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# *Staphylococcus lugdunensis*, a serious pathogen in periprosthetic joint infections: comparison to *Staphylococcus aureus* and *Staphylococcus epidermidis*

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SUMMARY

*Objectives:* The aim of this study was to assess the characteristics of periprosthetic joint infection (PJI) due to *Staphylococcus lugdunensis* and to compare these to the characteristics of PJI due to *Staphylococcus aureus* and *Staphylococcus epidermidis*.
*Methods:* A retrospective multicentre study including all consecutive cases of *S. lugdunensis* PJI (2000–2014) was performed. Eighty-eight cases of staphylococcal PJI were recorded: 28 due to *S. lugdunensis*, 30 to *S. aureus*, and 30 to *S. epidermidis*, as identified by Vitek 2 or API Staph (bioMérieux).
*Results:* Clinical symptoms were more often reported in the *S. lugdunensis* group, and the median delay between surgery and infection was shorter for the *S. lugdunensis* group than for the *S. aureus* and *S. epidermidis* groups. Regarding antibiotic susceptibility, the *S. lugdunensis* strains were susceptible to antibiotics and 61% of the patients could be treated with levofloxacin + rifampicin. The outcome of the PJI was favourable for 89% of patients with *S. lugdunensis*, 83% with *S. aureus*, and 97% with *S. epidermidis*.
*Conclusion: S. lugdunensis* is an emerging pathogen with a pathogenicity quite similar to that of *S. aureus*. This coagulase-negative Staphylococcus must be identified precisely in PJI, in order to select the appropriate surgical treatment and antibiotics .


## 1. Introduction

Periprosthetic joint infections (PJI) are the main complication of knee and hip prosthetic arthroplasty. Between 1% and 3% of patients undergoing prosthesis implantation are affected by these infections.[1,2] Staphylococci (*Staphylococcus aureus* and coagulase-negative staphylococci (CoNS)) are the major pathogens involved in PJI.[2,3] *Staphylococcus lugdunensis* is a CoNS that is considered part of the normal flora of human skin, as are other CoNS species.[4] It is widely distributed across the skin, especially in the inguinal and perineal areas.[5] *S. lugdunensis* was first described in 1988 and was shown to have morphological, biochemical, and pathogenic properties close to those of *S. aureus*.[6] These common properties can lead to misidentification of *S. lugdunensis*: it may be positive for clumping factor and thus could show positive latex agglutination test results, like *S. aureus*. *S. lugdunensis* is also ornithine decarboxylase-positive, like other CoNS, and may therefore be mistaken for another CoNS. Recent developments in bacteriological techniques have led to considerable improvements in species identification. Automated systems and mass spectrometry have resolved the misidentification problems especially for CoNS.

The virulence factors of *S. lugdunensis* are shared with *S. aureus*, such as the ability to adhere to host proteins (fibronectin, fibrinogen), slime production, and the secretion of various toxins.[7] Moreover, the gene *agr* (accessory regulator), ica operon, *fbl*, *atlL*, *vwbl*, and slush factors involved in bacterial virulence have been identified in *S. lugdunensis* strains. All of these common properties show that *S. lugdunensis* is an aggressive pathogen and may be responsible for serious infections.[8,9] *S. lugdunensis* is also described as a bacterium capable of biofilm production due to AtlL autolysin, particularly in prosthetic device-associated infections.[10]

The pathogenic role of *S. lugdunensis* was emphasized in 1991 when a total of 155 *S. lugdunensis* specimens were isolated from different sites in 143 patients.[4] In that study, the patients

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included often presented necrotizing wounds, empyema, or abscesses. *S. lugdunensis* is well described as an aggressive pathogen involved in brain, thoracic, cutaneous, and soft tissue abscesses.[11–13] Furthermore, *S. lugdunensis* can cause endocarditis on native valves, septicaemia, deep tissue infections, and peritonitis.[4,9] However, few studies have reported *S. lugdunensis* bone and joint infections.

*S. lugdunensis* shares several properties with *S. aureus*: in particular, *S. lugdunensis* may produce bound coagulase via a clumping factor. However, unlike *S. aureus*, it does not produce free coagulase. The rapid agglutination test (short coagulase test) may be positive for *S. lugdunensis* because of the same surface proteins shared with *S. aureus*. For these reasons it can be misidentified, and this could affect the management of PJI treatment. *S. lugdunensis* is more virulent and the clinical manifestations are more similar to *S. aureus* than CoNS.

Since its first description in 1988 by Freney et al.,[6,11] *S. lugdunensis* has been acknowledged as an agent causing severe infections such as endocarditis,[14,15] soft tissue infections, peritonitis, breast and cerebral abscesses, vascular graft infections, septicemia,[4,12,13] and toxic shock syndrome.[16] It appears that fewer than 30 cases of PJI due to *S. lugdunensis* have been reported in the literature.

The objective of this study was to assess the differences between *S. lugdunensis* and two other *Staphylococcus* species – *S. aureus* and *S. epidermidis* – in terms of clinical symptoms, delay between surgery and infection, antibiotic susceptibility, and clinical outcomes of PJI.

## 2. Materials and methods

### 2.1. Study population

A retrospective and descriptive study was conducted from 2000 to 2014, including patients from three orthopaedic centres in the same area. Eighty-eight consecutive cases of monomicrobial staphylococcal PJI due to *S. lugdunensis* ($n = 28$), *S. aureus* ($n = 30$), and *S. epidermidis* ($n = 30$) were analyzed.

### 2.2. Patients and samples

Data and information collected included age, sex, medical history, localization of the infection, clinical signs, surgical type, antibiotic therapy, duration of treatment, outcome post treatment, and delay between surgery and bacterial identification. These data are summarized in Table 1.

All patients included in the study were suffering from a PJI. The diagnosis was based on multidisciplinary criteria and was assessed clinically, biologically, microbiologically, histopathologically, and radiologically.[17]

The diagnosis of PJI was established in the presence of one major criterion or two minor criteria: (1) the major criteria were at least two positive periprosthetic cultures with phenotypically identical organisms, or a sinus tract communicating with the joint; (2) minor criteria were a C-reactive protein (CRP) value >10 mg/l and a histological analysis of periprosthetic tissue confirming a septic process .[18]

The surgical technique was chosen by the orthopaedic surgeon in consultation with an infectious diseases specialist.[17] Irrigation and debridement was the technique used for early PJI with less than 1 month between prosthesis implantation and clinical symptoms of infection. One-stage surgery was considered for patients with a chronic PJI but with an adequate state of bone and tissues. A gentamicin bone cement (Palacos-Genta; Zimmer 1800 West Center Street Warsaw, Poland) was used whenever possible. A two-stage revision procedure was indicated for patients who were not candidates for irrigation and debridement or one-stage surgery. These patients presented a chronic PJI, with bone and soft tissue defects. This strategy was used for patients who could undergo at least two surgeries. A local spacer impregnated with gentamicin was used until the placement of a new prosthesis.

Patient outcomes were based on at least 1 year of follow-up. This consisted of a multidisciplinary consultation (with a surgeon

**Table 1**
Patient characteristics and clinical information for cases of *Staphylococcus lugdunensis* periprosthetic joint infection

| Patient | Sex | Age (years) | Medical history | Prosthesis site | Clinical signs | Surgery type |
|---|---|---|---|---|---|---|
| 1 | F | 49 | None | Knee | Pain | Irrigation and debridement |
| 2 | M | 79 | CVD | Knee | Pain | Irrigation and debridement |
| 3 | F | 75 | None | Hip | Pain | Irrigation and debridement |
| 4 | M | 87 | CVD | Knee | Fever, pain, SLI | One-stage surgery |
| 5 | F | 63 | None | Foot | Fever, pain, fistula | Irrigation and debridement |
| 6 | F | 68 | None | Shoulder | Fever, pain, SLI | Irrigation and debridement |
| 7 | M | 63 | None | Hip | Pain | Two-stage revision |
| 8 | F | 67 | CVD | Hip | Pain | Two-stage revision |
| 9 | M | 37 | None | Knee | Fever, pain | One-stage surgery |
| 10 | M | 55 | CVD | Knee | Fever, pain | Irrigation and debridement |
| 11 | F | 83 | None | Hip | Fever, pain, SLI | Irrigation and debridement |
| 12 | M | 40 | None | Knee | Fever, pain, SLI | Irrigation and debridement |
| 13 | F | 70 | None | Knee | Fever, SLI, pain | Two-stage revision |
| 14 | M | 70 | None | Knee | Fever, pain, SLI | Two-stage revision |
| 15 | M | 40 | None | Hip | Fever, pain, SLI | Irrigation and debridement |
| 16 | F | 82 | Diabetes mellitus | Hip | Fever, D, pain | Irrigation and debridement |
| 17 | M | 48 | Rheumatoid disease | Hip | SLI | Irrigation and debridement |
| 18 | F | 78 | None | Knee | Fistula | Two-stage revision |
| 19 | F | 66 | Cancer | Knee | Loosening | Two-stage revision |
| 20 | M | 64 | Cancer | Hip | Loosening | Two-stage revision |
| 21 | M | 66 | None | Knee | SLI, fever, pain | One-stage surgery |
| 22 | M | 41 | None | Hip | SLI, pain | Two-stage revision |
| 23 | F | 87 | None | Knee | Fistula | Two-stage revision |
| 24 | F | 71 | None | Knee | SLI, fever, pain | Two-stage revision |
| 25 | F | 61 | None | Knee | Fever, D, SLI | One-stage surgery |
| 26 | F | 78 | None | Knee | D | One-stage surgery |
| 27 | F | 84 | None | Knee | D | Two-stage revision |
| 28 | M | 71 | None | Hip | Fever, D, SLI | One-stage surgery |

F, female; M, male; CVD, cardiovascular disease; D, dehiscence; SLI, signs of local inflammation.

and an infectious diseases physician), including a clinical and radiological evaluation and a blood analysis for CRP. A favourable outcome was considered a good clinical recovery, satisfactory joint mobility, and no signs of inflammation.

Intraoperative bone tissue, synovial membranes, and articular fluid samples were obtained for the microbiological diagnosis. It was recommended that antibiotics be stopped 15 days prior to surgery in order to obtain growing bacteria in culture.

At least three intraoperative deep samples were collected per patient. After collection, the samples were transferred to the microbiology laboratory within less than 1 h.

### 2.3. Bacteriological culture

For each suspected site, hard and soft tissue specimens were collected in sterile glass vials. Articular fluid was inoculated into blood culture bottles. All samples were incubated under aerobic conditions with $CO_2$ and an anaerobic atmosphere for 15 days. Gram staining was performed for each sample on day 1.

Hard and soft tissue specimens were crushed and vortexed in 1 ml of saline solution for 10 min. Standard cultures were performed on Columbia blood agar, PolyViteX chocolate agar, and thioglycolate solution (Oxoid, Dardilly, France). Articular fluids were inoculated into blood culture bottles and onto solid agar media.

Media were observed daily for microbial growth. Bacteriological criteria for a positive diagnosis of infection were the following: at least one positive sample for *S. aureus*-positive cultures; at least two positive samples for *S. epidermidis*- and *S. lugdunensis*-positive cultures.

Only monomicrobial cultures with *S. aureus*, *S. lugdunensis*, and *S. epidermidis* were selected. Seven polymicrobial infections including *S. lugdunensis* were excluded. In these cases, the PJI involved bacteria of the cutaneous flora: CoNS, corynebacteria, or *Propionibacterium acnes*. The exclusion of polymicrobial infections was necessary to be certain of the bacterium that caused the PJI . Thus all clinical, biological, and treatment-related results were specifically connected to a single bacterial species: *S. aureus*, *S. lugdunensis*, or *S. epidermidis*.

In the case of a positive culture, identification was performed by automated technique (Vitek 2; bioMérieux, Marcy l'Etoile, France) or manual technique (API Staph; bioMérieux). When identification results were conflicting, complementary tests were performed to confirm the species identification: (1) *S. aureus*: positive latex agglutination; (2) *S. lugdunensis*: typical salty smell, positive pyrrolidonyl arylamidase (L-PYR) test; (3) *S. epidermidis*: colistin resistance detected by disk diffusion test.

Antimicrobial susceptibilities were tested by Vitek 2 (bioMérieux) according to the recommendations of the Committee on Antibiotic Susceptibility of the French Society of Microbiology.[19] Methicillin resistance was interpreted from the oxacillin minimum inhibitory concentration (MIC). Staphylococcus strains were considered susceptible when the MIC was between 0.5 and 2 μg/ml. Conflicting results for methicillin susceptibility were verified by cefoxitin disk (Bio-Rad, Marnes-la-Coquette, France).

### 2.4. Statistical analysis

Continuous variables are presented as the median and interquartile range, while categorical variables are presented as the count and proportion. For the univariate analysis, continuous data were compared among the three groups of patients according to the type of Staphylococcus by Kruskal–Wallis test. Qualitative variables were compared by Chi-square test (or Fisher's exact test when necessary). The statistical analysis was performed using Stata 11.2 software (StataCorp, College Station, TX, USA).

## 3. Results

### 3.1. Population study

Twenty-eight cases of *S. lugdunensis* PJI were recorded between 2000 and 2014 at the three orthopaedic centres in the same area. Clinical and surgical data for these *S. lugdunensis* PJI are detailed in Table 1.

Age, sex, prosthesis site, clinical and biological signs, and the types of surgery performed in the three groups are summarized in Table 2.

The populations of the three groups were comparable statistically for age ($p = 0.34$) and sex ($p = 0.196$).

With regard to *S. lugdunensis* patients, eight (29%) presented a comorbidity: four (14%) had cardiovascular disease, one (4%) had inflammatory rheumatism, one (4%) had diabetes mellitus, and two (7%) had a history of cancer. The median CRP value in this group was 42 mg/l.

Nine (30%) of the *S. aureus* patients had a comorbidity: five (17%) had cardiovascular disease, one (3%) had been treated for

**Table 2**
Comparison of populations with *Staphylococcus lugdunensis*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* periprosthetic joint infections[a]

| | *S. lugdunensis* (*n* = 28) | *S. aureus* (*n* = 30) | *S. epidermidis* (*n* = 30) | *p*-Value |
|---|---|---|---|---|
| Age (years) | 67.5 (58–78) | 60.5 (44–75) | 67 (61–77) | 0.34 |
| Number of males | 13 (46.4%) | 20 (66.7%) | 20 (66.7%) | 0.196 |
| Prosthesis site | | | | |
| Knee | 16 (57%) | 18 (60%) | 11 (36.7%) | 0.145 |
| Hip | 10 (36%) | 9 (30%) | 16 (53%) | 0.158 |
| Other | 2 (7%) | 3 (10%) | 3 (10%) | |
| Clinical signs | | | | |
| Fever | 15 (53.6%) | 9 (30%) | 4 (13.3%) | 0.004 |
| Local signs of inflammation | 13 (46.4%) | 7 (23.3%) | 4 (13.3%) | 0.015 |
| Surgery type | | | | |
| Irrigation and debridement | 11 (39.3%) | 10 (33.3%) | 5 (16.7%) | 0.144 |
| One-stage surgery | 6 (21.4%) | 12 (40%) | 16 (53.3%) | 0.044 |
| Two-stage revision | 11 (39.3%) | 8 (26.7%) | 9 (30%) | 0.568 |
| Delay from surgery to infection (weeks) | 12 (3–56) | 44 (12–144) | 84 (44–192) | 0.0449 |
| Samples | | | | |
| Number of positive samples | 3.5 (1.5–5) | 4 (3–5) | 4 (3–5) | 0.449 |
| Total number of samples | 5 (2–6) | 4 (3–5) | 5 (4–6) | 0.413 |
| Treatment duration (weeks) | 7 | 7 | 7 | |
| Outcome positive | 89% | 83% | 97% | 0.233 |

[a] Data are displayed as the median (interquartile range), or as the number (percentage).

cancer, one (3%) had inflammatory rheumatism, one (3%) had diabetes mellitus, and one (3%) had hepatitis C. Thirteen (43%) of the *S. epidermidis* patients presented a comorbidity: five (17%) had cardiovascular disease, one (3%) had been treated for cancer, and five (17%) had diabetes mellitus. CRP data were available for only a few of the patients with *S. aureus* and *S. epidermidis* PJIs and so are not presented.

### 3.2. Surgical intervention

The median delay between surgery and infection and the type of surgery performed in the three groups are presented in Table 2. For *S. lugdunensis* PJI, the median delay was statistically shorter than in the other groups ($p = 0.0449$).

### 3.3. Bacteriological results

Bacteriological results for the deep intraoperative samples in the three groups are presented in Table 2; no significant difference was found between the three groups regarding the number of positive samples ($p = 0.449$) or the total number of samples ($p = 0.413$).

*S. lugdunensis* culture results and antibiotic resistance profiles are detailed in Table 3. A comparison of antibiotic resistance is presented in Table 4. *S. lugdunensis* was significantly the most susceptible species regarding penicillin G, methicillin, fluoroquinolones, clindamycin ($p = 0.000$), and rifampicin (0.038). Antibiotic resistance profiles in the three groups are compared in Figure 1.

### 3.4. Medical therapy

All patients received an empiric intravenous antibiotic regimen with vancomycin or daptomycin following surgery. After approximately 1 week of parenteral antibiotics, oral relay therapy was implemented for a mean duration of 7 weeks in all three groups. The main oral medical treatments are presented in Table 4. Antibiotics prescribed in *S. lugdunensis* and *S. aureus* PJI were mostly fluoroquinolones associated with rifampicin. Because *S. epidermidis* strains were more resistant than *S. aureus* and *S. lugdunensis*, second-line antibiotics like linezolid were more often used. A comparison of the oral medical treatment in the three groups is shown in Figure 2.

### 3.5. Patient outcomes

The outcome was evaluated during a follow-up period starting at the end of treatment and continuing for at least 12 months for all

**Table 3**
Microbiological results and patient treatments and outcomes for cases of *Staphylococcus lugdunensis* periprosthetic joint infection

| Patient | Antibiotic resistance | Treatment | Duration (weeks) | Positive/total samples | Outcome |
|---|---|---|---|---|---|
| 1 | Penicillin, fosfomycin | Fluoroquinolone, rifampicin | 6 | 2/5 | Favourable |
| 2 | Penicillin | Fluoroquinolone, rifampicin | 6 | 5/5 | Favourable |
| 3 | Penicillin | Fluoroquinolone, rifampicin | 6 | 2/2 | Favourable |
| 4 | Penicillin, rifampicin | Fluoroquinolone, clindamycin | 6 | 4/4 | Favourable |
| 5 | Penicillin, MLS | Fluoroquinolone, rifampicin | 6 | 1/1 | Favourable |
| 6 | None | SXT, rifampicin | 6 | 4/5 | Favourable |
| 7 | Penicillin, fosfomycin | Linezolid | 3 | 2/6 | Favourable |
| 8 | Penicillin | Linezolid | 4 | 6/7 | Favourable |
| 9 | None | Fluoroquinolone, rifampicin | 6 | 2/2 | Favourable |
| 10 | Penicillin | Fluoroquinolone, rifampicin | 6 | 3/6 | Favourable |
| 11 | None | Fluoroquinolone, rifampicin | 6 | 2/2 | Favourable |
| 12 | Penicillin | Fluoroquinolone, clindamycin | 8 | 2/2 | Favourable |
| 13 | None | Fluoroquinolone, rifampicin | 6 | 5/5 | Unfavourable |
| 14 | Penicillin | Fluoroquinolone, rifampicin | 9 | 5/5 | Favourable |
| 15 | None | Fluoroquinolone, rifampicin | 8 | 5/5 | Favourable |
| 16 | Penicillin, MLS, fluoroquinolone, tetracycline | Fluoroquinolone, rifampicin | 10 | 5/5 | Unfavourable |
| 17 | Fosfomycin, MLS | Fluoroquinolone, rifampicin | 6 | 6/7 | Favourable |
| 18 | Fosfomycin | Oxacillin | 17 | 3/4 | Favourable |
| 19 | Fosfomycin | Oxacillin, FA | 65 | 3/5 | Favourable |
| 20 | Fosfomycin | Oxacillin | 4 | 4/5 | Favourable |
| 21 | None | AMC, rifampicin | 17 | 1/1 | Favourable |
| 22 | Fosfomycin | Fluoroquinolone, rifampicin | 16 | 2/2 | Favourable |
| 23 | Fosfomycin, fluoroquinolone | Clindamycin | 13 | 4/5 | Favourable |
| 24 | Penicillin | Fluoroquinolone, clindamycin | 16 | 2/2 | Favourable |
| 25 | None | Fluoroquinolone, rifampicin | 6 | 9/9 | Favourable |
| 26 | Penicillin, AF | Fluoroquinolone, rifampicin | 6 | 6/6 | Favourable |
| 27 | None | Fluoroquinolone, rifampicin | 8 | 6/6 | Unfavourable |
| 28 | Penicillin, fosfomycin | Fluoroquinolone, rifampicin | 8 | 2/7 | Favourable |

SXT, trimethoprim–sulfamethoxazole; AMC, amoxicillin+clavulanic acid; FA=AF, fusidic acid; MLS, macrolide-lincosamide-streptogramin B; None, no antibiotic resistance.

**Table 4**
Comparison of antibiotic resistance and treatment in the three groups

| | *Staphylococcus aureus* | *Staphylococcus epidermidis* | *Staphylococcus lugdunensis* | *p*-Value |
|---|---|---|---|---|
| Resistance to | | | | |
| Penicillin G | 22 (73.3%) | 30(100%) | 14 (50%) | 0.000 |
| Methicillin | 4 (13.3%) | 23 (76.7%) | 0 | 0.000 |
| FQ | 5 (16.7%) | 18 (60%) | 1 (6.6%) | 0.000 |
| RIF | 1 (3.3%) | 6 (20%) | 1 (3.6%) | 0.038 |
| Clindamycin | 8 (26.7%) | 19 (63.3%) | 3 (10.7%) | 0.000 |
| Treatment with | | | | |
| FQ + RIF | 25 (83.3%) | 12 (40%) | 17 (60.7%) | 0.003 |
| Linezolid | 2 (6.7%) | 12 (40%) | 2 (7.1%) | 0.001 |

FQ, fluoroquinolones; RIF, rifampicin.

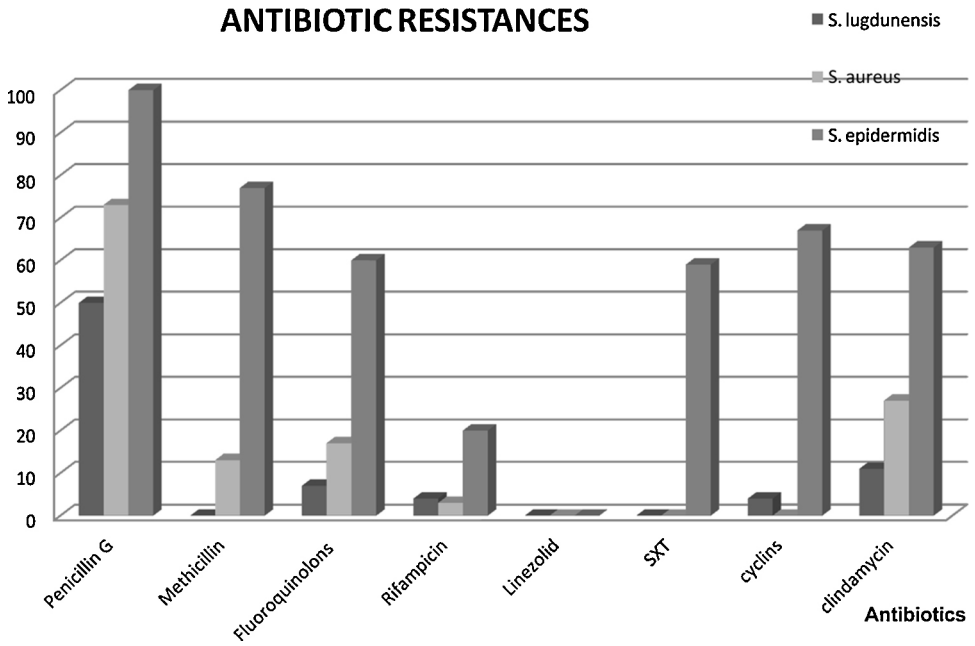


**Figure 1.** Antibiotic resistance of *Staphylococcus lugdunensis*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* strains.

patients. The outcome results are presented in Table 2 and were statistically comparable in the three groups ($p = 0.233$).

Nine unfavourable outcomes were reported in the total population. The overall success rate of the surgical technique applied, as defined by a lack of relapse, was 85% for irrigation and debridement, 97% for one-stage surgery, and 86% for two-stage revision.

## 4. Discussion

This study compared the clinical and bacteriological characteristics of 28 consecutive cases of *S. lugdunensis* PJI to those in PJI caused by other staphylococci.

*S. lugdunensis* colonization is described on the skin, especially in the inguinal and perineal areas.[5] This localization may play a role in the potential haematogenous or subcutaneous dissemination, which could lead to bone and joint infections. Several studies on *S. lugdunensis* bone and joint infections have reported osteomyelitis,[4,22] septic arthritis,[23] and PJI.[4,24] They have all described the invasive nature of these *S. lugdunensis* infections.

In this study, significantly more clinical symptoms such as pain, fever, and signs of local inflammation were observed in the *S. lugdunensis* and *S. aureus* series than in the *S. epidermidis* series. CRP at the time of diagnosis was not reported for all patients (especially for those with *S. epidermidis* PJI). Measurements were available for half of the patients with *S. lugdunensis* PJI and the mean value was 42 mg/l, which is much higher than the value usually reported for *S. epidermidis* PJI.[25]

The delay between surgery and infection was significantly shorter in *S. lugdunensis* and *S. aureus* PJI compared to *S. epidermidis* PJI. Others studies have also reported a short delay in *S. lugdunensis* PJI. This result confirms the similar clinical course of *S. lugdunensis* PJI and *S. aureus* infections.[23,26]

With regard to the type of surgical intervention, irrigation and debridement and two-stage revision were performed for *S. lugdunensis* and *S. aureus* PJI. In all other published studies, the most frequent type of surgery selected was two-stage revision with placement of an antibiotic spacer.[24,26,27] The treatment success rate for *S. lugdunensis* PJI was overall the same whatever the type of surgery. Three patients had an unfavourable outcome:

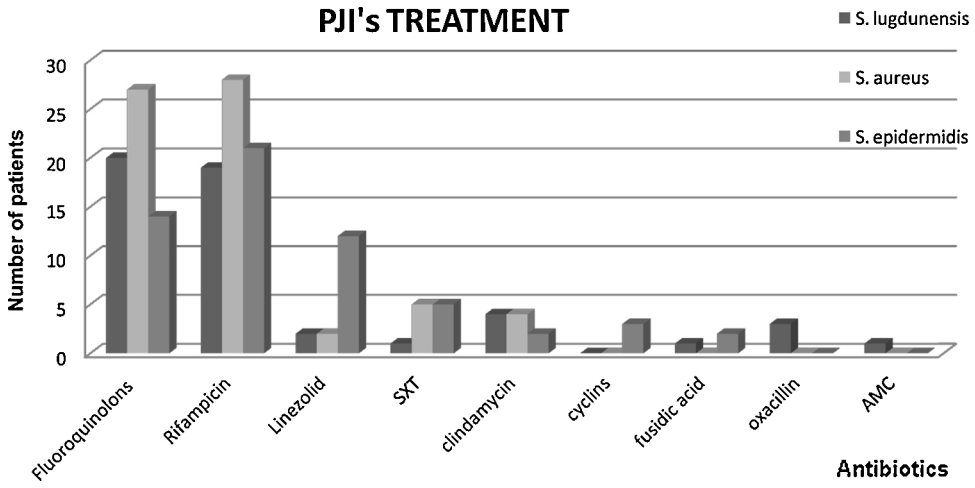


**Figure 2.** Antibiotic treatment of *Staphylococcus lugdunensis*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* periprosthetic joint infections.

one after irrigation and debridement and two after a two-stage revision.

In this study, *S. lugdunensis* was responsible for knee PJI more than hip PJI, as was *S. aureus*. In contrast, *S. epidermidis* was more involved in hip PJI. These data may confirm the suggestion of Shah et al., that *S. lugdunensis* could preferentially infect knees.[26]

Although *S. lugdunensis* shares many properties with *S. aureus*, one of the main differences between the two species is the antimicrobial susceptibility. It was found that *S. lugdunensis* strains were all susceptible to methicillin, and half were resistant to penicillin G. These results are different to those of some previous studies, especially for penicillin G resistance.[4,11,26] They seem to indicate that the parenteral β-lactam adopted to treat an *S. lugdunensis* PJI should be an anti-staphylococcal β-lactam agent.

As in previous studies, a high rate of susceptibility (90–100%) to quinolones, rifampicin, and clindamycin was found.[22,23,26,27] No strain was resistant to linezolid or trimethoprim–sulfamethoxazole (SXT). *S. aureus* strains were quite susceptible to methicillin (87%), but it was found that 17% of strains were resistant to quinolones and 27% to clindamycin. In comparison, 77% of *S. epidermidis* strains were resistant to methicillin, 60% to quinolones, and 20% to rifampicin, the first-line antibiotics for the treatment of PJI. Thus *S. aureus* and *S. lugdunensis* strains in this study were much more susceptible than *S. epidermidis* strains, as reported in other publications on staphylococcal bone and joint infections.[28]

The treatment of *S. lugdunensis* PJI was a combination of fluoroquinolone + rifampicin for 61% of the patients. This is the reference treatment for methicillin-susceptible CoNS PJI recommended in French and international guidelines.[17,29] This combination was also chosen as the first-line treatment for *S. aureus* PJI, but only for 40% of patients with an *S. epidermidis* PJI. More second-line antibiotics, such as linezolid, SXT, cyclins, clindamycin, and fusidic acid, were used for the treatment of *S. epidermidis* PJI, due to the resistance of *S. epidermidis*.

The duration of treatment was on average 7 weeks in the three groups. It appears that the good outcomes achieved in these patients were more a result of early surgery (at <1 month) associated with an adapted antibiotic combination than the duration of treatment. Previous studies have reported a mean duration of treatment of 4 to 8 weeks.[22–24]

Moreover 97% of patients with an *S. epidermidis* PJI had a favourable outcome, compared to 89% of patients with an *S. lugdunensis* PJI and 83% of patients with an *S. aureus* PJI ($p = 0.233$). These results were not significant in this population, but they nevertheless suggest the high pathogenicity of *S. lugdunensis*.

The total number of *S. lugdunensis* PJI cases collected in this study was only 28; this may not be statistically sufficient to confirm all of the observations. The present results warrant confirmation in prospective studies conducted on a larger number of *S. lugdunensis* PJI samples.

To conclude, *S. lugdunensis* is classified as a CoNS, but the clinical features of *S. lugdunensis* PJI, the early aspect of the infection, and the relapses observed are similar to those in *S. aureus* PJI. Regarding the microbiological diagnosis, the species of CoNS in PJI must be identified precisely and treatment adapted to the antibiotic susceptibility, even if only one deep sample is positive in culture.

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