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CASE SERIES

Can magnetically controlled growing rods be successfully salvaged after deep surgical site infection?

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Abstract

Purpose The purpose is to compare the rate of recurrent deep wound infection in patients who retained MCGRs versus those who underwent implant removal and exchange following index deep wound infection.

Methods Using a multicenter registry, we identified patients with EOS who underwent surgical correction with MCGR. We defined deep SSI as any infection that required subsequent I&D and antibiotic therapy. Recurrent infection was defined as any additional deep SSI following treatment of index deep infection. We considered MCGR to be salvaged if implant exchange or removal was not performed for at least 1 year following date of infection. Bivariate statistical analyses were performed.

Results 992 EOS patients were identified, of whom 33 (3.3%) developed deep SSI. The mean time between initial surgery and first deep SSI was 13.1 months (Interquartile range [IQR]: 1 to 25 months. Infection rates by EOS diagnosis were as follows: 13/354 patients (3.6%) had neuromuscular scoliosis (NMS), 9/225 (4.0%) syndromic, 6/248 (2.4%) idiopathic, 3/135 congenital (2.2%), and 2/30 (6.6%) unknown etiology. MCGR was salvaged in 69% of NMS patients, 77% of syndromic patients, 100% of congenital patients, and 83% of idiopathic patients (83%). There were only four recurrent infections (2/13 NMS, 2/9 syndromic) and no differences in rates of recurrent infection between salvaged or replaced/exchanged MCGR. ($p = 0.97$).

Conclusion Deep wound infection occurred in 3% of MCGR patients at a mean of 13.1 months. There were no significant differences in rates of recurrent infection between salvaged implants and those removed or exchanged.

Keywords Magnetically controlled growing rods · Deep wound infection · Recurrent infection · Early-onset scoliosis

Introduction

Early-onset scoliosis (EOS) can be secondary to a multitude of etiologies, including neuromuscular pathologies, congenital anomalies, connective tissue syndromes, or idiopathic [1]. In patients who have failed conservative management, magnetically controlled growing rods (MCGR) can delay the need for definitive fusion until the patient is closer to skeletal maturity. This technology has largely replaced traditional growing rods (TGRs), as they can be lengthened more non-invasively [2, 3]. This allows for increased frequency at which lengthening can be performed, thereby improving patient tolerance to lengthening and improving overall quality of life for the patient [1, 4].

Despite the significant advantages of MCGR systems, they come at immense cost to patients and their families. Though MCGR systems are more cost effective than TGRs, with cost neutrality achieved over 6 years, they have a high upfront financial burden [5]. Moreover, MCGRs have been reported previously to have implant related complication rates of approximately 34–54%, which included pedicle screw pull out, rod fracture, pain on distraction, and lack of lengthening [6, 7]. These complications often require unplanned return to the OR for MCGR revision or MCGR removal and exchange, additional procedures that place increased medical and financial burdens on the patient [6].

Previous literature reports a deep wound infection of approximately 4–10% in EOS patients who underwent MCGR implantation [8, 9]. However, no previous studies have determined whether MCGR implants can be effectively

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retained in EOS patients following deep wound infection or whether these implants require removal and exchange to decrease risk of recurrent deep wound infection. The primary purpose of this study was to determine the prevalence of recurrent deep wound infection in EOS patients who retained implants versus those who underwent implant removal and exchange.

Methods

Study population

This study was approved by the Institutional Review Board (IRB) for human subjects research. We identified pediatric patients with EOS who underwent surgical correction with MCGR using a prospective, multicenter surgical registry. Inclusion criteria included: (1) Patients must have received surgical intervention with MCGR (2) Patients had a confirmed diagnosis of EOS, secondary to idiopathic, neuromuscular, congenital, or syndromic etiologies (3) Patients had at least one documented case of deep wound infection, and (4) Patients with minimum follow-up of at least 5 months. For patients that met inclusion criteria, age at time of initial MCGR implantation, EOS etiology, prior treatment with traditional growing rods, prevalence of recurrent deep wound infection, number of MCGR revisions, and rate of MCGR removal and exchange were recorded. We defined deep wound infection as any deep soft tissue surgical site infection that required subsequent I&D with concurrent antibiotics or rod exchange and removal. We further defined acute infection as deep wound infection within 90 days of surgery. Time to index deep wound infection from date of initial MCGR implantation was recorded for all patients. Patients who had their implants removed and exchanged secondary to non-infectious etiology, including rod breakage, failure of the rod to distract, or for rod upsizing were excluded from analysis.

Outcome measures

MCGR removal and exchange

For patients with deep wound infection following MCGR implantation, patients were either treated with I&D with concurrent antibiotics alone, I&D/antibiotics with anchor replacement and revision, or with subsequent total implant removal and exchange. For those who underwent total implant removal and exchange, both rods and all fixation points were removed and exchanged. For those who retained implants, meticulous cleaning of visible implants to facilitate removal of any biofilms and concurrent debridement of devitalized tissue was performed. We considered the MCGRs to be salvaged if total implant exchange or removal was not performed for at least 1 year following date of infection. Across all patients, we recorded rates of rod salvaging versus those with rods removed and replaced. Rates of MCGR revision (i.e. number of anchor removals and replacement prior to total implant removal and exchange if performed) were recorded for patients who had their rods salvaged and those who did not.

Recurrent infection

Recurrent infection was considered to be any additional deep SSI following treatment of index deep infection. Prevalence of recurrent infection and time from index deep wound infection to first recurrent infection was recorded.

Statistical analyses

Descriptive statistics were performed to quantify the rates of each complication. Mean ± standard deviation is reported for quantitative data. Bivariate statistical analyses were performed to identify differences in rates of recurrent infection as well patient characteristics between those who underwent rod removal/exchange and those who had implants salvaged. Alpha was set to 0.05. All statistics were performed using STATA® version 15.0 (StataCorp, College Station, TX).

Results

Study population

From the multicenter database, we identified 992 EOS patients who underwent posterior spinal fusion, of whom 33 (3.3%) developed a deep wound infection following surgery. Among these 33 patients, 13 patients developed the infection within 90 days of surgery. Table 1 summarizes the prevalence of deep wound infection stratified by etiology of EOS. Risk of deep wound infection was nominally the highest in patients with syndromic ($n = 9/225$, 4.0%) and neuromuscular scoliosis ($n = 13/354$, 3.6%), followed by idiopathic scoliosis ($n = 6/248$, 2.4%) and congenital scoliosis ($n = 3/135$, 2.2%) (Table 1). The mean time between initial implantation and index deep wound infection was 400.3 days (interquartile range: 36–709 days) and mean cohort follow-up was 3.6 years from time of initial implantation (interquartile range: 2.6–4.8 years). Mean cohort follow-up from time of index deep wound infection was 2.5 years (interquartile range: 1.8–3.2 years). 16 patients (48%) had the microorganism responsible for index infection recorded, with Staph Aureus being the most common cause (Table 2).

Table 1 Summary of deep wound infection (DWI) across EOS etiologies

Type of EOS	Age at primary surgery (years)	Rates of DWI	Time from implantation to Index DWI (days)	Follow-up following implantation (years)	Follow-up following DWI (years)
Neuromuscular	6.9 ± 2.1	3.6% (*n* = 13/354)	235.6	2.9 ± 1.1	2.3 ± 0.9
Syndromic	7.3 ± 2.5	4.0% (*n* = 9/225)	519	3.9 ± 1.3	2.5 ± 1.3
Idiopathic	7.0 ± 3.1	2.4% (*n* = 6/248)	215	4.0 ± 1.2	3.4 ± 0.9
Congenital	4.6 ± 1.6	2.2% (*n* = 3/135)	903	4.7 ± 0.5	2.2 ± 0.5
Unknown	9.4 ± 0.9	6.6% (*n* = 2/30)	734	3.8 ± 1.9	1.7 ± 0.2

Table 2 Microorganisms cultured at index infection

Microorganism	Salvage (*n* = 14)	Removed/exchanged (*n* = 2)
Staph. aureus	6	2
Other gram-positive cocci	2	0
Pseudomonas aeruginosa	3	0
E. coli	1	0
M. morganii	1	0
P. acnes	1	0

Table 3 Salvage versus non-salvage groups

	Salvage (*n* = 25)	Non-salvaged (*n* = 8)	*P* value
Age	6.9 ± 2.6	7.1 ± 2.0	0.85
Etiology	NMS: 9/13 (69%)	NMS: 4/13 (31%)	0.70
	Syndromic: 7/9 (77%)	Syndromic: 2/9 (23%)	
	Idiopathic: 5/6 (83%)	Idiopathic: 1/6 (17%)	
	Congenital: 3/3 (100%)	Congenital: 0/3 (0%)	
	Unknown: ½ (50%)	Unknown: ½ (50%)	
Number of MCGR revisions	1.8 ± 0.8	1.5 ± 0.5	0.57
Prior TGR	11 (44%)	3 (37.5%)	0.74

MCGR removal and exchange

Of the 33 EOS patients who developed deep wound infections, MCGRs were salvaged in 76% (25/33) patients. There were no differences in age ($p = 0.85$), EOS etiology ($p = 0.70$), whether traditional growing rods were utilized previously ($p = 0.74$), or number of MCGR revisions ($p = 0.57$) between patients who retained MCGRs following deep wound infection and those who had implants removed and exchanged (Table 3). In patients with acute infections, rods were salvaged in 7/13 (54%) cases compared to 18/20 cases (90%) in patients with late infections ($p = 0.02$).

Recurrent infection

Only 4/33 patients (12.1%), 2 with neuromuscular scoliosis and 2 with syndromic scoliosis, had a recurrent infection at a mean of 81.2 ± 53.4 days after index infection. There were no significant differences in rates of recurrent infection between salvage (*n* = 3/25) and non-salvaged group (*n* = 1/8, p = 0.97). In our cohort, there were no differences in rates of recurrent infection between those with an acute infection (2/4) and those with a late infection (2/4) ($p = 0.64$).

Discussion

We conducted a retrospective review of 33 EOS patients queried from a multicenter database who underwent MCGR implantation complicated by subsequent deep wound infection. We assessed the prevalence of recurrent deep wound infection across those who retained their implants (salvage group) and those who underwent removal and exchange (non-salvage group). We found that across our cohort, rate of recurrent deep wound infection was 12.1%, with no significant differences between salvage and non-salvage group. However, rates of recurrent infection were nominally the highest in pediatric patients with neuromuscular (*n* = 2) and syndromic (*n* = 2) scoliosis.

With I&D and antibiotic therapy, spinal implants may be safely retained following deep wound infection. Yin et al. conducted a retrospective series on 42 adult patients who developed a deep wound infection following spinal instrumentation (cervical laminoplasty, transforaminal lumbar interbody fusion, or posterior lumbar interbody fusion) [10]. The authors reported that 41/42 (97.6%) patients were able to successfully retain their implants following debridement of devitalized tissue, biofilm removal, thorough washing with normal saline, hydrogen peroxide and povidone iodine, and postoperative antibiotic therapy. Only one patient developed recurrent infection and had implants removed. Similarly, we report that in EOS patients with MCGRs, implants may be safely retained in approximately 88% (22/25) of patients, with only 3 cases of recurrent infection

in the salvaged group. These findings indicate that in the EOS population, across all scoliosis etiologies, surgeons can consider I&D and antibiotic therapy prior to pursing total implant removal and exchange.

When stratifying prevalence of index deep wound infection and recurrent infection by scoliosis etiology, patients with neuromuscular or syndromic EOS had nominally higher rates of (1) Developing a primary deep wound infection following MCGR implantation and (2) Developing recurrent deep wound infection. Previous literature has established that neuromuscular and syndromic patients are at high risk of deep wound infection following posterior spinal fusion and growth-guided intervention. In a retrospective review of complications following posterior spinal fusion in 102 neuromuscular patients, Toll and colleagues reported that 36.7% of patients developed a deep wound infection postoperatively [11]. Similarly, in a retrospective series of 1353 pediatric scoliosis patients, Sullivan et al. determined that neuromuscular patients (10%) and syndromic (4.7%) have higher risks of deep wound infection following primary PSF, compared to idiopathic scoliosis [12]. With regards to EOS specifically, Cahill et al. reported that in EOS patients treated with rib-based distraction techniques, neuromuscular scoliosis patients were at the highest risk for deep wound infection (5.7%), compared to other types of scoliosis [13]. For the first time in the literature, we report that neuromuscular and syndromic EOS patients have a nominally greater prevalence of not only primary deep wound infection following MCGR implantation, but also recurrent infection. Further studies with greater sample sizes may be beneficial to determine statistical associations between EOS etiology and prevalence of recurrent infection.

Safely salvaging MCGRs following deep wound infection may have significant implications for EOS patients and their families. MCGRs have a high upfront cost, with costs reported to vary between $13,125 and $21,875 for a single rod. In addition, the implantation surgery can cost upwards of sixty-four thousand dollars. Moreover, despite allowing for less invasive distraction and having a lower infection rate compared to traditional growing rods, MCGRs may still experience implant malfunction. In a retrospective review of 54 EOS patients treated with MCGRs, Choi et al. reported that 11.1% of patients had broken rods, 11.1% failed to lengthen, and 13% had a proximal or distal anchor complication [9]. These complications often require surgical revision or subsequent rod removal and exchange. Considering this immense financial and medical burden placed on patients and their families, the results of our study may indicate that for some complications, specifically deep wound infection, total implant replacement is not necessary. Rather, deep wound infection in this patient population may be safely managed with more conservative treatment first, without significant differences in risk of recurrent infection on long-term follow-up. These results have the potential to result in immense cost savings for the patient, without compromising on their postoperative outcomes.

Our retrospective cohort study has several strengths. To identify EOS patients who developed a deep wound infection following MCGR implantation, we utilized a large, multicenter database with prospectively enrolled patients to maximize our sample size. As such, this study represents the largest analysis of recurrent infection rate in EOS patients following MCGR implantation. Further, we verified that all patients who under MCGR rod removal and exchange following deep wound infection did not undergo rod removal for non-infectious etiologies, including rod breakage, failure of the rod to distract, or for rod upsizing. Additionally, the long duration of mean follow-up time allowed us to capture development of wound infection outside the immediate perioperative period.

However, the results of this study must be taken in context of its limitations. First, our study is retrospective in design with a small sample size, increasing the likelihood of a Beta statistical error. Further, there was a limited amount of demographic and comorbidity information provided for each patient in the database, which prevented us for controlling for possible confounders including curve size, concurrent health issues, and ambulatory status. Moreover, our dataset did not have information on specific antibiotic regimens following deep wound infection for each patient. Due to these limitations of our multicenter dataset, we are unable to comment on each surgeon's decision to retain implants following deep wound infection. Future studies are warranted to further analyze which patients can safely retain implants following infection. Finally, we did not assess all complications or outcomes that may be associated with retaining MCGRs following infection, including extent of curve correction on final follow-up, thoracic height gain, and duration of antibiotic use.

Conclusion

Deep SSI following MCGR implantation occurs in approximately 3.3% of EOS patients. Surgeons may attempt more conservative interventions, such as I&D or revision, prior to considering total implant removal/exchange.

Author contributions KVS, MM, JG, YL, PDS and Pediatric Spine Study Group are made substantial contributions to the conception or design of the work, data analysis, interpretation of data, drafted the work and revised it critically for important intellectual content, approved the version to be published, and agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Code availability Not applicable.

Declarations

Conflict of interest The authors have no conflicts of interest with respect to the authorship and/or publication of this article. No portions of this work were previously published.

Ethical approval All studies have been carried out in accordance with relevant regulations of the US Health Insurance Portability and Accountability Act (HIPAA). IRB approval was attained for this study.

Consent to publication All authors consent to publication of this article.

Consent to participate All patient data were obtained with consent for use in clinical research. All patient information is de-identified.

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