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Implant removal for late-developing infection after instrumented posterior spinal fusion for scoliosis: reinstrumentation reduces loss of correction. A retrospective analysis of 45 cases

Received: 5 July 2003
Revised: 9 January 2004
Accepted: 14 February 2004
Published online: 26 June 2004
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Abstract A retrospective follow-up study of patients who, having undergone instrumented posterior spinal fusion for scoliosis, experienced late infection and then underwent either implant removal alone or implant removal and instrumented refusion. We conducted this study to determine whether it is possible to avoid loss of correction by a single-stage implant removal and reinstrumentation procedure. There have been a few reports of late-appearing infections after spinal instrumentation. Implant bulk, metallurgic reactions, and contamination with low-virulence microorganisms have been suggested as possible etiologic factors. The clinical symptoms include pain, swelling, redness, and spontaneous drainage of fluid. Complete instrumentation removal and systemic antibiotics is usually curative. We retrospectively reviewed 45 patients who underwent instrumented posterior spinal fusion for scoliosis and experienced development of late infections and, after a mean of 3 years after the initial procedure, either underwent implant removal alone [$n=35$, instrumentation removal (HR) group] or additionally underwent reinstrumentation and fusion [$n=10$, reinstrumentation and fusion (RI&F) group]. Three patients were reinstrumented 1.5 years after

instrumentation removal, and seven underwent a one-stage rod removal and reinstrumentation/refusion procedure. Allergic predisposition, protracted postoperative fever, and pseudarthrosis appear to increase the risk of late-developing infection after posterior spinal fusion. All wounds in both groups healed uneventfully. Preoperative radiographic Cobb measurements showed no statistically significant between-group differences. At follow-up, however, outcome was clearly better in the RI&F group: Loss of correction was significantly smaller in reinstrumented patients. Thus, the thoracic Cobb angle was $28\pm 16^\circ$ (range $0\text{--}55^\circ$) in the RI&F group versus $42\pm 15^\circ$ ($21\text{--}80^\circ$) in the HR group, and the lumbar Cobb angle was $22\pm 11^\circ$ ($10\text{--}36^\circ$) in the RI&F group versus $29\pm 12^\circ$ ($13\text{--}54^\circ$) in the HR group. The results of our study demonstrate that wound healing is usually uneventful after instrumentation removal for late infection, also when patients undergo instrumented refusion in a one-stage procedure. Reinstrumentation appears to achieve permanent correction of scoliosis.

Keywords Scoliosis · Spinal fusion · Late infection

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Introduction

The incidence of late-developing infections after spinal fusion has increased with the widespread use of metal implants to support the scoliosis correction until bony fusion occurs. There have been a few reports of late-appearing infections after anterior spinal instrumentation: Robertson and Taylor achieved resolution of post-Dwyer procedure late infections by implant removal [12]. Most late infections, however, develop after posterior instrumentation. The clinical signs and symptoms of late infection include pain, swelling, and redness, typically in the middle and distal scar area, and eventually spontaneous drainage of fluid, which is often sterile. Radiographs occasionally show implant loosening, such as resorption margins around pedicle screws [4, 11].

According to Clark and Shufflebarger, late-developing infections typically appear later than 1 year after an uneventful initial procedure: In a retrospective review of 1,247 patients who underwent posterior spinal instrumentation for scoliosis, 22 patients (1.7%) required Cotrel-Dubousset or Moss Miami rod removal after a mean of 3.1 years after the initial procedure [3]. Richards reported that ten out of 146 patients (7%) with adolescent idiopathic scoliosis developed infections after a mean of 25 months after posterior spinal fusion with Texas Scottish Rite Hospital (TSRH) instrumentation. The delayed infections were thought to be due to intraoperative seeding during the initial procedure and late activation of low-virulent bacteria (*Propionibacterium acnes*, *Staphylococcus epidermidis*) [11]. While some authors have reported a high percentage of positive bacterial cultures, others had mainly sterile wound swabs [3, 9, 13]. Glycocalyx, a membrane that surrounds bacteria adjacent to surgical implants, may cause difficulty in culturing bacteria and result in poor antibiotic penetration. Corrosion of bulky steel implants, fretting, pseudarthrosis formation, or implant micromovements have been associated with histologically confirmed extensive foreign body granulomas and superinfected synovial bursae [3, 6, 8, 11, 16]. Immunologic/allergologic responses to metal implants, triggered by denaturation of and conformational changes in endogenous proteins at the implant surface, have been implicated as well [14].

Conservative antibiotic therapy or local surgical wound debridement without implant removal is rarely successful. Complete instrumentation removal with subsequent primary wound closure and systemic antibiotics is usually curative [3, 6, 8, 9, 11, 13, 16]. Implant removal is problematic where insufficient bony fusion or pseudarthrosis requires spinal stabilization by reinstrumentation which, however, appears prone to complications because of the potentially infectious wound.

In the mid-1990s, we observed significant progression of scoliosis and the appearance of abnormal kyphosis in some of our patients who required instrumentation removal for late-developing infection. We therefore began perform-

ing refusion and reinstrumentation with titanium implants immediately after steel implant removal, i.e., in a one-stage procedure. In so doing, we followed the principles developed for the primary exchange of infected total hip replacements [1, 2].

For this review, we analyzed the radiographic outcome measures (Cobb angles, apical rotation, thoracic kyphosis, lumbar lordosis) of patients who, having undergone instrumented posterior spinal fusion for scoliosis, experienced late infection and then underwent either implant removal alone or implant removal and instrumented refusion.

Fig. 1 **a** Sixteen-year-old girl with right convex thoracic adolescent idiopathic scoliosis who experienced development of late infection 2 years after posterior spinal fusion. **b** Three years after instrumentation removal: increase in scoliosis and thoracic kyphosis

Patients and methods

From 1988 to 1998, 937 patients underwent posterior spinal fusion for scoliosis (842 cases with idiopathic scoliosis, 67 for neuromuscular, and 28 for congenital disorders). Forty-five (5%) experienced development of late infections and, after a mean of 2.9 ± 1.7 (range 0.5–8.0) years after the initial procedure, either underwent implant removal alone [$n=35$, instrumentation removal (HR) group] or additionally underwent reinstrumentation and fusion [$n=10$, re-instrumentation and fusion (RI&F) group]. Mean ($\pm$ SD) age at initial surgery (posterior spinal fusion) was 15 ± 4 (range 9–29) years. Mean age at device removal and, in the RI&F group, refusion, was 18 ± 4 (11–32) years, and mean age at follow-up was 22 ± 5 (13–37) years. The follow-up time after reinstrumentation (RI&F group) was 3 years and 6 months on average.

The initial procedure was performed with the patient positioned prone in a Relton-Hall frame. Hooks and screws were placed after posterior exposure of the spine. We opened the small vertebral joints and decorticated the laminae. Then we attached the bent rods, correcting the scoliosis either by the rod rotation technique, by translation technique, or by combination of these techniques [9] and attaching the cross connectors. Finally, corticocancellous bone grafts harvested from the patient's iliac crest were applied for spinal fusion. Only one patient required allogeneic bank bone grafts. Enoxaparin (Clexane) was given to prevent thrombosis. Patients were mobilized from postoperative day 2 without wearing a brace.

Clinical and radiographic follow-up was performed at 3, 6, 12, and 24 months after surgery. All 45 patients who experienced late-developing infections had their metal implants removed. Patients in the HR group underwent primary wound closure and received systemic antibiotics until wound healing. No further scoliosis surgery was performed (Fig. 1). Ten patients underwent reinstrumentation and fusion (RI&F group). Three RI&F patients underwent instrumented refusion 1.5 years after instrumentation removal. The other seven patients of the RI&F group had their fistulae excised and wounds thoroughly irrigated immediately after implant removal, and existing fusions were again decorticated. This was followed by spinal instrumentation with titanium implants (Universal Spinal System) according to the guidelines of primary scoliosis surgery. In seven patients, the same levels were reinstrumented as compared with the original instrumentation; in two patients, one caudal level was enclosed; and in one patient, two caudal levels were added into the fusion. The reinstrumentation was covered with morselized allograft cancellous bone. Primary wound closure was performed. Aftercare was the same as that described for the initial procedure (Fig. 2).

Patient records including radiographs were reviewed and analyzed for preoperatively existing secondary diagnoses and allergies, operation duration, blood loss, perioperative antibiotic therapy, postoperative body temperature, and complications. Patients experiencing late-developing infections were additionally analyzed for clinical symptoms, serologic variables, and histologic and microbiological findings. Only normal incubation period was carried out until 1998.

Posteroanterior and lateral radiographs of the spine were obtained before the initial procedure, prior to instrumentation removal, after instrumentation removal with or without instrumented refusion, and at follow-up. We documented the extension of spinal fusion,

Fig. 2 a Fifteen-year-old girl with right convex thoracic adolescent idiopathic scoliosis (*left*) and 6 months after dorsal spondylodesis: development of pseudarthrosis (*right*). b Late infection 1 year after instrumentation was extended into the lumbar spine due to pseudarthrosis and lumbar decompensation (*left*) and 3 years after one-stage instrumentation removal and instrumented refusion (*right*). c Normal kyphosis before surgery and at follow-up examination

the type of implant used, and the occurrence of pseudarthroses and hardware loosening. The Cobb angle and Perdriolle apical rotation of the primary and secondary curves were measured on the posteroanterior spinal radiograph [10]. The lateral spinal radiograph was used to measure thoracic kyphosis between T4 and T12 and lumbar lordosis between L1 and L5.

Statistical analysis was by the SPSS statistics software program for Windows, Version 10. We calculated the mean and standard deviation and reported the range (minimum-maximum). Normal distribution of the database was not always likely. We therefore used nonparametric tests (Wilcoxon test, 95% confidence interval).

Results

Clinical data, serology, and microbiology

Thirty-nine of our 45 patients with late-developing infections had undergone posterior spinal fusion for idiopathic scoliosis, and one each had scoliosis due to Arnold-Chiari malformation, Down syndrome, William-Beuren syndrome, hereditary polyneuropathy, lumbar spina bifida, and neurofibromatosis. The mean number of fused segments was 10 ± 2 (6–13). All implants were steel (CD 7, Harrington 1, TSRH 9, USIS 1, USS 27). No patient had a preoperative history of chromium or nickel allergy. However, 13/45 patients (29%) reported allergies to pollens, hay, flowers, animal danders (7), antibiotics (4), diclofenac (1), or tramadol (1).

The initial procedures were uneventful. Operation duration was 235 ± 73 (135–460) min, and blood loss was $1,709 \pm 922$ (200–3,700) ml. Thirty-four patients had $>37.5^\circ\text{C}$ axillary body temperature for up to 3 postoperative days. Ten patients had fever until postoperative day 7, and one patient had fever for 13 postoperative days. Forty-three patients received perioperative antibiotic therapy. Two patients with extended postoperative fever received antibiotics for 7 and for 21 days. Wound healing was by primary intention in all patients, and the subsequent clinical course was uneventful.

The appearance of late-developing infections after a mean of 3.5 years was associated with the following clinical symptoms: wound sinus and spontaneous drainage of fluid ($n=40$, 89%), local pain ($n=38$, 84%), swelling ($n=34$,

76%), redness ($n=28$, 62%), and fever $>38.0^\circ\text{C}$ ($n=7$, 16%). Laboratory studies: erythrocyte sedimentation rate (1 h) 29 ± 18 mm (3–79), C-reactive protein 30 ± 23 mg/l (0–86), hemoglobin 0.48 ± 0.06 g/l (0.37–0.61), hematocrit 0.38 ± 0.04 (0.31–0.47), white blood cells $8.7 \pm 2.4 \times 10^9/\text{l}$ (4.1–18.9), red blood cells $4.7 \pm 0.4 \times 10^{12}/\text{l}$ (4.0–5.5), platelets $330 \pm 90 \times 10^9/\text{l}$ (169–620).

Preoperative or intraoperative microbiological swabs were negative in 37 cases (82%) and positive for *Staphylococcus aureus* or *Staphylococcus epidermidis* in six or two cases, respectively. Histologic examination of tissue specimens was performed in 24/45 patients (53%) at implant removal. All specimens showed evidence of chronic nonspecific signs of inflammation including foreign-body reactions (granuloma, eosinophil accumulation). Bone infection was never observed. Both the initial and revision procedures, including all seven one-stage implant removal and instrumented refusion procedures, healed by primary intention. There were no neurologic complications. All patients were asymptomatic at follow-up.

Radiographic measurements

Table 1 shows the radiographic measurements for all 45 patients prior to initial surgery, at late-developing infection, after instrumentation removal (and instrumented refusion in ten patients), and at follow-up. Initial surgery achieved significant thoracic and lumbar-curve correction (improvement in primary and secondary Cobb angles) and significant thoracic apex derotation, while the sagittal profile and lumbar apex rotation were unchanged. Five patients (all of them had idiopathic scolioses) with infection showed resorption margins around loosened pedicle screws (Fig. 2), and one had a broken screw. Pseudarthroses were found in these five cases at surgery (11% of all patients). Only one patient with pseudarthrosis received a reinstrumentation (Fig. 2). The other four pseudarthroses were resected, and local bone was filled in but no reinstrumentation was carried out. Separate calculation of measurements for patients with pseudarthrosis versus patients with intraoperative solid fusion showed significant differences only for

Table 1 Radiographic measurements in $^\circ$ (degrees) for all late-infected patients ($n=45$) before initial surgery, at late infection, after instrumentation removal (and instrumented refusion in ten patients), and at follow-up

Values in $^\circ$ (degrees)
Mean $\pm$ standard deviation and range (minimum-maximum)
* $p < 0.05$ versus preoperation
§ $p < 0.05$ versus measurement at appearance of late infection

$N=45$	Before initial surgery (posterior spinal fusion)	Late infection	After instrumentation removal (and instrumented refusion in ten patients)	Follow-up
Thoracic Cobb angle	52 ± 14 (36–86)	31 ± 14 (6–66) *	34 ± 14 (10–74) *	37 ± 16 (10–80) * §
Lumbar Cobb angle	37 ± 18 (11–90)	22 ± 13 (2–60) *	26 ± 12 (4–52) *	27 ± 12 (10–54) * §
Thoracic kyphosis	27 ± 10 (6–49)	28 ± 12 (0–57)	33 ± 13 (10–70)	39 ± 14 (14–79) * §
Lumbar lordosis	41 ± 16 (10–70)	41 ± 15 (13–68)	44 ± 15 (18–70)	45 ± 17 (15–80)
Thoracic apex rotation	21 ± 9 (5–40)	16 ± 8 (0–40) *	16 ± 8 (0–35) *	18 ± 9 (0–40) §
Lumbar apex rotation	11 ± 10 (0–40)	10 ± 8 (0–25)	11 ± 8 (0–25)	11 ± 7 (0–25)

Table 2 Radiographic measurements for patients with pseudarthrosis ($n=5$) versus patients without pseudarthrosis ($n=40$) before the initial procedure and at follow-up

	Pseudarthrosis ($n=5$)	Solid fusion ($n=40$)	Statistical significance
Preoperation			
Thoracic Cobb angle	50± 9 (36–60)	53±14 (36–86)	N.S.
Lumbar Cobb angle	34±13 (22–50)	37±19 (11–90)	N.S.
Thoracic kyphosis	26±12 (8–40)	27±10 (6–49)	N.S.
Lumbar lordosis	49±10 (38–59)	39±16 (10–70)	N.S.
Thoracic apex rotation	11± 4 (5–15)	22± 8 (5–40)	$p<0.05$
Lumbar apex rotation	10±10 (0–25)	11±10 (0–40)	N.S.
Follow-up			
Thoracic Cobb angle	40±16 (22–60) *	37±16 (10–80) *	N.S.
Lumbar Cobb angle	26± 7 (18–34) *	27±13 (10–54) *	N.S.
Thoracic kyphosis	33±11 (21–50) *	40±14 (14–79) *	N.S.
Lumbar lordosis	52±11 (37–62)	43±18 (15–80)	$p<0.05$
Thoracic apex rotation	15± 6 (5–20)	18±10 (0–40)	N.S.
Lumbar apex rotation	11± 5 (5–20)	10± 7 (0–25)	N.S.

Values in ° (degrees)

Mean ± standard deviation and range (minimum-maximum)

* $p<0.05$ versus preoperation

Table 3 Radiographic measurements for the patients of the instrumentation removal (HR) group and the reinstrumentation and fusion (RI&F) group. N.S. not significant before the initial procedure and at follow-up

	HR group ($n=35$)	RI&F group ($n=10$)	Statistical significance
Preoperation			
Thoracic Cobb angle	53±14 (36–86)	51±17 (40–72)	N.S.
Lumbar Cobb angle	38±18 (11–90)	32±20 (11–74)	N.S.
Thoracic kyphosis	26±10 (8–49)	28±10 (6–40)	N.S.
Lumbar lordosis	44±14 (20–70)	32±18 (10–58)	N.S.
Thoracic apex rotation	21± 9 (5–40)	21± 9 (10–35)	N.S.
Lumbar apex rotation	12±11 (0–40)	8± 6 (0–15)	N.S.
Follow-up			
Thoracic Cobb angle	42±15 (21–80) *	28±16 (01–55) *	$p=0.03$
Lumbar Cobb angle	29±12 (13–54) *	22±11 (10–36) *	N.S.
Thoracic kyphosis	38±12 (20–62) *	42±18 (14–79) *	N.S.
Lumbar lordosis	48±15 (20–80)	37±20 (15–75)	N.S.
Thoracic apex rotation	19± 9 (0–40) *	14± 8 (5–30) *	N.S.
Lumbar apex rotation	12± 7 (0–25)	7± 5 (0–15)	$p=0.03$

Values in ° (degrees)

Mean ± standard deviation and range (minimum-maximum)

* $p<0.05$ versus preoperation

the lumbar lordosis at follow-up (Table 2). Radiographic follow-up revealed significant loss of correction versus the measurements obtained immediately before instrumentation removal in all 45 patients (Table 1). Mean correction loss was 6° (from 31° to 37°) for the primary (thoracic) curve, 5° (from 22° to 27°) for the secondary (lumbar) curve, 11° (from 28° to 39°) for thoracic kyphosis, and 2° (from 16° to 18°) for thoracic apex rotation. Table 3 compares the radiographic measurements obtained in the 35 patients in the HR group with data of the ten patients in the RI&F group. Preoperative measurements demonstrated no statistically significant differences between the groups. The initial procedure achieved significant primary and secondary Cobb correction. Comparison with the follow-up data reveals significant loss of correction in the HR group. Residual primary Cobb correction was as small as 11° in the HR group (53° preoperation versus 42° at follow-up; 21% correction) compared to 23° in the RI&F group (51° preoperation versus 28° at follow-up; 45% correction).

Sagittal profile also appeared to be better in the RI&F group. While both groups showed an increase in thoracic kyphosis from appearance of infection to follow-up, the mean change was statistically significant in the HR group (+11°; from 27° before instrumentation removal to 38° at follow-up; $p=0.000$) but not in the RI&F group (+7°; from 35° to 42°; $p=0.388$).

Discussion

After a mean of 3.5 years, 5% of our patient population experienced the development of late infections. Bacterial cultures were negative in 37/45 patients (82%). In a series of 667 patients who underwent CD instrumentation, Lukaniec et al. observed 34 late-appearing infections (5%, as in our series). Also, 81% of bacterial cultures were negative [8, 9, 13]. However, a significantly higher percentage (up to 90%) of specimens cultured for longer

than 7 days were positive for low-virulence skin organisms [3].

The etiology and pathogenesis of late-developing infections are as yet unclear. However, 29% of the patients in our series had a preoperative history of allergic predisposition, and this percentage is clearly higher than the 8–12% prevalence among the general pediatric population of children and adolescents the same age [5]. Moreover, the percentage of patients who had fever ($>37.5^{\circ}\text{C}$) for 7 or more postoperative days appeared to be increased: 24% (11/45 patients). In the series reported by Clark and Shufflebarger, four out of 22 patients (18%) had fever 72 h after surgery [3].

As far as we know, only steel implants have to date been associated with late-appearing infections. Gaine et al. consider it possible that metallic debris and corrosion products from fretting at cross-connector junctions may provide the environment for the incubation of dormant or inactive endogenous microbes [6, 16]. Histology demonstrated foreign-body reactions also in our patients. The infections affected the scar tissue but not the bony fusions [3]. In fact, none of the surgical revisions revealed clinical or histologic evidence of osteomyelitic processes. There is relative consensus in the literature that implant removal and short-term antibiotic therapy achieves uneventful healing with primary wound closure and that delayed closure is unnecessary [3, 9, 11, 13, 16]. This approach was curative also in our patients with late infections. Few authors have reported successful treatment concepts that involve leaving the implant in place. Lukaniec et al., however, achieved healing of implant infection in 25 patients treated with surgical wound sinus debridement and fistula excision, postoperative suction drainage, and parenteral antibiotics [8]. These authors reported that significant loss of correction occurred in only one patient.

In our series, on the other hand, implant removal caused significant loss of primary and secondary Cobb correction in some patients. We therefore began reinstrumenting patients. The principle of exchanging rather than simply removing metal implants was, as far as we know, developed by Buchholz at St. Georg Hospital and, later on, at Endo-Klinik, Hamburg, Germany, in the early 1970s and has been used successfully in the surgical management of infected hip replacements [1, 2]. This surgical approach consists of scar-tissue and fistula excision, complete arthroplasty and cement removal, careful bone-stock debridement with thorough wound irrigation, implantation of the new arthroplasty with antibiotic-loaded cement, and primary wound closure. In 1998, Ure et al. reported about 20 patients who underwent direct exchange of infected total hip arthroplasties. After a mean of 10 years, no patient had experienced recurrent infection. Revision surgery was performed in two patients with aseptic loosening after 9 or 17 years [15].

We modified this principle to adapt it to the exigencies of the management of late-infected instrumented spinal

fusions. We used titanium implants for reinstrumentation, as recommended by Clark and Shufflebarger for two-stage procedures [3]. In addition, the authors feel that low-profile instrumentation systems may help to avoid mechanical irritation of the soft tissue. Our one-stage approach consisting of fistula excision, instrumentation removal, wound debridement and irrigation, reinstrumentation, and allograft cancellous bone grafting has to date produced encouraging results. The wounds healed by primary intention, and at follow-up after a mean of 3 years, there was neither clinical nor radiographic evidence of recurrent infection. Retrospective thoracic Cobb measurement comparison between our groups revealed that instrumented refusion achieves significantly better, lasting scoliosis correction.

Helenius et al. reported on 78 patients with adolescent idiopathic scoliosis [7]. Fifty patients underwent routine Harrington rod removal 2 years after spinal fusion, i.e., when stable bony fusion was firmly established. Twenty patients did not have their rods removed; these were correctly and stably in place. The mean preoperative thoracic Cobb angle was 53° and 54° in the two groups. At the 20-year follow-up, the mean thoracic Cobb angle was 40° (24% correction) in the patients in whom the Harrington rod had been left in place versus 48° (9% correction) in the patients who had undergone rod removal. Mean secondary (lumbar) Cobb correction at follow-up was also better in the patients whose Harrington rods had been left in place (27% correction versus 6%). A relatively rigid implant may, via stress shielding, prevent the development of a bony fusion mass that is stable to bending. Metal implant removal with no reinstrumentation will then cause loss of correction because the anterior spine is still flexible at the intervertebral disks.

Conclusion

Five percent of our series of scoliosis patients developed late infections after extended posterior spinal fusion. The etiology of late infections is still poorly understood. Implant bulk, metallurgic reactions, and contamination with low-virulence microorganisms have been suggested as possible etiologic factors. A history of allergic predisposition, protracted postoperative fever, and nonunion of the fusion are risk factors for late infections after posterior spinal fusion. Instrumentation removal and primary wound closure are reliably curative. A one-stage procedure consisting of implant removal and spinal reinstrumentation using titanium implants and allogeneic cancellous bone grafting is possible and appears to achieve better and permanent scoliosis correction.

Acknowledgment The authors wish to thank Prof. Dr. H. W. Buchholz for a critical review of the manuscript. Prof. Buchholz was the founder of Endo-Klinik, Hamburg, Germany, and developed the surgical management of infected hip replacements. He died on March 24, 2002, at the age of 91 years.

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