High rate of late revision with multiple *Cutibacterium acnes* tissue isolates in paediatric spinal deformity suggesting implant associated infection.

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Background: Scoliosis surgery is increasing worldwide, with adolescent idiopathic scoliosis (AIS) accounting for ~60% and neuromuscular scoliosis (NMS) for ~30% of paediatric deformity procedures. Postoperative implant related infection remains a serious complication, causing substantial morbidity, reoperations, and healthcare costs. Reported rates range from 1.0–2.6% in AIS and 9.2–14.0% in NMS. In a recent cohort from our institution, 13.6% of deformity surgery patients required reoperation for infection, and *Cutibacterium acnes* was identified in 50% of cases. Although *C. acnes* is increasingly recognized as a cause of postoperative spinal implant infection (PSII), contemporary data on microbiology, treatment outcomes, and long-term implant survival in paediatric scoliosis patients are limited.

Aim: To describe frequency, microbiology, management and outcomes of PSII in instrumented scoliosis surgery, with focus on *C. acnes* infections.

Methods and patients: Single-centre retrospective cohort study conducted at a Swedish university hospital. All patients aged 10–18 years with AIS or NMS undergoing primary instrumented spinal fusion between 2015 and 2021 were included (**Figure 1**). Minimum follow-up was 2 years. Patient characteristics, surgical variables, antibiotic prophylaxis, microbiology, and outcomes were collected from medical records. PSII was defined using modified EBJIS criteria (**Table 1**). Chi-square and Mann-Whitney U tests were used for group comparisons, and Cox proportional hazards regression in time-to-event analyses for confirmed AIS-PSII. Results are presented as HRs with 95% CIs; $p<0.05$ was considered statistically significant.

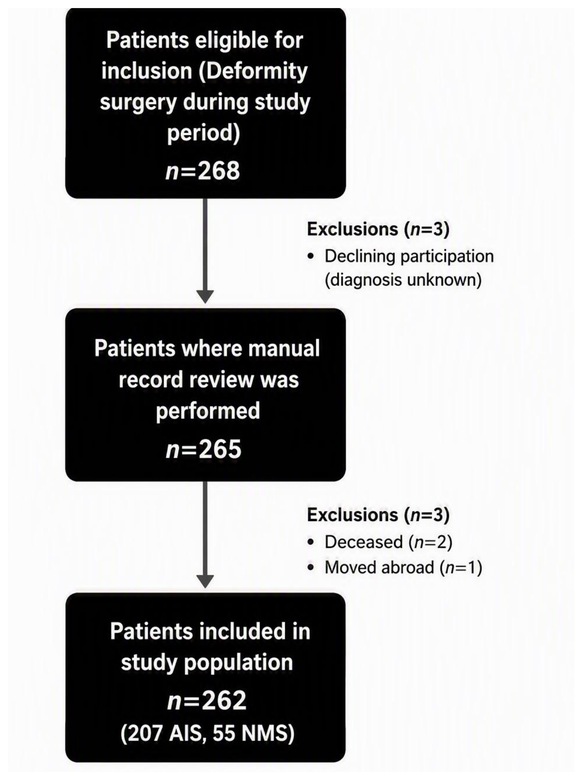

Figure 1. Flow chart of study population.
AIS = Adolescent idiopathic scoliosis, **NMS** = Neuromuscular scoliosis

Table 1. Study definition of PSII. Adapted from EBJIS PJI definition.

CRITERION	INFECTION UNLIKELY	INFECTION LIKELY (≥2 FINDINGS)	INFECTION CONFIRMED (≥1 FINDING)
CLINICAL FEATURES	Alternative reason for re-op.	• Implant loosening ≤2 years • Purulence around implants	• Sinus tract • Visible implant
INTRAOPERATIVE CULTURES	Negative	Single positive culture	≥2 positive cultures, same microorganism
RE-OP. FOLLOW-UP		Revision and/or antibiotics ≤24 months	

Results: Thirty-eight of 207 AIS (18.4%) and 11 of 55 NMS patients (20.0%) had revision surgery for confirmed infection. 8.7% of AIS patients underwent revision within 18 months, increasing to 18.4% by 5 years, with a median time of 20 months (range 0–63) **(Figure 2).** *C. acnes* accounted for 78.9% (30/38) of AIS infections and was associated with a longer latency period **(Table 2)**. The mean time to growth in *C. acnes* was 8.0 days (SD 2.6), supporting the need for prolonged incubation. All isolates, relapses included, remained susceptible to benzylpenicillin and clindamycin. Treatment outcomes after single revision were excellent among AIS patients; only 1/38 (2.6%) required a second infection-related reoperation, compared with 27.3% (3/11) in NMS. The most common treatment strategy in AIS was one-stage implant revision (57.9%), whereas debridement and implant retention was most frequently used in NMS patients (45.5%). Mean total and oral antibiotic treatment duration was 93.9 days (SD 21.8) and 86.5 days (SD 21.1) respectively. Multivariable Cox regression identified overweight (ISO-BMI) and number of instrumented vertebrae as independent risk factors for PSII.

Discussion: PSII rates were substantially higher than previously reported, with most infections presenting more than one year after surgery. Notably, application of the strict CDC 90-day definition would have identified only 3 AIS cases (1.4%), markedly underestimating the "true" incidence. *C. acnes* predominated in AIS, while polymicrobial infections were more common in NMS. The high incidence of late-onset *C. acnes* infections highlights potential limitations of commonly used CDC-based surveillance definitions and suggests under-recognition of delayed infections. It is further evident that systemic antibiotic prophylaxis against *C. acnes* needs to be further researched. Despite the high infection burden, revision surgery combined with antibiotics achieved high treatment success, particularly in AIS patients.

Table 2. Characteristics of confirmed PSII

Variable	AIS (n=38)	NMS (n=11)
CONFIRMATION CRITERIA		
Macroscopic + ≥2 positive cultures	33 (86.8%)	10 (90.9%)
≥2 positive cultures	5 (13.2%)	1 (9.1%)
TIME TO REOPERATION		
Mean ± SD, months	22.4 ± 15.8	14.6 ± 22.7
Early infection (<3 months)	3 (7.9%)	5 (45.5%)
REASON FOR REOPERATION		
Sinus tract	17 (44.7%)	4 (36.4%)
Pain + implant loosening	10 (26.3%)	2 (18.2%)
Pain + clinical infection	3 (7.9%)	1 (9.1%)
Pain only	3 (7.9%)	0 (0.0%)
Wound dehiscence	2 (5.3%)	4 (36.4%)
Implant loosening only	2 (5.3%)	0 (0.0%)
Pain + curve progression	1 (2.6%)	0 (0.0%)
REOPERATION TYPE		
DAIR	4 (10.5%)	5 (45.5%)
Complete revision	22 (57.9%)	2 (18.2%)
Incomplete revision	4 (10.5%)	3 (27.3%)
Implant removal	8 (21.1%)	1 (9.1%)
MICROBIOLOGY		
C. acnes	30 (78.9%)	2 (18.2%)
Polymicrobial	4 (10.5%)	3 (27.3%)
S. aureus	1 (2.6%)	2 (18.2%)
S. epidermidis	1 (2.6%)	1 (9.1%)
Group B streptococcus	1 (2.6%)	0 (0.0%)
P. mirabilis	0 (0.0%)	1 (9.1%)
S. capitis	0 (0.0%)	1 (9.1%)
E. coli	0 (0.0%)	1 (9.1%)
Missing data	1 (2.6%)	0 (0.0%)

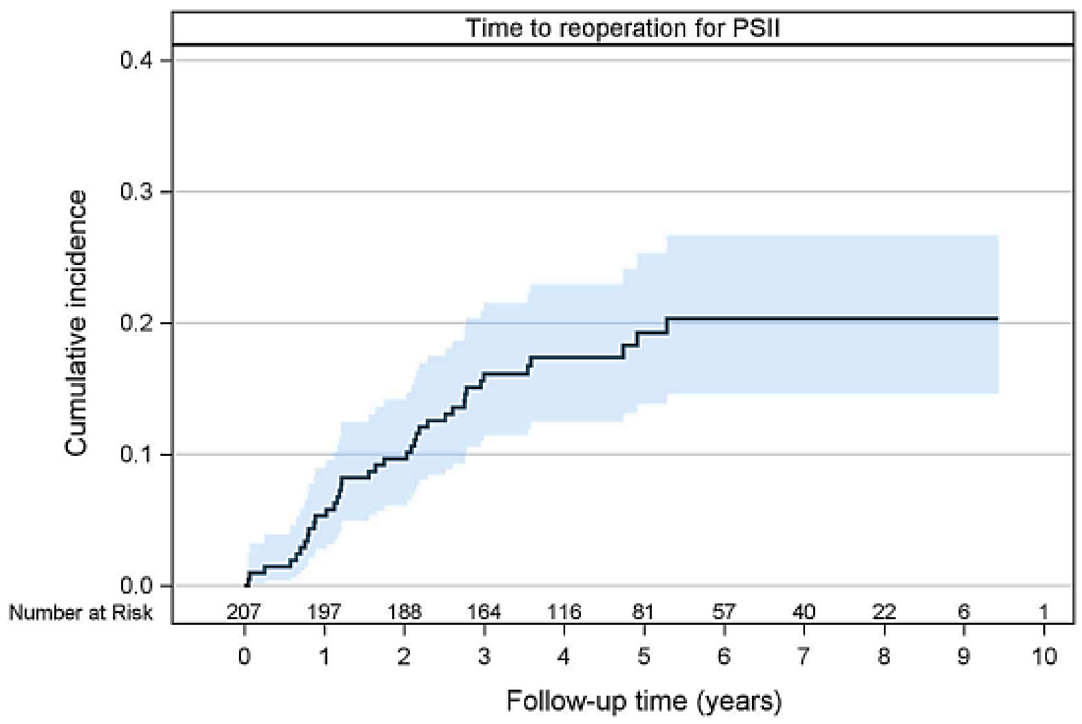

Figure 2. Cumulative incidence (95% CI) of revision surgery for postoperative spinal implant infection (PSII) after AIS surgery. Shaded area indicates 95% CI. Risk increased mainly during the first postoperative years.

Conclusions: The predominance of *C. acnes* highlights the need for standardised, validated diagnostic criteria for low-virulence PSIIs and further research into host–microbe interactions. Despite favourable treatment outcomes, *C. acnes* appeared to pose a greater PSII risk than staphylococci after standard prophylaxis, supporting targeted prevention in this population.