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ORIGINAL ARTICLE

Late-developing infection following posterior fusion for adolescent idiopathic scoliosis

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Abstract This study is a retrospective case series review of patients with adolescent idiopathic scoliosis (AIS) who were revised more than 1 year after the index procedure, due to a late-developing deep wound infection, to determine onset, bacteriology, possible influence of implant alloy (titanium vs. stainless-steel) and treatment outcome of patients. From a total of 540 patients who underwent posterior-only fusion for AIS from 1993 through 2005 at our institution, 15 cases (2.77%) were revised due to a late-developing post-operative infection: there were six males and nine females, with an average age at initial surgery of 15.8 years (range 12–18). Late infections occurred at a mean of 70 months (15–95) after the index procedure. The implant alloy used was a stainless-steel instrumentation in 11 patients (4.56% of 241) and a titanium one in 4 patients (1.33% of 299): there was an higher incidence of late infections in stainless-steel alloy group of patients ($P < 0.0001$). Complete removal of instrumentation was performed in nine patients, obtaining in all cases wound healing and no symptoms of infection, at a minimum 3 years follow-up. In the other six patients, presenting less severe clinical signs of infections, an attempt to save/replace the previous instrumentation was performed, but a complete instrumentation removal had to be performed 11.6 months later (range 3–24) for the persistence or recurrence of infection: all patients healed uneventfully at a minimum 3 years follow-up. Intraoperative cultures were obtained in all 15 cases, being positive in 13 cases (*S. epidermidis* in 5 patients, *S. aureus* in 3, *Propionibacterium acnes* in 1, *Serratia marcescens* in 1, *Propionibacterium acnes* + *S. epidermidis* in 1, *S. aureus* + *S. epidermidis* in 1 and coagulase-negative Staphylococci in 1). None presented at latest follow-up scoliosis progression: there was no statistically significant difference between final and pre-operative revision surgery values ($P = 0.17$). In conclusion, treatment of late-developing post-operative infection in AIS surgery required complete removal of the implant, continuous drain and adequate antibiotic therapy based on intraoperative swab antibiogram. Titanium alloy instrumentations resulted less subject to late post-operative infections, when compared to stainless-steel ones ($P < 0.0001$).

Keywords Adolescent idiopathic scoliosis · Posterior fusion · Late-developing infection

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Introduction

Late-developing infections following posterior fusion for adolescent idiopathic scoliosis (AIS) are relatively uncommon. The incidence ranges from 1.7 [1] to 6.9% [2]. However, the clinical course may be very prolonged and complicated [3].

There is no agreement on definition of delayed infection after posterior spinal fusion. According to DeWald [4] infections must be considered delayed when they occur 20 weeks or longer from the initial procedure. Other authors concluded that late infections are those that occurred more than 6 months after the index procedures, after an asymptomatic period [5]. The great part of authors considered late infection after 12 months of a previous posterior fusion [1, 6–9].

The aetiology remains still controversial. Gristina and Kolkin [10] considered several factors in sepsis after orthopaedic joint replacement and stressed the role of glycocalyx, a polysaccharide membrane surrounding

bacteria adjacent to infected surgical implants. Glycocalyx has adhesive properties that permit bacteria to adhere to surfaces of implants and it is responsible for poor antibiotic penetration of the bacteria, macrophage resistance and difficulties in obtaining cultures by routine methods. Later on, Dubousset et al. [7] considered fretting corrosion the cause of late infection after CD instrumentation in many patients, caused by micromotion between components of instrumentation, producing particulate debris and granulomatous reaction. Conversely, other studies, with high rate of positive cultures, concluded that fretting could not be the cause of such granulomatous reaction [10–12].

Actually, late infection after scoliosis surgery is considered a low grade infection [8, 9, 13, 14], resulting from two possible pathways. The first one is direct seeding from the surgical field, followed by a latent period and then activation at some remote time [15, 16]. Another probable mechanism could be the haematogenous seeding of the spinal fusion [6]. According to Clark and Schufflebarger [1], the mechanism of development of these late infections appears to be the late activation of bacteria implanted at the time of the initial surgery; it is doubtful that haematogenous seeding may be the real origin. Recently, Ho et al. [5] concluded that lumbar fusions, blood transfusions, failure to utilise drains and medical comorbities increased the risk of late infections.

The purpose of this study was to determine onset, bacteriology and treatment outcome of patients developing a late post-operative infection following posterior instrumented fusion for AIS. Moreover, the possible influence of the alloy of instrumentation (titanium vs. stainless-steel) on the development of this infection was also investigated.

Materials and methods

A retrospective case series review was performed including all patients who underwent a posterior-only fusion (PSF) for AIS from January 1993 through December 2005 in our institution. The inclusion criteria for the present study were: (1) diagnosis of AIS; (2) PSF with segmental third generation instrumentation; (3) a revision surgery performed for the development of delayed deep wound infection, occurring more than 12 months from the index procedure; (4) a minimum final clinical and radiographic follow-up of 3 years.

From a consecutive series of 540 AIS patients, 15 cases (2.77%) required a new surgical treatment due to a late-developing post-operative infection and constitute the present series.

An independent spine surgeon reviewed all medical and radiographic records of the patients. Inpatient and outpatient charts were used for collection of demographic data, height, weight, body mass index (BMI), previous medical history, type of implant alloy used, number of levels fused, use of autograft and/or bone-bank allograft, intraoperative blood loss, amount and type of blood transfusion, use of pre-operative and post-operative antibiotics and length of use, and annotation of any medical and surgical-related complications, including revision surgeries.

Onset and clinical signs of infection, presence of fever, empirical antimicrobial treatment before revision surgery when available, instrumentation failure present, initial haematological evaluation, culture reports of pre-operative wound swabs and intraoperative specimens, intraoperative evaluation of pseudarthrosis, nature of surgical treatment, type of wound closure (primary or delayed) and antibiotic regimen after the revision surgery were also annotated. Latest available follow-up evaluation consisted in both clinical and laboratory confirm of absence of infection signs.

Radiographic evaluation included standing postero-anterior and lateral films on long-cassettes (90 × 30 cm), before and after surgery, both for index and revision surgery, and at the latest follow-up. Lenke et al. [17] surgical classification of AIS was used to describe curve patterns. Cobb measurements [18] of the main curve were obtained.

Statistical analysis was performed using the *t* test (paired and unpaired), Wilcoxon test for non-parametric paired analysis, and the Mann–Whitney test for non-parametric unpaired analysis. Results are expressed as the mean (range), with a P value of <0.05 considered as being statistically significant.

Results

There were six males and nine females, with an average age at initial surgery of 15.8 years (range 12–18): a late post-operative site infection occurred at a mean of 70 months (range 15–95) after the index procedure (Table 1).

Previous treatment

Pre-operative comorbidities such as smoking, alcohol abuse, increased BMI and recurrent pharyngitis were observed (Table 1). Surgical time at index procedure was on average 4.15 h (range 2.5–5.5), intraoperative bleeding as a mean normalized estimated blood loss in these series of patients was 17.45 cc/kg, ranging from 7.7 to 27.27 cc/kg. All patients received autologous blood for a mean of 3.1 units (range 2–4). None presented fever or other signs infection in the early post-operative period.

All cases underwent a posterior-only instrumented fusion, using both autologous and homologous bank-bone graft. The spine was instrumented by means of a hybrid instrumentation in all patients, with a combination of proximal thoracic hooks and distal pedicle screws

Table 1 Demographic data

Case	Initials	Gender	Age	Weight (kg)	Height (cm)	BMI	Smoke	Diabetes	Alcohol abuse	Other	Alloy	Posterior fusion
1	BM	F	15	65	165	24	N	N	N		Stainless-steel	T4–L2
2	CA	M	15	60	180	19	N	N	N		Stainless-steel	T3–L2
3	DM	M	12	77	165	28	Y	N	N		Stainless-steel	T12–L5
4	FG	M	17	65	175	21	N	N	N		Stainless-steel	T3–L1
5	GT	M	17	80	160	31	Y	Y	N		Stainless-steel	T4–L2
6	TB	F	14	51	166	19	N	N	N		Stainless-steel	T3–L1
7	LCF	F	17	67	148	31	Y	N	N	Cardiopathy	Stainless-steel	T10–L5
8	LG	F	18	75	158	30	N	N	Y		Stainless-steel	T8–L4
9	PE	M	18	60	185	18	N	N	N		Stainless-steel	T4–L2
10	PF	F	16	64	168	23	N	N	N	Recurrent pharyngitis	Stainless-steel	T4–L1
11	PD	F	16	65	165	24	N	N	N		Stainless-steel	T5–L2
12	RV	F	18	52	158	21	N	N	N	Recurrent pharyngitis	Titanium	T4–L3
13	SC	F	15	73	162	28	N	N	N		Titanium	T2–L2
14	SL	M	13	60	178	19	N	N	N		Titanium	T3–L1
15	TV	F	16	42	149	19	N	N	N		Titanium	T2–L2

BMI body mass index, *N* not present, *Y* present

construct. The average number of posterior levels fused was 10.6 (range 6–13), with an average of 11 anchors points (range 8–17) per patient, with no statistical difference found considering the two groups (stainless-steel vs. titanium). Rod diameter used was 5.5 mm.

Concerning the implant alloy used, our consecutive series of 540 AIS patients could be broken down to two distinct groups. The first consecutive 241 patients received a stainless-steel instrumentation: from this group 11 patients (4.56%) had to be re-visioned due to a late-developing post-operative infection. The remaining consecutive 299 patients were treated using titanium alloy instrumentation: 4 patients (1.33%) developed a late onset infection (Table 1). Comparing the two groups, there was a statistically significant difference on the incidence of late-developing infection ($P < 0.0001$), resulting titanium alloy instrumentations less subject to these infections.

During the period considered for the current investigation the same surgical team (three different surgeons) has performed all index surgeries, following the same perioperative management protocol. Perioperative infection prophylaxis during the index operation routinely consisted in intravenous first generation cephalosporin (e.g. Totacef, 200 mg) plus an aminoglycoside (e.g. Nebicine, 100 mg) administrated at induction of anaesthesia, followed by a 48 h intravenous post-operative doses (e.g. Totacef, 200 mg × 3/day plus Nebicine, 100 mg/day), switched to another 7 days of oral first generation cephalosporin (e.g. Totacef, 200 mg × 3/day). Intraoperative strict aseptic rules were observed. The same pre-operative prep solution was always used. The scalpel was immediately changed after the skin incision. Double layers of gloves were worn and were changed every 1 h during the course of the operation. Thorough irrigation of the surgical wound with normal saline was repeatedly done during the operation. Stepwise wound closure by layers with non-absorbable suture material and absorbable intracutaneous skin closure was done, with two subfascial drains at continuous suction being placed. The wound drains were removed after 24–48 h (when <50 cc/12 h amount of drainage was observed). Patients were placed on a sitting position at first post-operative day and encouraged to walk as soon as pain permitted it. Average stay in the hospital was 11 days (range 8–15). All wounds were primarily healed on discharge. No post-operative brace or a cast was prescribed in any of the patients. No neurological injuries or any other medical or mechanical complication was encountered, necessitating a revision surgery until initial signs of late onset deep wound infection arose.

Surgical treatment

Diagnosis of late post-operative site infection was based on increasing pain and swelling at the operation site after a pain-free interval, at a mean 70 months (range 15–95) after the index procedure. The clinical signs of infection on admission included a mild back pain in 11 patients, while an intractable pain was present in four cases. There was a spontaneous sinus drainage in 11 and a fluctuant mass in 3, whereas 5 patients presented with hook disengagement (Table 2). Routine blood tests and radiographs were performed in all cases. Initial haematological evaluation at revision surgery showed an average white blood cells count

of 7.880 mm^3 (range 4,300–12,400), and erythrocyte sedimentation rate up to 47 mm/h (range 19–89) (Table 2). None presented with fever.

Complete removal of instrumentation was performed in nine patients; three of them presented proximal hooks disengagement. A solid fusion mass was present in all cases (Table 2). A continuous irrigation/suction drainage (Amuchine 5%) was used for an average of 5 days (range 3–8). Primary closure was performed in all patients and all wounds healed uneventfully. At a minimum 3 years follow-up (range 38–70 months), there was no curve progression, no symptoms of infection and laboratory confirm of normalised infection parameters.

In the remaining six patients, presenting less severe clinical signs of infection, an attempt to save/replace the previous instrumentation was performed, by a debridement with pulse irrigation and positioning of continuous irrigation/suction drainage (Amuchine 5%) in all patients. In two cases of them, an instrumentation replacement was also done, for a proximal hook disengagement (Table 2). A solid fusion mass was present in all cases. In all these six patients, we had to perform the complete removal of the instrumentation at a mean of 11.6 months later (range 3–24) due to persistence or recurrence of active infection. All healed uneventfully at a minimum 3 years follow-up (range 37–72 months): there was no curve progression and no symptoms of infection, at last follow-up.

Antibiotic treatment

Before revision surgery, empirical pre-operative antibiotics were administered for a week on average, using cephazoline associated with tobramicine in 13 cases, whereas teicoplanine was maintained in two patients.

As a general rule, microbiologic specimens, both from pre-operative wound and intraoperative swabs, were cultured aerobically and anaerobically using unselective media by both direct and broth enrichment culture for at least 10 days. Media were examined for growth of both high-grade pathogens (e.g. *Staphylococcus aureus*) and low virulence organisms (e.g. *Propionibacterium* sp., *Corynebacterium* sp., coagulase-negative staphylococci).

Pre-operative microbiologic examination of wound swabs were obtained in 13 patients, being positive in 9 (*S. epidermidis* in 4 cases, *S. aureus* in 2, *Propionibacterium acnes* in 2 and *Serratia marcescens* in 1). Intraoperative cultures were obtained in all 15 patients, being positive in 13 (*S. epidermidis* in 5 cases, *S. aureus* in 3, *Propionibacterium acnes* in 1, *Serratia marcescens* in 1, *Propionibacterium acnes* + *S. epidermidis* in 1, *S. aureus* + *S. epidermidis* in 1 and coagulase-negative Staphylococci in 1) (Table 2). Post-operative antibiotic treatment was tailored to the intraoperative specimens' microbiologic analysis, as soon as antibiograms were available. All patients received a minimum of 48 h parenteral drug coverage, followed by a 4 weeks oral therapy.

Radiological evaluation

The 15 patients with late post-operative site infection presented, according to the Lenke's classification, in 9 cases a type 1 curve, in 4 a type 2, and in 2 a type 3 scoliosis curve. We found a pre-operative main thoracic

Table 2

Case	Initials	T infection	WBC	ESR	Clinical Signs	Pre-op wound	Pre-operative culture	Type of surgery	Pseudo	Instrumentation problems	Intraoperative swabs culture
1	BM	63	8.2	45	Sinus	P	Negative	Removal	NO	Hook disengagement	*S. aureus*
2	CA	47	6.4	49	Fluctuance	N	Not available	Removal	NO	NO	Negative
3	DM	37	12.4	78	NO	P	Negative	Dèbris + re-instrumentation	NO	Hook disengagement	*S. aureus*
4	FG	25	7.4	27	Sinus	P	*Serratia marcescens*	Dèbris	NO	NO	*Serratia marcescens*
5	GT	24	7.7	45	Sinus	P	*S. epidermidis*	Removal	NO	Hook disengagement	*S. epidermidis*
6	TB	67	7.1	31	Fluctuance	N	Not available	Removal	NO	Hook disengagement	*S. epidermidis*
7	LCF	84	7.9	42	Sinus	P	*S. epidermidis*	Dèbris	NO	NO	*S. aureus* + *epidermidis*
8	LG	64	8.42	63	Sinus	P	*S. aureus*	Dèbris + re-instrumentation	NO	Hook disengagement	*S. aureus*
9	PE	96	8.91	89	Sinus	P	*S. epidermidis*	Removal	NO	NO	*S. epidermidis*
10	PF	195	4.3	27	Sinus	P	*S. epidermidis*	Removal	NO	NO	*S. epidermidis*
11	PD	43	7.5	64	Sinus	P	*S. aureus*	Removal	NO	NO	*S. epidermidis*
12	RV	50	7.85	19	Sinus	P	*P. acnes* + *S. epidermidis*	Dèbris	NO	NO	*P. acnes* + *S. epidermidis*
13	SC	174	5.3	42	Fluctuance	P	Negative	Removal	NO	NO	Negative
14	SL	15	8.1	40	Sinus	P	*P. acnes*	Dèbris	NO	NO	*P. acnes*
15	TV	72	10.7	48	Sinus	P	Negative	Removal	NO	NO	*S. coagulasi* Neg.

T infection timing after index procedures in months, *WBC* white blood cells count, *ESR* erythrocyte sedimentation rate, *P* positive, *N* negative

Table 3 Main curve Cobb angles and significance as measured in the pre-operative index procedure, post-operative index procedure, pre-operative revision for infection, latest follow-up

	Main curve Cobb (°)	Significance
Pre-op index	56 ± 8.9	–
Post-op	22.4 ± 2.51	–
Pre-op Rev.	34 ± 10.8	–
F.U	36 ± 9	–
Pre-op index vs. post-op	–	0.0001
Pre-op rev. vs. post-op	–	0.06
F.U vs. pre-op rev	–	n.s
F.U vs. pre-op index	–	0.04

n.s. Not statistically significant

Cobb of 56° (range 48–85), with an initial post-operative correction down to 22.4° (range 20–35) ($P < 0.0001$). The radiographic evaluation of pre-operative revision surgery showed a mean loss of −11.3° (range −14.23 to −7.5) ($P = 0.06$), with an average main thoracic Cobb angle of 34.1° (range 28–44). At a minimum of 3 years follow-up (range 37–70 months) after complete removal of the instrumentation, considering the entire series, there was no main curve progression: the mean final main thoracic curve was 36° (range 29–45), with no statistically significant difference between final and pre-operative revision surgery values ($P = 0.17$), whereas average main thoracic curve overall correction (final-index pre-operative) was still significant ($P = 0.04$) (Table 3).

Discussion

Late onset infections are not common after posterior fusion for AIS. The reported incidence in literature reaches up to 6.9% of cases [2], whereas in the present series the overall incidence was of 2.77% (15 cases out of 540). It is still not clear when an infection should be considered delayed; however, the majority of authors postulate a 12 months period after a previous uneventful posterior fusion [1, 6–9].

Identification of the causative organism is of paramount importance. A late onset infection is thought to be correlated to a late activation of bacteria implanted at the time of initial surgery: therefore an extended period of incubation of microbiologic specimens is required, and its identification may require up to 10 days [1, 14]. Once the organism is indentified, an antibiogram-based post-operative antibiotic treatment should be established. Post-operative antibiotic treatment must be tailored to the intraoperative specimens' microbiologic analysis with 48 h intravenous drug coverage and a 4 weeks oral therapy [1, 14].

Nevertheless, the antibiotic treatment alone seems not sufficient for the complete resolution of the infection. Once a drainage or a fluctuant mass has developed, the complete removal of the instrumentation seems necessary [1, 10, 14]. This appears the only way in which the infection can be eliminated, because the organisms remain protected by a biofilm (glycocalyx), that is found to be adherent to the rods [1, 9, 10, 14, 19]. The removal of instrumentation with thorough debridement, pulse irrigation and continuous irrigation/suction drain for 1 week, obtained in all our cases the primary wounds closure without signs of infection at follow-up. The results were different in our series, when we performed an attempt to retain or replace instrumentation, followed by continuous suction/irrigation for 1 week: a complete removal of instrumentation was necessary on average 11 months later for persistence of infection, obtaining sound closure and no signs of infection at follow-up.

It remains controversial the possibility of scoliosis loss of correction after the removal of instrumentation [20–22]. Some authors advocate re-instrumentation so as to achieve a permanent correction. Muschik et al. [20] retrospectively reviewed 45 patients with late infections that either underwent implant removal alone (35 cases), or underwent re-instrumentation and fusion (10 cases); they concluded that wound healing is usually uneventful after instrumentation removal for late infection, also when patients underwent a new instrumented fusion in a one-stage procedure: re-instrumentation appeared to achieve permanent correction of scoliosis. Rathjen et al. [22] concluded that implant removal after posterior fusion for idiopathic scoliosis may be complicated by progression of deformity. Another study has reported no curve progression after instrumentation removal, with no particular complaints from patients requiring a revision surgery for new instrumentation [23]. In our series, the scoliosis correction remained stable at latest follow-up after the complete removal of the instrumentation: a solid fusion mass was present in all cases. We found no main curve progression with mean final main thoracic curve of 36° (range 29°–45°), with no statistically significant difference between final and pre-operative revision surgery values ($P = 0.17$), whereas average main thoracic curve overall correction (final-index pre-operative) was still significant ($P = 0.04$) (Table 3).

There is also no consensus about the role of implant on the development of late post-operative infection. According to Richards et al. [14], the great volume of new instrumentation can be a risk factor: perhaps the most significant problem is the nature, bulk and modularity of modern implant systems; bursal formation can develop over prominent areas of the rod system, particularly the crosslinks. Ho et al. [5] did not agree with this conclusion, as crosslinks were not found to be associated with delayed infection.

The instrumentation alloy and it is influence on the development of late onset infection in AIS is another interesting question to be answered. There is some evidence correlating the use of stainless-steel with post-operative infections versus titanium implants [24–26]. It appears that titanium implants present a lower rate of late infections, and less loosening of instrumentation, generally associated with the fretting corrosion phenomenon [25]. In a recent article, Soultanis et al. [24] studied 50 cases with AIS treated by posterior stainless-steel multihook instrumentation and 40 patients with AIS operated on with posterior titanium multihook-multiscrew instrumentation: a delayed infection was observed in 5/50 AIS stainless-steel versus 0/40 AIS titanium constructs; they concluded that newer multihook-multiscrew titanium spinal instrumentation systems, having the advantage of greater bone adhesion on the hardware (thus resulting in the production of thinner biofilm), decreased the chances of infection [27–29]. The same results were observed in our series with a greater incidence of late infections in the stainless-steel group ($P < 0.0001$). In our institution, there was a conversion, in early 1998, to titanium alloy mainly based on the possibility to perform MRI later on life: therefore we performed so far more instrumentations with titanium alloy, nevertheless the overall incidence is lower when compared to stainless-steel ones.

In conclusion, treatment of late-developing post-operative infection in AIS surgery required complete removal of the implant, continuous drain and adequate antibiotic therapy based on intraoperative swab antibiograms.

The present series should be interpreted in the context of its limitations, including the retrospective nature of the review and the fact that patients were not randomized between stainless-steel and titanium alloy instrumentation. However, this series is a consecutive, single institution experience on 540 AIS patients, following the same perioperative management protocol. Titanium alloy instrumentations seemed less subject to late post-operative infection, when compared to stainless-steel one. Comparing the two groups, there was a statistically significant difference on the incidence of late-developing infection ($P < 0.0001$).

Conflict of interest None.

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