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ORIGINAL ARTICLE

Monomicrobial bone and joint infection due to *Corynebacterium striatum:* literature review and amoxicillin-rifampin combination as treatment perspective

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Abstract

Corynebacterium striatum is a ubiquitous colonizer of human skin and mucous membranes. It is increasingly involved in infections, especially with prosthetic devices or in immunocompromised individuals. Microbiological diagnosis is challenging and bacterial resistance is a major concern. We performed a retrospective study of monomicrobial bone and joint infections (BJI) due to *C. striatum* in two referral centers from April 2012 to July 2017. We collected the patients' clinical and microbiological characteristics and outcomes. We also performed a literature review of BJI due to *C. striatum.* We identified 12 cases (nine prosthetic joint infections, one osteosynthetic device infection, one non-union, and one arthritis) in 11 patients, five of which were immunocompromised. Microbiological diagnosis was performed with prolonged culture media. Ten out of 12 strains were susceptible to aminopenicillin, a drug class not recommended for testing by the EUCAST/CASFM guidelines, and 8/12 patients were treated with amoxicillin-rifampicin. The cure rate was 8/12, after a median follow-up period of 487.5 days (IQR 140.3–1348.5). Twelve cases of BJI due to *C. striatum* were previously reported. Among them, 5/12 patients were immunocompromised, 3/12 cases were acute BJI, and 2/12 were device-related infections. The diagnosis was performed by PCR in one case, and 10/12 patients were treated with glycolipopeptides, with a cure rate of 11/12. We report the largest cohort of monomicrobial BJI with *C. striatum*. Determination of aminopenicillin susceptibility is essential since it is frequently active in our experience, even in BJI. The cure rate of this infection seems high.

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Keywords Corynebacterium striatum · Bone and joint infection · Prosthesis joint infection · Multidrug-resistant organism · Opportunistic infection

Introduction

Corynebacterium spp. are Gram-positive club-shaped rods, best known for the etiologic implication of *Corynebacterium diphtheriae* in diphtheria. They are commensals of the skin and mucous membranes of humans [1], often considered contaminants when isolated in culture [2, 3]. Their potential pathogenicity was commonly ignored. They have recently emerged as opportunistic human pathogens responsible for several infectious diseases, including respiratory tract infections, urinary tract infections, endocarditis, and bone and joint infections (BJI) [1, 4]. They are now a well-known cause of infection in immunocompromised patients and device-related infections [3, 5, 6].

Corynebacterium striatum, initially described in 1901 as *Bacterium striatum*, has been associated with infective endocarditis, pulmonary infections, and BJI [6–9]. However, monomicrobial BJI and prosthetic joint infections (PJI) due to *C. striatum* are poorly described in the literature [6, 10, 11]. This may be due to a challenging species level identification prior to matrix-assisted laser desorption ionization-time of flight (MALDI-TOF) mass spectrometry identification [1, 12].

The treatment usually relies on a medico-surgical strategy, with no consensus on treatment regimen or duration. Indeed, only reports of the prolonged use of intravenous agents such as glycopeptides can be found, since *C. striatum* appears to be resistant to most of the EUCAST recommended agents for susceptibility testing [13, 14].

In this study, we present a cohort of monomicrobial BJIs due to *C. striatum* and a review of the literature.

Material and methods

Study design and case definitions

We performed a retrospective cohort studying monomicrobial BJI due to *C. striatum* in a bicentric referral center for BJI from April 2012 to July 2017.

The microbiological significance criteria for all types of infection were extrapolated from the definition of PJI with commensal microorganisms, requiring the growth of a microorganism with identical species level identification and susceptibility testing from two intraoperative samples. Monomicrobial cases featured a single significant microorganism from the surgical procedure considered.

We extracted from the microbiology laboratory database all intraoperative samples positive with *C. striatum* and included monomicrobial infections for the study.

Demographics, clinical, biological, and microbiological data, and BJI outcome were collected through a standard dataset from the patients' medical charts. BJI were classified as early (≤ 1 month) and delayed (≥ 1 month), according to the time of symptoms onset. Cure was defined as the absence of the recurrence of symptoms and/or absence of additional antibiotic therapy or surgical treatment at last follow-up. No patient included in the study expressed opposition to the use of clinical data in retrospective studies.

Bacteriological methods

Intraoperative samples obtained from suspected BJI were processed independently as previously described [15]. Briefly, samples were topped with 17 mL sterile distilled water and bead milled for 150 s on a Retsch MM400 mixer mill (Verder, France) with 10 to 15 5-mm-diameter stainless steel beads. One hundred microliters of the resulting suspension was plated on 5% sheep blood Columbia agar and chocolate agar and incubated for 5 days at 35 °C under aerobic, anaerobic, and 5% CO_2-enriched atmospheres. Enrichment was performed in blood culture vials in 34 samples and in Schaedler's broth in 27 samples.

All isolates were identified by mass spectrometry (Biotyper on a Microflex LT mass spectrometer, Bruker Daltonics, Bremen, Germany) and their antimicrobial susceptibility tested by disk diffusion. Confirmation of the minimal inhibitory concentration (MIC) was performed by ellipsometry or broth microdilution (Etest, BioMérieux, Marcy l'Etoile, France or UMIC, Biocentric, Bandol, France) on available isolates and reinterpreted according to the EUCAST 2018 guidelines [16].

Literature review

Secondarily, we performed a literature review of all articles on *C. striatum* BJI, from 1975 to 2018.

We searched the Medline/PubMed and Web of Science databases with the following keywords: "*Corynebacterium striatum,*" "*Corynebacterium striatum* bone and joint infection," "*Corynebacterium striatum* prosthesis infection." Articles on experimental models, in vitro data, and articles without management and outcome data were excluded from the review (see PRISMA flow diagram in Fig. 1).

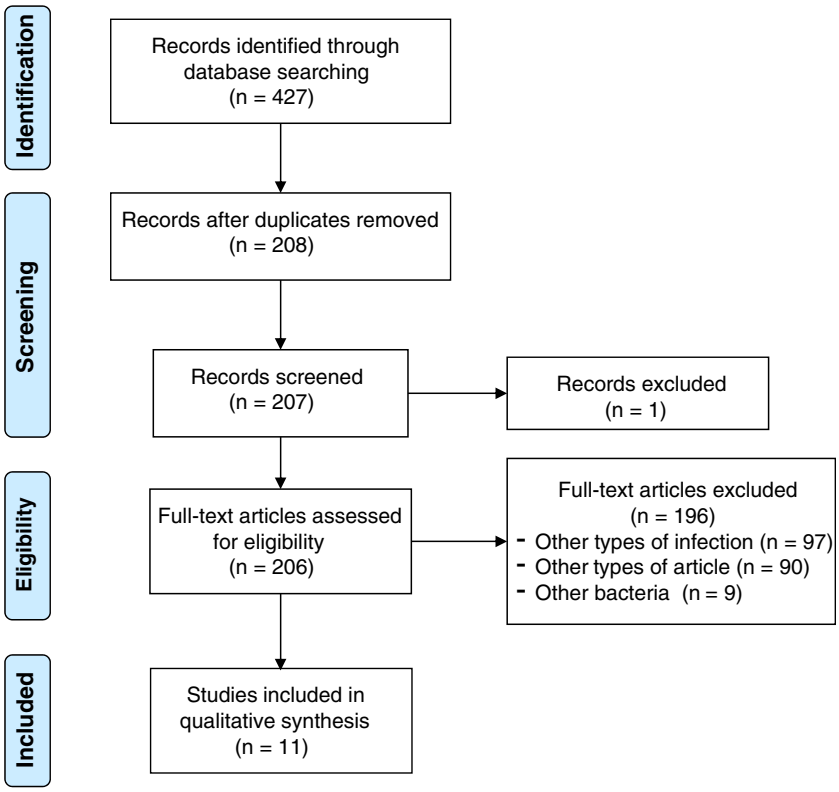

Fig. 1 PRISMA flow diagram

Statistical analysis

Survival analysis for medium positivity was analyzed using the Mantel-Cox Test. Continuous variables were analyzed using Student's t test, and categorical variables were analyzed by Fischer's exact test. *P* values were considered significant when < 0.05.

Results

Patient characteristics are reported in Table 1. Overall, we included 12 episodes among 11 patients. Mean age was 63.5 ± 17.2 years (median 67.0; IQR 55.0–71.8), and sex ratio (M/F) was 0.5; 5/11 patients were immunocompromised. Finally, 9/12 procedures were revision arthroplasties and 6/12 cases were recurring infections. Infection onset was early in 5/12 cases and delayed in 7/12 cases, with a median delay of 152.5 days (IQR 15.3–604.5). Half of all BJI occurred within 3 months of the last surgery. Locations were on the knee ($n = 5$), hip ($n = 4$), shoulder ($n = 1$), tibia ($n = 1$), and foot ($n = 1$).

Chief complaints were pain (5/12), functional impotence (5/12), sinus tracts (5/12), and fever (3/12). C-reactive protein level was elevated (67.8 ± 74.6 mg/L) and leukocyte count was normal (6.7 ± 2.3 G/L).

Growth characteristics

Sixty-one intraoperative samples from 12 surgeries were processed (mean 5.1 ± 0.7 samples per surgery). Growth on solid media was observed in 42.6% of samples, with visible colonies after 24 h for 3 samples, 48 h for 21 samples, and greater than 48 h in 2 samples. In contrast, broth positivity was detected in 28 h (13–168 h) in 29/34 (85.3%) of Ped + vials and in 109 h (21–236 h) in 26/34 (76.4%) of anaerobic lytic media. Also, Schaedler's broth only yielded positivity in 13/27 (48.1%) cases in 77 h (48–120 h), despite systematic subculture after 14 days of incubation (Fig. 2). In 1/61 sample, blood agar culture was positive and enrichment on Schaedler's broth was sterile. In this case, diagnosis was achieved with one agar positive-broth negative sample and one agar negative-broth positive sample. Conversely, the diagnosis of *C. striatum* BJI was obtained solely with broth culture in 3/12 cases.

Only two patients had pre-operative joint aspiration. Synovial fluid analysis showed elevated leukocyte counts. Culture was positive with *C. striatum* in both cases.

Disk diffusion susceptibility testing was performed for the 12 isolates, and MICs were determined on nine available biobanked strains (Table 2). Strains were commonly susceptible to amoxicillin, rifampin, linezolid, daptomycin, and vancomycin, while they were usually resistant to fluoroquinolones, macrolides, lincosamides, cyclins, penicillin G, and cephalosporins.

Table 1 Characteristics and outcome of monomicrobial bone and joint infections due to *Corynebacterium striatum* ($n = 12$)

#	Year	Sex, age	Comorbidities	ID	Number of previous surgeries	Symptoms	Fever	Delay	Site
1	2012	F, 67	Valvular heart disease (two mechanical valves), atrial fibrillation, COPD	No	3	Pain and sinus tract with abundant purulent discharge	No	Delayed	Femur
2	2012	F, 65	HIV, chronic hepatitis C, deep vein thrombosis treated with long-term anticoagulant therapy	Yes	3	Pain and functional impotence	No	Delayed	Knee
3	2012	F, 70	None	No	2	Pain and fever	Yes	Delayed	Knee
4	2013	F, 57	None (penicillin allergy)	No	1	Sinus tract	No	Delayed	Foot
5	2013	M, 49	Hypothyroidism, gastroesophageal reflux	No	4	Functional impotence and delayed wound healing with purulent discharge	No	Early	Knee
2	2014	F, 67	HIV, chronic hepatitis C, deep vein thrombosis treated with long-term anticoagulant therapy	Yes	4	Pain and functional impotence	No	Delayed	Knee
6	2014	F, 70	Myelodysplastic syndrome	No	5	Functional impotence and sinus tract	No	Delayed	Shoulder
7	2014	M, 24	Sickle cell anemia, heterotopic ossifications	Yes	5	Pain, fever, functional impotence, sinus tract	Yes	Early	Hip
8	2014	F, 77	Diabetes	Yes	2	Sinus tract	No	Early	Hip
9	2016	M, 87	COPD, diabetes	Yes	1	Delayed wound healing	No	Early	Hip
10	2016	M, 82	Hypertension, peripheral vascular disease, chronic renal failure, chronic anemia, ulcer	Yes	2	Prosthesis loosening	No	Delayed	Knee
11	2017	F, 47	Multiple sclerosis, deep vein thrombosis	No	1	Fever, abscess, and delayed wound healing	Yes	Early	Hip

#	Device	AMX susceptibility (MIC (mg/L))	RIF susceptibility (MIC (mg/L))	Antibiotic treatment	Treatment duration	Surgical treatment	Outcome
1	Osteosynthesis equipment (pins)	S	S	1) AMC-CIP 2) AMX-RIF	50 days	Prosthesis removal	Failure (amputation)
2	Prosthesis	S (0.38)	S (0.002)	1) AMX-RIF	6 weeks	Lavage and debridement	Failure (recurrence)
3	Prosthesis	S	S	1) VAN-GEN 2) DAP-RIF	7 weeks	Single-stage change of prosthesis	Cure
4	None	S (0.5)	S (0.023)	None	Not applicable	Prosthesis removal	Cure
5	Osteosynthesis equipment (plate)	S (1.5)	S (< 0.002)	1) TZP-VAN 2) AMX-RIF	5 weeks	Lavage and debridement	Cure
2	Prosthesis	S (0.38)	S (0.002)	1) TZP-DAP 2) AMX-RIF	5 weeks	Lavage and debridement	Cure
6	Prosthesis	S (1)	S (0.002)	1) TZP-DAP 2) AMX-RIF	6 weeks	Prosthesis removal	Cure
7	Prosthesis	S (0.5)	S (< 0.002)	1) TZP-VAN 2) AMX-RIF	6 weeks	Single-stage change of prosthesis	Cure
8	Prosthesis	S (1)	R (> 32)	1) TZP-DAP 2) AMC- AMX-OFL	5 weeks	Single-stage change of prosthesis	Cure

Table 1 (continued)

#	Device	AMX susceptibility (MIC (mg/L))	RIF susceptibility (MIC (mg/L))	Antibiotic treatment	Treatment duration	Surgical treatment	Outcome
9	Prosthesis	S (1)	S	1) TZP-DAP 2) AMX-RIF	5 weeks	Single-stage change of prosthesis	Failure (recurrence and death)
10	Prosthesis	S (0.5)	S (< 0.002)	1) TZP-DAP 2) AMX-RIF	2.5 months	Single-stage change of prosthesis	Failure (superinfection)
11	None	I (3)	R (> 32)	1) TZP-VAN 2) DAP	1 month	Lavage and debridement	Cure

F, female; *M*, male; *ID*: immunodepression; *AMC*, amoxicillin-clavulanate; *AMX*, amoxicillin; CIP, Ciprofloxacin; *DAP*, daptomycin; *GEN*: gentamicin; *OFL*, ofloxacin; *RIF*: rifampicin; *TZP*, piperacillin-tazobactam; *VAN*, vancomycin; *MIC*, minimal inhibitory concentration; *S*, susceptible; *I*, intermediate; *R*, resistant

Treatment

Surgical management consisted in single-stage exchange arthroplasty (5/12 cases), implant removal alone (3/12), and debridement, antibiotics, and implant retention (DAIR) (4/12).

The median duration of the antimicrobial regimen was 40.0 days (IQR 36.0–47.5), for a target duration of 6 weeks. A combination therapy was performed in 10/12 cases, with 8/12 cases of amoxicillin-rifampicin combination (8/12). Alternate regimen were chosen due to bacterial resistance in three cases (two with glycolipopeptides and one with fluoroquinolones), and one patient was not treated with antibiotics.

Cure was observed in 8/12 cases (single-stage exchange arthroplasty, 3/5; implant removal, 2/3; and DAIR, 3/4) with a median follow-up of 487.5 days (IQR 140.3–1348.5).

Failure occurred in four patients: three patients had PJI and one patient had osteosynthesis device infection. Failure was characterized by one amputation, one superinfection (due to methicillin-susceptible *Staphylococcus aureus*), one with additional surgical treatment (recurrence due to *C. striatum*), and one death due to BJI.

Literature review

The literature review is presented in Table 3. Overall, we included 12 case reports of monomicrobial *C. striatum* BJI [9, 13, 14, 17–24]. Mean patient age was 69.1 ± 21.3 years (median 78.5; IQR 59.8–84.0), with a sex ratio of 1.0; 5/12 patients were reported to be immunocompromised.

It was the first BJI occurrence for 8/12 patients, 4/12 following trauma. Two out of 12 PJIs were reported with delayed onset. The reported locations were on the knee ($n = 5$), shoulder ($n = 3$), elbow ($n = 1$), spine ($n = 1$), ankle ($n = 1$), and foot ($n = 1$).

The main clinical signs were pain (11/12), functional impotence (4/12), fever (4/12), and delayed wound healing (1/12).

Surgical management consisted in debridement (8/12) and amputation (1/12); three patients did not receive any surgical treatment.

Glycopeptides were the chosen treatment for all cases except for two. Cure was observed in 11/12 cases.

Pooling our data with case reports in literature, the total cohort shows the following characteristics:

Mean age was 66.3 ± 19.2 years (median 69.5; IQR 58.5–80.5) and sex ratio (M/F) was 0.7; 11/23 patients were immunocompromised. Infections occurred on orthopedic devices in 12/24 cases.

Overall, nine cases were early BJI, and seven patients were febrile.

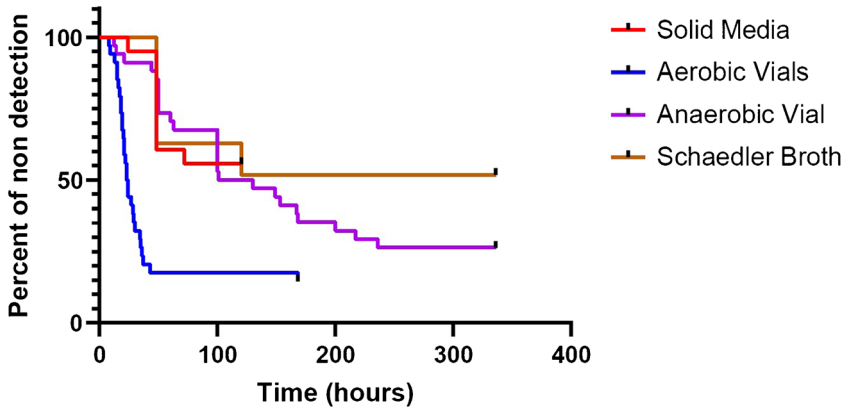

Fig. 2 Delay of *Corynebacterium striatum* detection depending on types of culture

Microbiological identification was obtained by culture in 22/24 cases and by PCR in 2/24.

Cure was achieved in 19/24 cases (79.2%).

Discussion

Clinical presentation

C. striatum BJI can occur in immunocompromised and immunocompetent patients with various clinical presentations. Patients present with acute infections regardless of their immune status [11]. Indeed, five patients, including two immunocompetent patients, had an early infection with clinical signs of acute infection (fever for two cases, sinus tract or wound healing in all five patients). This observation, in line with previous reports, highlights the pathogenic potential of *C. striatum* [9, 11, 20].

Seven and ten patients presented with chronic infections and orthopedic device-related infections (ODRI), respectively. Our twelve-case series is the largest number of monomicrobial ODRI due to *C. striatum* in the literature search we performed and includes a large number of ODRIs, the majority of which were PJIs. In contrast, only 2/12 literature-reported cases are PJIs, which might account for some difference in outcomes and is most likely due to the intraoperative recruitment of the cases we included. According to Ferry et al., *Corynebacterium* BJI is frequently chronic and polymicrobial [25]. Conversely, the monomicrobial nature of the cases described leaves no doubt regarding the pathogenicity of *C. striatum* in this context.

Table 2 Susceptibility of 9 *Corynebacterium striatum* clinical isolates to 15 antimicrobial agents. Isolates were classified as resistant according to criteria defined by EUCAST 2016

Antimicrobial agent	MIC breakpoint		Range (mg/L)	Resistant total (%)
	S ≤	R >		
Penicillin	0.12	0.12	0.19–1.5	9 (100)
Amoxicillin	2*	8*	0.38–3	1 (11.1)
Cefotaxime	1*	2*	1 ≥ 32	5 (55.5)
Ceftaroline	0.5*	0.5*	0.125–0.38	0
Piperacillin-tazobactam	4*	16*	4–64	6 (66.6)
Ciprofloxacin	1	1	0.125 ≥ 32	7 (77.7)
Levofloxacin	0.5*	1*	0.25 ≥ 32	7 (77.7)
Moxifloxacin	0.5	0.5	0.094 ≥ 32	7 (77.7)
Clindamycin	0.5	0.5	1.125 ≥ 256	9 (100)
Daptomycin	NA	NA	0.047–0.064	0
Linezolid	2	2	0.125–0.25	0
Tedizolid	NA	NA	0.125–0.75	0
Tigecycline	0.25*	0.25*	0.016– 0.032	0
Rifampicin	0.06	0.5	< 0.002–≥ 32	2 (22.2)
Vancomycin	2	2	0.25–0.25	0

NA: not available; *MIC*: minimum inhibitory concentration

*Non-species related

Microbiological diagnosis

BJI due to *C. striatum* are still rare, but exist and could be misdiagnosed, so it needs to be further studied. The microbiological diagnosis of BJI is challenging and needs liquid media and prolonged cultures. According to our results, liquid media leads to positive diagnosis in 91.6% of cases (11 cases; for the remaining case, the liquid culture was positive only in one sample) and was the unique positive culture medium in 25% (3/12) of cases. These results showed that the association of solid culture media with prolonged incubation and liquid media with a significant superiority of aerobic blood culture vial is a requisite to guarantee an optimal diagnosis of *C. striatum* BJI.

Corynebacterium species have not received a great deal of attention so far, probably because their identification long relied on morphological observation of the Gram stain. The genus was redefined with the advent of 16S rRNA or rpoB sequence-based identification schemes, but the technique was too cumbersome to be used routinely in clinical microbiology laboratories. The advent of matrix-assisted laser desorption ionization-time of flight mass spectrometry (MALDI-TOF MS) for the routine diagnosis of bacterial infections in clinical laboratories has improved and

Table 3 Cases of monomicrobial bone and joint infections due to *Corynebacterium striatum* in literature

Article	Year	Sex, age	Comorbidities / Risk factors	ID	Number of previous surgeries	Symptoms	Febrile	Delay	Site
Cone et al. [17]	1998	M, 51	Laceration on left arm with scalpel blade (during surgery) 3 days before	No	0	Pain, swelling, and erythema + chills and fever	Yes	Early	Elbow
Fernandez-Ayala et al. [18]	2001	M, 60	Myocardial infarction, infrainguinal vascular graft 5 years earlier, minor low back trauma 3 weeks before	No	0	Fever and lumbar back pain	Yes	Early	Spine
Scholle [9]	2007	M, 87	Osteoarthritis, advanced heart failure, institutionalization, chronic ulcers, fall 4 days earlier	No	0	Pain, fever, effusion around the left knee, tenderness, inability to bear weight	No	Early	Knee
Boltin et al. [14]	2009	F, 80	Myasthenia gravis, remitting seronegative symmetric arthritis with pitting edema (RS3PE), managed with low-dose steroids	Yes	0	Weight loss, malaise, fever, and pain	Yes	Hematogenous	Shoulder
		F, 80	None	No	2	Pain and swelling	No	Hematogenous	Knee
Feced Olmos et al. [19]	2013	F, 59	Hypercholesterolemia, infiltration with steroids treatment 4 days before admission	No	0	Pain, tumefaction, low-grade fever, and functional impotence	No	Hematogenous	Shoulder
Westblade et al. [20]	2014	M, 84	Diabetes, coronary artery disease, hypertension, deep vein thrombosis, and anticoagulant use, fall a week prior to admission	Yes	0	Pain, swelling, and fever with chills	Yes	Early	Knee
Verma et al. [21]	2016	F, 69	Severe rheumatoid arthritis, necrotizing pneumonia with bilateral pleural effusions 3 months prior, treated with 7 weeks of AAC	Yes	0	Ulceration of second right toe, and clinical signs of recurrence of pneumonia	No	Hematogenous	Foot
Beltrán-Arroyave et al. [22]	2016	F, 13	None	No	2	Inflammation and delayed wound healing with purulent discharge	No	Delayed	Ankle
Roy et al. [13]	2016	M, 77	Bilateral lung transplant in 2001, on immunosuppressive therapy, and hemodialysis-dependent end-stage renal disease	Yes	0	Pain, edema, and functional impotence	No	Hematogenous	Shoulder
Molina Collada et al. [23]	2017	M, 84	COPD, atrial fibrillation, left nephrectomy	Yes	1	Low-grade fever, inflammation, and functional impotence	No	Delayed	Knee
Fernández-Esgueva et al. [24]	2018	F, 85	Hypertension, atrial fibrillation, asthma, breast cancer treated in 1998	No	2	Pain, inflammation, and functional impotence	No	Hematogenous	Knee

Article	Device	Type infection	Sample type	Identification	Antibiotic treatment	Treatment duration	Surgical treatment	Outcome
Cone et al. [17]	None	Septic arthritis	Synovial fluid	Culture (API-Coryne)	1) VAN-ATM 2) VAN 3) CIP	17 days	Incision and drainage	Cure
	None	Vertebral osteomyelitis	Blood	Culture	1) CIP	8 weeks	No	Cure

Table 3 (continued)

Article	Device	Type infection	Sample type	Identification	Antibiotic treatment	Treatment duration	Surgical treatment	Outcome
Fernandez-Ayala et al. [18]					2) AMP-CLI 3) AMP			
Scholle [9]	None	Septic arthritis	Synovial fluid	Culture + 16S rRNA	VAN	2 weeks	Drainage and bacitracin treatment	Cure
Boltin et al. [14]	None	Septic arthritis	Synovial fluid + blood	Culture	VAN	Unknown	No (Aspiration)	Death (septic complications)
	Prosthesis	Septic arthritis	Synovial fluid	Culture	VAN	2 months	No (Aspiration)	Cure
Feced Olmos et al. [19]	None	Septic arthritis	Synovial fluid	Culture	1) CRO-CXA 2) CRO	4 weeks	No	Cure
Westblade et al. [20]	None	Septic arthritis	Synovial fluid	Culture + molecular identification (MALDI-TOF)	1) VAN-FEP 2) VAN	4 weeks	Arthrocentesis + arthroscopic lavage	Cure
Verma et al. [21]	None	Osteomyelitis	Bone culture (+ pleural fluid)	Culture	1) LVX 2) IPM 3) VAN	at least 1 month	Amputation	Cure
Beltrán-Arroyave et al. [22]	None	Osteomyelitis	Pre-operative samples	Culture + MALDI-TOF	1) CFZ 2) CLI 3) VAN 4) LZD	Unknown	Debridement	Cure
Roy et al. [13]	None	Septic arthritis	Synovial fluid + pre-operative samples	Culture	1) VAN-CRO 2) VAN	4 months	Debridement + acromyoplasty, then interposition graft placement	Cure
Molina Collada et al. [23]	None	Septic arthritis	Pre-operative samples	NA	1) LZD 2) TEC 3) DAL	Unknown	Lavage	Cure
Fernández-Esgueva et al. [24]	Prosthesis	Prosthetic joint infection	Synovial fluid + Per-operative samples	Culture + MALDI-TOF	1) VAN-CAZ 2) LZD	14 days, then 9 days following surgery	Change of knee prosthesis	Cure

F, female; *M*, male; *ID*, immunodepression; *AMC*, amoxicillin-clavulanate; *AMP*, ampicillin; *AMX*, amoxicillin; *ATM*, aztreonam; *CAZ*, ceftazidime; *CFZ*, cefazolin; *CLI*, clindamycin; *CIP*, ciprofloxacin; *CRO*, ceftriaxone; *CXA*, cloxacillin; *DAL*, dalbavancin; *DAP*, daptomycin; *FEP*: cefepime; *GEN*, gentamicin; *IPM*, imipenem; *LVX*, levofloxacin; *LZD*, linezolid; *OFL*, ofloxacin; *RIF*, rifampicin; *TEC*, teicoplanin; *TZP*, piperacillin-tazobactam; *VAN*, vancomycin

facilitated the identification of *Corynebacterium* species [12, 26]. All *Corynebacterium striatum* in our case series were reliably identified using the CE-IVD Biotyper system (Bruker Daltonics, Bremen, Germany) with unambiguous scores that never required sequence-based identification [4]. It is noteworthy that when we reviewed the monomicrobial *Corynebacterium* infection cases diagnoses over a decade in our complex BJI reference center, *C. striatum* was almost exclusively the species identified.

Bacterial resistance

C. striatum BJI should be treated according to the results of the susceptibility testing. Antimicrobial susceptibility testing of *Corynebacterium* species should be performed when the isolate is considered clinically relevant, as antimicrobial susceptibility is not predictable on the basis of genus- and species-level identification [1]. However, definition of susceptibility to antibiotics used to be difficult as few breakpoints were available for corynebacteria prior to the publication of the 2010 CLSI guidelines [27]. Yet, according to the EUCAST guidelines of 2018, clinical breakpoints only account for benzylpenicillin, ciprofloxacin, moxifloxacin, gentamicin, vancomycin, clindamycin, tetracyclin, linezolid, and rifampicin [16]. None of the commonly used β-lactams and oral agents are to be tested, and no genus specific breakpoints exist. All isolates tested were resistant to benzylpenicillin; only three were susceptible to cefotaxime and piperacillin-tazobactam, but all but one were susceptible to amoxicillin and ceftaroline. Isolates were always found susceptible to oxazolidinones, glycopeptides, and lipopeptides, while in 10/12 cases, isolates were susceptible to rifampin. Most isolates were found to be resistant to all fluoroquinolones, clindamycin, and cotrimoxazole. Failed treatment of *Corynebacterium* BJI is often blamed on their multidrug resistance, and vancomycin is the drug of choice in the literature [9, 13, 20], with a reported susceptibility solely to vancomycin, daptomycin, and linezolid [1, 28, 29]. Our study is the first one to report the general susceptibility of *C. striatum* to amoxicillin and its use in the treatment of *C. striatum* BJI, in combination with rifampin. More recent drugs such as tedizolid or dalbavancin have also demonstrated their activity against *Corynebacterium* species and are new options for the treatment of *C. striatum* BJI [30, 31]. However, the emergence of drug resistance of *C. striatum* to daptomycin appears to be of concern [32–34]. In defiance of the antimicrobial escalation broadly reported, our therapeutic scheme relying on an amoxicillin-rifampin combination for all strains testing susceptible provided us with satisfactory cure rates considering the risk factors of the population.

Conclusion

Corynebacterium striatum is a common colonizer of human skin and mucous membranes. It should be considered an emerging pathogen with a significant tropism for bone and joints both in the presence or absence of implanted hardware. The identification of *Corynebacterium* species isolates recovered from multiple prolonged cultures to the species level and an antimicrobial susceptibility testing extended to amoxicillin and rifampin should allow the ambulatory care of the patients under oral therapy, sparing the complications of prolonged intravenous access devices and the complications of vancomycin therapy.

Data availability Data will be made available on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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