulative probability of treatment success according to the microorganism and compared using the log-rank test. Statistical significance was defined as a two-tailed $p<0.05$. The analysis was performed using SPSS, version 15.0 (SPSS, Inc., Chicago, IL, USA).

RESULTS

During the study period, 96 patients met the inclusion criteria of the study. The mean (SD) age of cohort was 70.2

Table 1 **Characteristics of patients with staphylococcal prosthetic joint infections according to the outcome (N=96)**

Characteristics	Remission[1] (%) N= 72	Failure[1] (%) N=24	p
Mean Age (SD) years	70.4 (10.7)	69.4 (9.7)	0.67
Age > 70 years	40 (55.6)	9 (37.5)	0.16
Sex Male	34 (47.2)	14 (58.3)	0.48
Comorbidity[2]	23 (31.9)	11 (45.8)	0.23
Primary arthroplasty	61 (84.7)	22 (91.7)	0.51
Revision arthroplasty	11 (15.3)	2 (8.3)	
Hip arthroplasty	26 (36.1)	5 (20.8)	0.21
Knee arthroplasty	46 (63.9)	19 (79.2)	
Mean (SD) age of prosthesis in days	26.3 (21.1)	24.3 (28.7)	0.71
Age of prosthesis: < 15 days	20 (27.8)	10 (41.7)	0.22
15 - 45 days	46 (63.9)	12 (50.0)	0.24
> 45 days	6 (8.3)	2 (8.3)	1
Mean (SD) days of symptoms	4.9 (4.6)	5.4 (4.9)	0.68
Interval of days with symptoms: 0-2 days	31 (43.1)	9 (37.5)	0.81
3-5 days	18 (25.0)	6 (25.0)	1
6-10 days	14 (19.4)	5 (20.8)	1
>10 days	9 (12.5)	4 (16.7)	0.73
Fever	13 (18.1)	5 (20.8)	0.77
Mean (SD) leukocyte count (cells/mm^3)	8837 (3678)	9043 (3537)	0.81
Mean (SD) CRP (mg/dL)	7.1 (9.2)	9.5 (10.2)	0.27
Interval of CRP (mg/dL): <5	43 (59.7)	13 (54.2)	0.64
5-12	17 (23.6)	5 (20.8)	1
>12	11 (15.3)	6 (25.0)	0.36
Methicillin-resistance	27 (37.5)	7 (29.2)	0.62
Fluoroquinolone-resistance	20 (27.8)	6 (25.0)	1
Bacteraemia	3 (4.2)	4 (16.7)	0.063
Polymicrobial	16 (22.2)	11 (45.8)	0.036
Mean (SD) days of oral antibiotics[3]	82.3 (42.0)	73.2 (48.0)	0.48
Intervals of days of oral antibiotics[3]:			
< 90 days	50 (69.4)	10 (41.7)	1
> 90 days	16 (22.2)	3 (12.5)	
Oral antibiotics[3]			
Levofloxacin + rifampin	40 (58.8)	6 (46.2)	0.37
Linezolid + rifampin	9 (13.2)	2 (15.4)	1
Other combinations	19 (27.9)	5 (38.5)	0.52
Linezolid	16 (23.5)	3 (23.1)	1
No rifampin	8 (11.8)	1 (7.7)	1

SD, standard deviation. CRP, C-reactive protein.

[1] See text for definitions.

[2] Diabetes mellitus, chronic renal failure, rheumatoid arthritis, chronic obstructive pulmonary disease or history of steroid therapy.

[3] Includes those patients who received oral antibiotics for > 15 days (n=81, 68 remission vs 13 failures)

Table 2 **Characteristics of PJI due to methicillin-resistant and methicillin-susceptible staphylococci**

Characteristics	Methicillin-R (%) n=34	Methicillin-S (%) n=62	p
Mean Age (SD) years	70.5 (9.2)	70.0 (11.0)	0.81
Age > 70 years	18 (52.9)	31 (50.0)	0.83
Sex Male	18 (52.9)	30 (48.4)	0.83
Comorbidity[2]	20 (58.8)	42 (67.7)	0.50
Primary arthroplasty	24 (70.6)	59 (95.2)	**0.001**
Revision arthroplasty	10 (29.4)	3 (6.2)	
Hip arthroplasty	11 (32.4)	20 (32.3)	1
Knee arthroplasty	23 (67.6)	42 (67.7)	
Mean (SD) age of prosthesis in days	25.6 (21.4)	25.9 (24.2)	0.96
Age of prosthesis: < 15 days	10 (29.4)	20 (32.3)	0.82
15 - 45 days	21 (61.8)	37 (59.7)	1
> 45 days	3 (8.8)	5 (8.1)	1
Mean (SD) days of symptoms	4.2 (4.4)	5.5 (4.8)	0.18
Interval of days with symptoms: 0-2 days	18 (52.9)	22 (35.5)	0.13
3-5 days	7 (20.6)	17 (27.4)	0.62
6-10 days	6 (17.6)	13 (21.0)	0.79
>10 days	3 (8.8)	10 (16.1)	0.37
Fever	5 (14.7)	13 (21.0)	0.58
Mean (SD) leukocyte count (cells/mm^3)	8283 (3321)	9226 (3769)	0.22
Mean (SD) CRP (mg/dL)	5.2 (5.4)	9.1 (10.8)	**0.02**
Interval of CRP (mg/dL): <5	22 (64.7)	34 (54.8)	0.51
5-12	8 (23.5)	14 (22.6)	1
>12	4 (11.8)	13 (21.0)	0.28
S. aureus	5 (14.7)	51 (82.3)	**<0.001**
Coagulase-negative staphylococci	29 (85.3)	11(17.7)	
Fluoroquinolone-resistant	20 (58.8)	6 (9.7)	**<0.001**
Bacteraemia	1 (2.9)	6 (9.7)	0.41
Polymicrobial	11 (32.4)	16 (25.8)	0.64
Mean (SD) days of oral antibiotics[3]	68.9 (40.5)	89.0 (43.0)	**0.04**
Intervals of days of oral antibiotics[3]:			
< 90 days	27 (79.4)	33 (53.2)	0.19
> 90 days	5 (14.7)	14 (22.6)	
Oral antibiotics[3]			
Levofloxacin + rifampin	9 (27.3)	37 (77.1)	**<0.001**
Linezolid + rifampin	9 (27.3)	2 (4.2)	**0.006**
Other combinations	15 (45.5)	9 (18.7)	**0.013**
No rifampin	6 (18.2)	3 (6.2)	0.147
Linezolid	15 (46.9)	4 (8.5)	**<0.001**

Table 2 **Characteristics of PJI due to methicillin-resistant and methicillin-susceptible staphylococci (cont.)**

Characteristics	Methicillin-R (%) n=34	Methicillin-S (%) n=62	p
Failure[1] (%)	7 (20.6)	17 (27.4)	0.62
Relapse[1] (%)	7 (20.6)	14 (22.6)	1
Failure during antibiotic therapy (%)	3 (8.8)	9 (14.5)	0.53
Failure after finishing antibiotic therapy (%)	31 (91.2)	53 (85.5)	
Mean (SD) years of follow-up	3.6 (1.9)	4.0 (2.3)	0.34

SD, standard deviation. CNS, coagulase-negative staphylococci. CRP, C-reactive protein.

[1]See text for definitions.

[2]Diabetes mellitus, chronic renal failure, rheumatoid arthritis, chronic obstructive pulmonary disease or history of steroid therapy.

[3]Includes those patients who received oral antibiotics for > 15 days (n=81, 33 MRS vs 48 MSS)

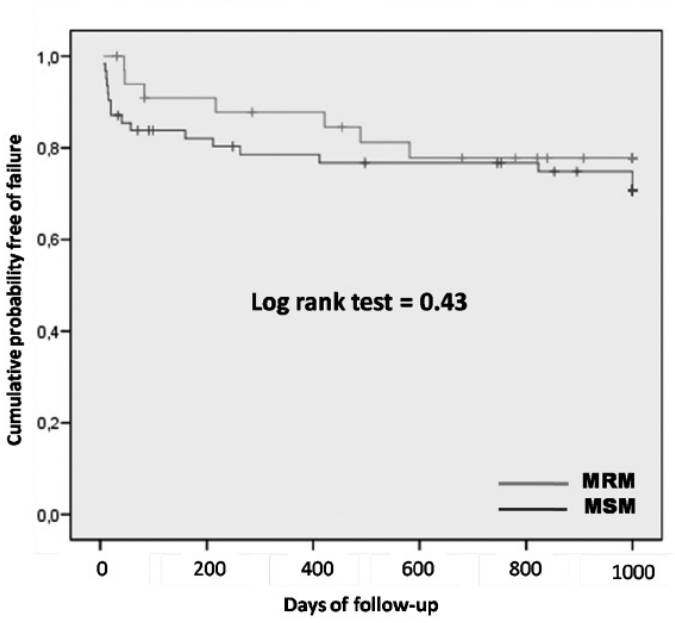

Figure 1 **Cumulative probability of being free of failure according to the staphylococcal methicillin resistance in the first 1000 days of follow-up.**

(10.4) years. Forty-eight were male (50%), and 31 infections (32.3%) were on a hip and 67 (67.7%) on a knee prosthesis. In 83 (86.5%) cases the infected prosthesis was a primary arthroplasty and in 13 (13.5%) a revision arthroplasty. The mean (SD) age of prosthesis at the moment of infection diagnosis was 25.8 (23.1) days, and it was <15 days, 16 to 45 days or >45 days in 30, 58 and 8 cases respectively. The mean (SD) days of symptoms was 5.0 (4.7) days and it was <3 days, 3 to 5 days, 6 to 10 days or >10 days in 40, 24, 19 and 13 cases respectively. Fever was present in 18 patients (18.8%) and the preoperative mean (SD) leukocyte count was 8889 (2626) cells/mm3. The preoperative mean (SD) CRP was 7.7 (9.4) mg/dl, and it was <5 mg/dl, 5-12 mg/dl or >12mg/dl in 56, 22 and 17 cases, respectively. There were 51 S. aureus (82.3%) among MSS and 29 CNS (85.3%) among MRS (p<0.001). Seven patients (7.3%) had bacteremia and in 27 cases (28%) the infection was polymicrobial. The mean (SD) duration of intravenous and oral antibiotics was 9.5 (5.6) and 81 (43) days, respectively. The mean follow-up period was 3.9 years and at least 2 years in all patients in remission except one who died after 6 months due to an unrelated cause and without evidence of failure. The failure rate was 25% (24 out of 96) and the characteristics of

patients according to the outcome are summarized in table 1. The only variable significantly associated with failure in the global cohort was polymicrobial infection (59.3% vs. 40.7%, p=0.036) and there was a trend towards significance for bacteremia (42.9% vs 57.1%, p=0.063)

Thirty-four (35.4%) patients had an infection due to a MRS and 62 (63.6%) due to a MSS. The characteristics of these two groups are shown in table 2. It is of note the relationship between resistance pattern and the type of surgery, 95.2% of PJI due to MSS corresponded to primary arthroplasties while 29.4% of PJI due to MRS were after revision arthroplasties (p=0.001). There were no statistically significant differences between both groups in age, sex, co-morbidity, type of prosthesis (hip or knee), age of prosthesis, fever, leukocyte count, rate of polymicrobial infections, days of symptoms or days of intravenous and oral antibiotics. CRP was significantly higher in PJI due to MSS (5.2 mg/dl vs 9.1 mg/dL, p=0.02). Fluoroquinolone-resistance was higher in MRS than in MSS (58.8% vs 9.6%, p<0.001). Oral antibiotic regimen including levofloxacin plus rifampin was more frequently given to patients with PJI due to MSS (76% vs 28%, p<0.001) while the use of linezolid plus rifampin (28% vs 4%, p=0.006) or other combinations (46% vs 18%, p=0.013) were more frequent in PJI due to MRS. The failure rate (20% vs 27%, p=0.62) and the relapse rate (20% vs 22%, p=1.0) were very similar in MSS and MRS groups. The cumulative probability of being in remission during the first 1000 days of follow-up according to the resistance pattern is shown in figure 1. The figure shows that failure in MSS appeared earlier than in MRS although the final result is very similar.

DISCUSSION

The success rate in our cohort of patients with PJI treated with debridement and retention of the implant after at least 2 years of follow-up was 75% (72 out of 96), considering both relapse or re-infection as failure. This result is similar to other authors using a rifampin combination[3-5,7,11-12]. In our series, MRS were predominantly CNS, infected revision arthroplasties, had lower CRP at the time of diagnosis and received less frequently levofloxacin plus rifampin but the outcome of infections due to MRS was not significantly worse than the outcome of infections due to MSS. Previous reports suggested lower remission rates in PJI due to MRS[8,13-16], however, the majority of these authors analyzed infections due to MR *S. aureus*. In contrast, in our series the predominant methicillin-resistant pathogens were CNS. Previous experience describing the outcome in MR-CNS treated without implant removal is scarce. Our results suggest that oral combinations with rifampin, including levofloxacin, linezolid and others, are effective in MR-CNS.

The abscense of good predictors of failure in PJIs treated with open debridement has been previously described by others[9]. In the future, it is necessary to analyze factors associated with the microorganism (i.e. biofilm production), in order to improve the selection of those patients that could benefit of a conservative surgery o require a more aggressive one.

Byren et al.[17] using a prolonged oral regimen including rifampin, described a failure rate in *S. aureus* PJIs of 27.6%. In our study, 94% of patients were treated with an antibiotic combination including rifampin, the duration of intravenous (9.5 days) and oral (80 days) antibiotic treatment was significantly shorter than in the Byren study but a similar failure rate (25%) was observed. Our results are in agreement with others[18] and suggests that the duration of both intravenous and oral regimens could be reduced.

The main drawback of our study was the relative small sample size and its retrospective nature, however, it is one of the largest series with a long-term follow-up and a standardized surgical protocol.

In conclusion, open debridement and retention of the prosthesis in staphylococcal PJI was associated with a failure rate of 25%. PJI due to MRS were mainly CNS, more frequent after revision arthroplasties, had a lower inflammatory response, and had a similar failure rate than MSS infections using a rifampin oral combination.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest

ACKNOWLEDGEMENTS

Hip and knee surgeons and nurses of the orthopedic department.

REFERENCES

1. Zimmerli W, Trampuz A, Ochsner PE. Prosthetic-joint infections. N Engl J Med 2004; 351:1645–54.
2. Darouiche RO. Treatment of infections associated with surgical implants. N Engl J Med 2004; 350:1422–9.
3. Cobo J, Miguel LGS, Euba G, Rodriguez D, García-Lechuz JM, Riera M et al. Early prosthetic joint infection: outcomes with debridement and implant retention followed by antibiotic therapy. Clin Microbiol Infect 2011; 17:1632–7.
4. Vilchez F, Martínez-Pastor JC, Garcia-Ramiro S, Bori G, Maculé F, Sierra J et al. Outcome and predictors of treatment failure in early post-surgical prosthetic joint infections due to *Staphylococcus aureus* treated with debridement. Clin Microbiol Infect 2011; 17:439–44.
5. Zimmerli W, Widmer AF, Blatter M, Frei R, Ochsner PE. Role of rifampin for treatment of orthopedic implant-related staphylococcal infections: a randomized controlled trial. JAMA 1998; 279:1537–41.
6. Lora-Tamayo J, Murillo O, Iribarren JA, Soriano A, Sanchez-Somolinos M, Baraia-Etxaburu JM et al. A Large Multicenter Study of Methicillin Susceptible- and Methicillin Resistant-Staphylococcus aureus Prosthetic Joint Infections Managed with Implant Retention. Clin Infect Dis 2012; DOI: 10.1093/cid/cis746.
7. Senneville E, Joulie D, Legout L, Valette M, Dezèque H, Beltrand E et al. Outcome and Predictors of Treatment Failure in Total

Hip/Knee Prosthetic Joint Infections Due to *Staphylococcus aureus*. Clin Infect Dis 2011; 53:334–40.

8. Ferry T, Uçkay I, Vaudaux P, François P, Schrenzel J, Harbarth S et al. Risk factors for treatment failure in orthopedic device-related methicillin-resistant Staphylococcus aureus infection. Eur J Clin Microbiol Infect Dis 2010; 29:171–80.
9. Tattevin P, Crémieux AC, Pottier P, Huten D, Carbon C. Prosthetic joint infection: when can prosthesis salvage be considered? Clin Infect Dis 1999; 29:292–5.
10. Moran E, Masters S, Berendt AR, Mclardy-Smith P, Byren I, Atkins BL. Guiding empirical antibiotic therapy in orthopaedics: The microbiology of prosthetic joint infection managed by debridement, irrigation and prosthesis retention. J Infect 2007; 55:1–7.
11. Aboltins CA, Page MA, Buising KL, Jenney AW, Daffy JR, Choong PF et al. Treatment of staphylococcal prosthetic joint infections with debridement, prosthesis retention and oral rifampicin and fusidic acid. Clin Microbiol Infect 2007; 13:586–91.
12. Stein A, Bataille JF, Drancourt M, Curvale G, Argenson JN, Groulier et al. Ambulatory treatment of multidrug-resistant Staphylococcus-infected orthopedic implants with high-dose oral co-trimoxazole (trimethoprim-sulfamethoxazole). Antimicrob Agents Chemother 1998; 42:3086–91.
13. Barberán J, Aguilar L, Carroquino G, Giménez MJ, Sánchez B, Martínez D et al. Conservative treatment of staphylococcal prosthetic joint infections in elderly patients. Am J Med 2006; 119:993.e7–10.
14. Salgado CD, Dash S, Cantey JR, Marculescu CE. Higher risk of failure of methicillin-resistant *Staphylococcus aureus* prosthetic joint infections. Clin Orthop Relat Res 2007; 461:48–53.
15. Bradbury T, Fehering TK, Taunton M, Hanssen A, Azzam K, Parvizi J et al. The Fate of Acute Methicillin-Resistant Staphylococcus aureus Periprosthetic Knee Infections Treated by Open Debridement and Retention of Components. Journal of Arthroplasty 2009; 24:101–4.
16. Parvizi J, Pawasarat IM, Azzam KA, Joshi A, Hansen EN, Bozic KJ. Periprosthetic Joint Infection. Journal of Arthroplasty 2010; 25:103–7.
17. Byren I, Bejon P, Atkins BL, Angus B, Masters S, McLardy-Smith P et al. One hundred and twelve infected arthroplasties treated with 'DAIR' (debridement, antibiotics and implant retention): antibiotic duration and outcome. Journal of Antimicrobial Chemotherapy 2009; 63:1264–71.
18. Bernard L, Legout L, Zürcher-Pfund L, Stern R, Rohner P, Peter R et al. Six weeks of antibiotic treatment is sufficient following surgery for septic arthroplasty. J Infect 2010; 61:125–32.