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DEFORMITY

Magnetically Controlled Growing Rods Graduation

Deformity Control with High Complication Rate

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Study Design. A multicenter retrospective review of consecutive series of patients.

Objective. Long-term experience with using the magnetically controlled growing rods (MCGR) to treat patients with deformity in the growing spine to the conclusion of treatment with posterior spine fusion.

Summary of Background Data. MCGR treatment for growing spine gained popularity with paucity of long-term follow up data. We hypothesized that final fusion might be more effective in bringing additional correction of the spine deformity after treatment with MCGR than that reported after traditional growing rods (TGR) due to less scarring and auto-fusion.

Methods. Retrospective review of 47 patients with varied etiology, treated between 2011 and 2017 which graduated treatment were followed in five academic medical centers for average of 50 months (range, 10–88).

Results. The initial mean coronal deformity of 69.6° (95% CI 65–74) was corrected to 40° (95% CI 36–40) immediately after the MCGR implantation but progressed to 52.8° (95% CI 46–59) prior to the final surgery ($P < 0.01$). Nevertheless, thoracic spine growth (T1–T12 height) improved from 187.3 mm (95% CI 179–195) following index surgery to 208.9 mm (95% CI 199–218) prior to final fusion ($P < 0.01$). Significant correction and spinal length were obtained at final fusion, but metallosis was a frequent observation (47%, 22/47). The average growth rate was 0.5 mm/month (95% CI 0.3–0.6). The overall complication rate within our cohort was 66% (31/47) with 45% (21/47) of unplanned returns to the operating theater. 32% (15/47) of the patients had an implant related complication. Unplanned surgery was highly correlated with thoracic kyphosis greater than 40° (OR 5.42 95% CI 1.3–23).

Conclusion. Treatment of growing spine deformities with MCGR provides adequate control of spine deformity it is comparable to previously published data about TGR. The overall high complications rate over time and specifically implant related complications.

Key words: complications, growing spine deformity, magnetically controlled growing rods, metallosis, traditional growing rods.

Level of Evidence: 4

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Treating deformity in the growing spine is challenging regardless of the underlying etiology. Traditional growing rods (TGR) have been used to treat deformity in the growing spine with a high rate of complications and a need for multiple lengthening procedures.[1] The popularity of TGR declined after the introduction of magnetically controlled growing rods (MCGR) with its potential to treat growing patients without subsequent lengthening procedures.[2,3] The potential advantages of the system extend beyond minimizing surgeries to stimulating spine growth, reducing interference with daily life, improving long-term quality of life (QOL), and reducing the incidence of surgical site infection.[4,5] Many of these beliefs have since been challenged including any effects of metallosis, the long-term impact of which is not fully understood.[6–13]

Due to complications seen with growth friendly systems and metallosis with the MCGR, it is recommended that implants are removed at the end of growth prior to definitive instrumented fusion. This has been reported as difficult after TGR due to significant buildup of scaring of the soft tissues and auto-fusion.[14–16]

In this retrospective, multicenter study we aimed to describe the surgical outcomes, complications, and radiographic results of patients followed until graduation from

MCGR treatment to final fusion. We hypothesized that final fusion could be more effective in bringing additional correction of the spine deformity after treatment with MCGR than that reported after TGR due to less scarring and autofusion. Only a single previous study has investigated graduates from MCGR, thus this study provides novel long-term follow up.[17]

PATIENTS AND METHODS

Patients

We performed a retrospective study of MCGR graduates from five tertiary academic centers. Data collection followed individual institution review board approval. The inclusion criteria were: patients with significant remaining spinal growth (open triradiate cartilage) treated using MCGR (MAGEC, NuVasive, San Diego, CA) between October 2011 and May 2017 and subsequent posterior spine fusion (PSF). There was no minimum follow up and the postoperative image assessed was that taken at last follow up.

Surgical Procedure

The index surgical procedure was carried out with hooks, pedicle screws, or both for the proximal foundation and screws for the distal foundation. Double rod constructs were used in 46 of the cases (29 patients with 4.5 mm and 18 cases with 5.5 mm rods). Intraoperative spinal cord monitoring with motor evoked potentials (MEP) and somatosensory evoked potentials (SSEP) was used for all patients. Most patients were protected with a thoracolumbar sacral stabilization orthosis (TLSO) brace for 3 to 4 months following the index procedure. One patient with a syndromic deformity was diagnosed with a late surgical infection that necessitated implant removal 2 years prior to the PSF. The timing of final fusion varied and was based on the residual growth potential, any complications and possible need for a revision.

MCGR Lengthening Protocol

Implant distraction took place in the outpatient clinic with an external remote controller. The rate of distraction was at the surgeons' discretion and ranged from 0.7 to 1 mm per month of treatment at a mean interval of 2.5 months (range, 2–3 months). Patients were evaluated with an x-ray or every 6 months. Some centers conducted ultrasound evaluation to assess lengthening after each distraction.

Outcome Parameters

Radiographic parameters were measured by a senior spine surgeon and included the coronal angular deformity (using the Cobb method), T1–T12 height (measured from the superior endplate of T1 to inferior endplate of T12), and proximal junctional kyphosis (PJK). Thoracic kyphosis was measured as the maximal kyphosis visible on the sagittal radiograph regardless of its length and location, as this more usefully represents the sagittal deformity being considered. Complications were identified from patient charts. Metallosis was recorded but not considered as a complication.

Data were preoperatively, immediately after the index surgery, prior to the final surgery, and at the final follow up following PSF.

Statistical Analysis

Data were recorded and analyzed in Microsoft Excel v.16.32 (Microsoft, WA, USA) and analyzed using Stata v14.0 (StataCorp, TX, USA). Continuous variables were assessed for normality using the Shapiro-Wilks test and compared using two tailed *t* tests. Continuous data within a single case were compared using a paired *t* test. Correlation between continuous and categorical data was carried out using one-way Analysis of variance (ANOVA). Categorical data were compared using chi-square and Fisher exact test. A significance level of 0.05 was used for all analyses.

RESULTS

Forty-seven eligible patients (12 males, 35 females) were included. The mean age at the time of MCGR surgery (index surgery) was 9.2 years (range, 5–14 yrs). Patients presented with varied etiologies: 17 neuromuscular (NMS), 10 syndromic (SS), 10 congenital (CS), and 10 idiopathic (IS) (Table 1).

Insertion of MCGR was the primary surgery in 42 patients. One patient was converted from traditional growing rods and four from vertical expandable prosthetic titanium rib (VEPTR) devices.

The mean preoperative major angular coronal deformity was 69.6° (95% CI 65.2°–73.9°), which reduced to a mean of 40° (95% CI 36.1°–43.9°) following the index surgery ($P < 0.01$) (Figure 1). At an average of 4.2 (range, 0.9–7.4) years of MCGR treatment and prior to final fusion, the mean angular deformity increased to 52.8° (95% CI 46.6°–59°), reducing to 34.8° (95% CI 28.9°–40.8°) following PSF (Table 2). Mean thoracic kyphosis prior to MCGR was 39.2° (95% CI 32.0°–46.5°) which changed to 37.8° (95% CI 30.4–45.3) prior to fusion and 37.6° (95% CI 31.1–44.2) after fusion.

The mean thoracic height (T1–T12 segment) was 174.8 mm (95% CI 166.9–182.7) before the index surgery, increasing to 187.3 mm (95% CI 179.3–195.2) following the index surgery owing to the intraoperative distraction and partial correction of the deformity ($P < 0.01$). Prior to final fusion, the thoracic height was 208.9 mm (95% CI 199.3–218.5), representing an average rate of spine growth of 0.5 mm (95% CI 0.3–0.6) per month. After final fusion, the mean T1–T12 height improved to 219 mm (95% CI 211–227) ($P < 0.01$) (Figure 2). Metallosis was seen in 22 patients (47%) during final fusion.

Subgroup Analysis

Subgroup analysis by underlying diagnosis showed no significant difference in deformity correction or spinal growth (Table 2). Further analysis comparing patients that were

TABLE 1. Demographics of the Cohort by Diagnosis

Demographic/ Diagnosis	CS (n = 10)	Idiopathic (n = 10)	NMS (n = 17)	SS (n = 10)	Total (n = 47)
Female/Male	9/1	9/1	11/6	6/4	35/12
Age at MCGR implantation in years (range)	9.6 (7.0–14.0)	9.6 (5.0–13.0)	8.9 (6.2–13.0)	9.0 (7.0–11.0)	9.2 (5.0–14.0)
Age at graduation (range)	14.2 (11.9–18.3)	13.9 (11.3–15.9)	12.7 (9.6–15.1)	13.1 (9.8–16.1)	13.4 (9.6–18.3)
Preoperative thoracic kyphosis (TK) ° (95% CI)	45.3 (35.5–55.1)	46.1 (18.0–74.2)	32.2 (19.2–45.2)	38.3 (26.1–50.5)	39.2 (32.0–46.5)
Preoperative major curve ° (95% CI)	62.3 (56.0–68.6)	68.4 (59.5–77.4)	76.2 (66.6–85.9)	66.6 (60.1–73.1)	69.6 (65.2–73.9)
Preoperative T1–T12 height in mm (95% CI)	173.9 (157.1–190.6)	187.5 (156.9–218.1)	169.9 (156.2–183.6)	176.5 (163.2–189.8)	174.8 (166.9–182.7)

CS indicates congenital scoliosis; MCGR, magnetic controlled growing rod; NMS, neuromuscular scoliosis; SS, syndromic scoliosis.

converted to MCGR from either TGR or VEPTR confirmed no differences in change in angular coronal deformity, gain in thoracic height and rate of spinal growth (Table 3).

Complications

Sixteen patients (34%) graduated from MCGR treatment without complications or unplanned surgery. Thirty-one patients (66%) had at least one complication (Table 4). Twenty-one patients (44%) required an unplanned return to the operating theatre. Fifteen patients (32%) had rod related complications; 10 sustained rod breakage and five rod slippage. Five patients (11%) were diagnosed with deep wound infection treated with debridement. Seven intraoperative neuromonitoring events were recorded during final

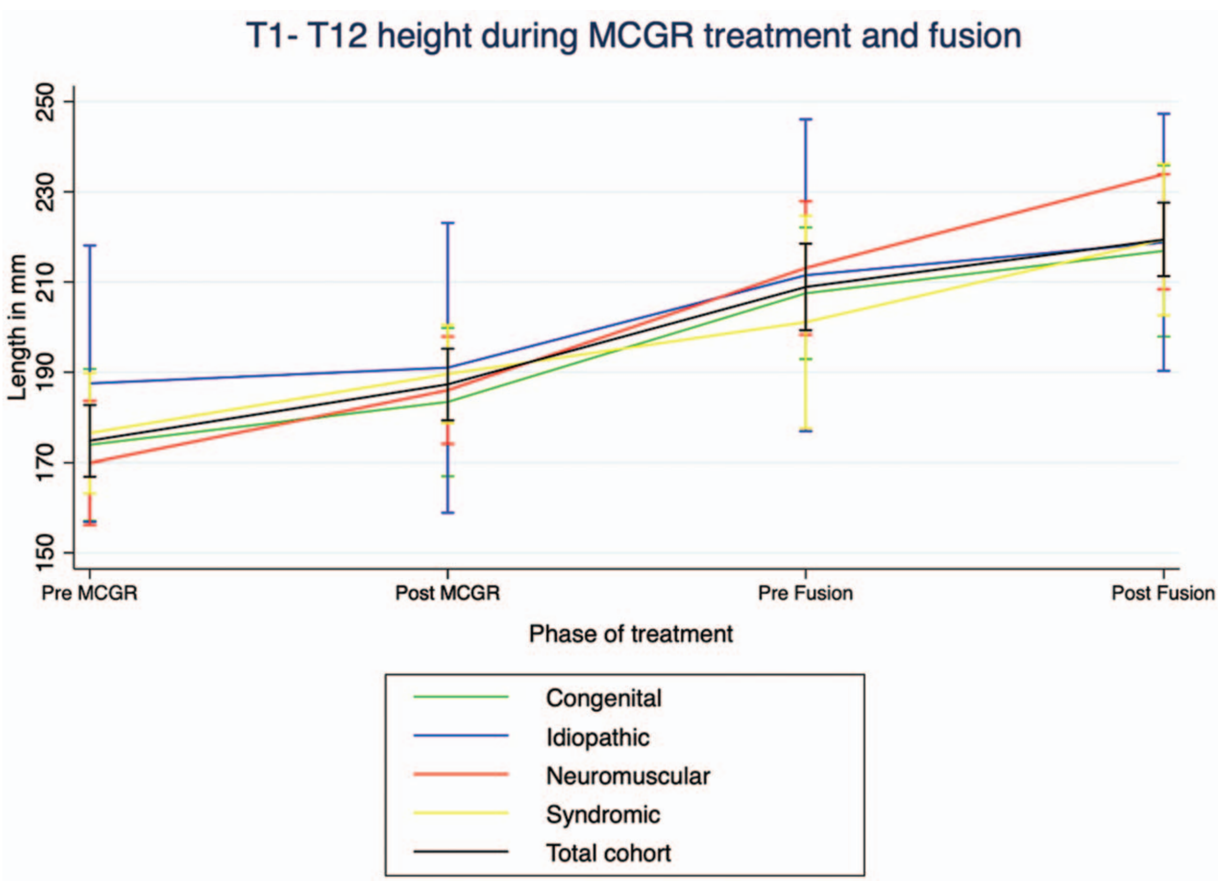

Figure 1. T1–T12 height change over time. Data points represent mean ± SD. MCGR indicates magnetically controlled growing rod.

TABLE 2. Radiographic Outcomes

Outcome/Diagnosis (N)	CS (10)	Idiopathic (10)	NMS (17)	SS (10)	Total (47)	*P*
Length of distraction phase, months (range)	55.6 (28.1–88.9)	51.9 (26.9–85.1)	46.5 (22.3–86.3)	49.4 (10.1–84.8)	50.2 (10.1–88.9)	
Median number of lengthenings (IQR)	19 (12–22)	12 (6–14)	14 (7–20)	9 (5–15)	14 (7–21)	
Post index major curve in ° (95% CI)	41.8 (36.0–47.6)	38.2 (27.9–48.5)	43.5 (35.7–51.4)	34.1 (25.4–42.8)	40.0 (36.1–43.9)	0.3244
Pre-definitive thoracic kyphosis in ° (95% CI)	43.6 (26.3–60.9)	45.9 (20.9–70.9)	30.1 (20.3–39.9)	37.2 (18.4–56.0)	37.8 (30.4–45.3)	0.3924
Pre-definitive major curve graduation in ° (95% CI)	49.5 (42.2–56.8)	54.2 (38.4–70.0)	57.0 (43.0–71.0)	47.6 (35.6–59.6)	52.8 (46.6–59.0)	0.6781
Thoracic kyphosis after final fusion in ° (95% CI)	45.0 (31.4–58.6)	40.1 (20.3–59.9)	31.3 (21.8–40.8)	38.5 (19.5–57.5)	37.6 (31.1–44.2)	0.4625
Major curve after final fusion in ° (95% CI)	33.6 (20.2–46.9)	40.8 (27.6–54.0)	35.8 (22.8–48.7)	28.5 (18.2–38.8)	34.8 (28.9–40.8)	0.5989
Post index T1–T12 height in mm (95% CI)	183.4 (167.0–199.8)	191.0 (158.9–223.1)	186.0 (174.1–197.9)	189.6 (178.7–200.5)	187.3 (179.3–195.2)	0.9237
Pre-definitive T1–T12 height in mm (95% CI)	207.5 (192.9–222.1)	211.5 (176.9–246.1)	213.1 (198.3–227.9)	201.1 (177.5–224.7)	208.9 (199.3–218.5)	0.8268
T1–T12 height after final fusion in mm (95% CI)	216.9 (197.9–235.9)	218.8 (190.3–247.3) N = 10	221.2 (208.4–233.9) N = 17	219.4 (202.6–236.2) N = 10	219.4 (211.3–227.6)	0.9863
T1–T12 growth (mm/month) (95% CI)	0.4 (0.3–0.6)	0.4 (0.2–0.7)	0.7 (0.3–1.0)	0.3 (-0.1–0.7)	0.5 (0.3–0.6)	0.2716

One-way ANOVA was used to compare between groups.
CS indicates congenital scoliosis; NMS, neuromuscular scoliosis; SS, syndromic scoliosis; t1, immediately post-implantation of MCGR; t2, immediately pre fusion.

fusion. Five patients woke without any neurological deficit. Two patients with NMS had postoperative urinary incontinence which was considered as a potential neurologic complication. One patient with NMS developed a neurologic deterioration 1 year following his index surgery which was attributed to medial migration of his proximal anchors. The mean duration of PSF was 259 minutes (95% CI 238–280) with a mean estimated blood loss of 503 mL

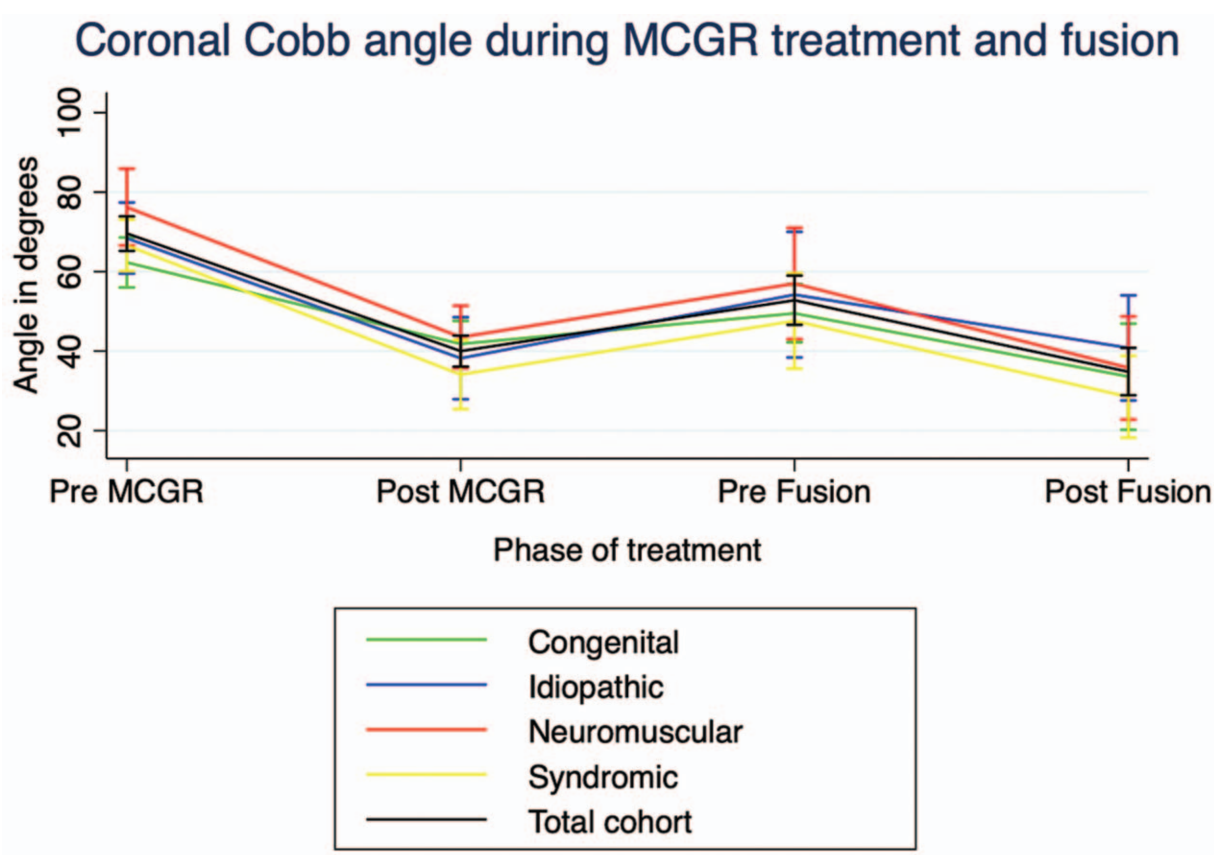

Figure 2. Coronal Cobb angle control over time. Data points represent mean ± SD. MCGR indicates magnetically controlled growing rod.

TABLE 3. Conversion *Versus* the Rest of the Patients

Demographic/Diagnosis	Converted	Not Converted	Pv	Total
N	5	42	–	47
Female/Male	4/1	31/11	–	35/12
Age at MCGR implantation in years (range)	9 (7–14)	9.2 (5–13)	0.8196	9.2 (5.0–14.0)
Age at graduation (range)	13.7 (11.3–18.3)	13.3 (9.57–16.4)	0.6832	13.4 (9.6–18.3)
Pre MCGR TK in ° (95% CI)	38.4 (31.5–45.3)	39.4 (31.2–47.5)	0.9348	39.2 (32.0–46.5)
Pre MCGR-Cobb in ° (95% CI)	65.0 (54.1–75.9)	70.1 (65.4–74.9)	0.4616	69.6 (65.2–73.9)
Length of MCGR months (range)	56.5 (28.0–80.4)	49.5 (10.1–88.9)	0.8394	50.2 (10.1–88.9)
Median number of lengthenings (IQR)	23 (15–23)	14 (6–20)	0.2387	14 (7–21)
Cobb after MCGR insertion in ° (95% CI)	40.8 (27.0–54.6)	39.9 (35.7–44.2)	0.8917	40.0 (36.1–43.9)
TK prior to graduation in ° (95% CI)	38.4 (31.5–45.3)	39.2 (30.9–47.4)	0.3125	39.2 (32.0–46.5)
Cobb prior to graduation in ° (95% CI)	57.2 (43.6–70.8)	52.3 (45.4–59.1)	0.6269	52.8 (46.6–59.0)
TK after definitive fusion in ° (95% CI)	32.6 (25.1–40.1)	38.3 (31.0–45.7)	0.5858	37.7 (31.1–44.2)
Cobb after definitive fusion in ° (95% CI)	44.0 (22.4–65.6)	34.0 (27.6–40.4)	0.3469	35.8 (22.8–48.7)
Pre MCGR T1–T12 height in mm (95% CI)	162.8 (150.7–174.8)	176.9 (168.9–185.2)	0.2571	175.4 (167.8–183.0)
T1–T12 height after insertion of MCGR in mm (95% CI)	177.4 (159.9–194.9)	188.5 (179.7–197.2)	0.3955	187.3 (179.3–195.2)
T1–T12 height before definitive fusion in mm (95% CI)	196.2 (173.5–218.9)	210.5 (199.9–221.1)	0.3570	208.9 (199.3–218.5)
T1–T12 height after definitive fusion in mm (95% CI)	203.5 (173.5–233.5)	221.0 (212.3–229.6)	0.2295	219.4 (211.3–227.6)
t1–t2 rate of growth (mm/mo) (95% CI)	0.38 (−0.11–0.76)	0.50 (0.34–0.65)	0.6053	0.5 (0.3–0.6)

Comparison between converted patients and the rest of the patients. t Test was used to compare between the groups. t1 indicates immediately post-implantation of MCGR; t2, immediately pre-fusion.

(95% CI 403–605). Instrumented levels were expanded either proximally, distally or both in 25 patients (53%) during the final surgery and fusion was extended to the pelvis in 10 cases. Four patients sustained a dural tear during the final fusion. A complete list of complications is presented in Table 5.

There was a trend towards a higher rate of complication within the CS patients (90%) when compared with the

TABLE 4. Complications *Versus* Non-complications

Demographic/Complication	Number of Patients With At Least One Complication	Number of Patients With No Complication	*P*-Value
n	31 (66%)	16 (34%)	
Age in years at insertion of MCGR (range)	8.9 (5–14)	9.7 (7–13)	$P = 0.2353^{**}$
Gender			$P = 0.725^{*}$
Male	7	5	
Female	24	11	
Etiology			$P = 0.232^{*}$
CS	9	1	
Idiopathic	5	5	
NMS	10	7	
SS	7	3	
Rod diameter			$P = 0.236^{\dagger}$
4.5	21	10	
5.5	8	8	

Comparison between patients that had complications and patients that did not.
CS indicates congenital scoliosis; NMS, neuromuscular scoliosis; SS, syndromic scoliosis.
***t test.*
**Fishers exact.*
†*Chi-square.*

TABLE 5. Complications by Diagnosis

Complication/Diagnosis	CS (n = 10)	Idiopathic (n = 10)	NMS (n = 17)	SS (n = 17)	Total (n = 47)
Number of cases undergoing an unplanned surgery	6 (60%)	5 (50%)	7 (41%)	3 (18%)	21 (45%)
Number of cases with a diagnosed infection requiring treatment	0	2 (20%)	3 (18%)	0	5 (11%)
Number of cases showing proximal foundation failure	4 (40%)	1 (10%)	2 (12%)	4 (23%)	11 (23%)
Number of cases with a rod breakage (at least 1)	5 (50%)	2 (20%)	2 (12%)	1 (6%)	10 (21%)
Number of cases showing rod slippage	1 (10%)	1 (20%)	1 (6%)	2 (12%)	5 (10%)
Number of cases showing metallosis at definitive fusion	8 (80%)	7 (70%)	4 (23%)	3 (18%)	22 (47%)
Neurologic deficit	0	0	2 (12%)	1 (6%)	3 (6%)
CSF leak	0	0	3 (18%)	1 (6%)	4 (8%)
PJK	2 (20%)	1 (10%)	0	3 (18%)	6 (13%)

Complete list of complications with breakdown by diagnosis. Percentage is calculated by diagnosis.
CS indicates congenital scoliosis; CSF, cerebral spinal fluid; NMS, neuromuscular scoliosis; PJK, proximal junctional kyphosis; SS, syndromic scoliosis.

idiopathic group (50%) (Table 3). Among patients treated with 4.5 mm rather than 5.5 mm rods, 13/29 (45%) had rod breakage or slippage compared with 2/18 (11%) respectively. Thoracic kyphosis greater than 40° was associated with more frequent returns to unplanned surgeries with OR 5.42 (95% CI 1.3–23) ($P = 0.0006$), however was not associated with proximal foundation failure, rod breakage, or rod slippage.

Patients converted to MCGR from TGR or VEPTR showed significantly more proximal anchor failure than patients without previous surgery ($P = 0.008$). Within the broken rods, five out of 10 were diagnosed with congenital scoliosis (50%). Complications are presented according to the classification system for growing spine surgeries introduced by Smith *et al*[18] (Table 6).

DISCUSSION

Since its introduction, MCGR technology has become commonplace in managing deformity in the growing spine. In this study we present the long-term results for a consecutive series of patients treated with MCGR until definitive PSF. These data suggests that MCGR achieves an increase in thoracic length beyond that seen at intraoperative distraction while controlling thoracic kyphosis, and that although the major curve deteriorates during the course of treatment, patients gain some thoracic height and correction with final fusion.

Attention has been increasingly paid to expanding systems in the management of deformity in the growing spine as the consequences of early fusion have become understood.[19] At its inception, MCGR technology showed huge promise and a growing body of evidence has investigated the potential of the technology.[1,6] This series contributes through presenting the results of long-term follow-up of a consecutive series of patients who have completed MCGR treatment and graduated to PSF.

This cohort shows an average thoracic height gain of 0.5 mm/month, close to that observed by Subramanian *et al*[20] in 31 patients followed for average of 4 years. Similar results were found by Cheung *et al*[17] in 10 patients that were treated with MCGR for minimum 4 years. A recent systemic review compared growth rates between different growth friendly systems for scoliosis, finding that T1–T12 growth rates for patients treated with MCGR were 0.6 mm/month

TABLE 6. Device related Complications According to Early Onset Scoliosis Complication Classification (Smith *et al*)

Grade	Description	Number of Complications
I	Does not require unplanned surgery	23
II	Inpatient medical management	
IIA	Requires one unplanned surgery	21
IIB	Requires multiple unplanned surgeries	–
III	Requires abandoning growth friendly strategy	4
IV	Death	–

Number of complications divided by complication grade.

(range, 0.2–1.2) with an average follow up of 1.5 years.[21] Upasani *et al*[22] looked at 110 patients treated with TGR followed for an average of 8.2 years from the index procedure to fusion, finding an average growth rate of the T1–T12 segment of 0.25 mm/month. The differences might be attributable to length of follow up and the development of soft tissue scaring and auto-fusion following TGR treatment.[14–16,23]

The ability of the growing rod system to control deformity is key to its success. We were able to show that MCGR sustains a correction and permits an increase in thoracic height without changing thoracic kyphosis. Furthermore, these data show a deterioration in the magnitude of the coronal deformity which has also been observed with long-term follow up of TGR patients.[22] PSF after MCGR treatment increased thoracic height by a mean of 10 mm and improved coronal deformity by 34% (range, 0–83), suggesting that following MCGR, the spine has some residual flexibility. These results are comparable to previous TGR studies, including Cahill *et al*,[14] who reported an average of 44% additional correction on progression from TGR to final fusion with an average of 7 Smith-Petersen osteotomies. Helenius *et al*[16] calculated an average T1–T12 height gain of 10 mm with 24% of additional major curve correction during final fusion and an overall major curve correction in patients with severe early onset scoliosis of 51%, similar to our findings.

The number of participants and the length of follow up allowed analysis of the control of coronal and sagittal deformity, thoracic height, and rate of growth by underlying diagnosis. No differences were found between groups, which to our knowledge has not been previously described. It is possible that our analysis is underpowered owing to small number of patients within each group and multicenter studies with significantly larger numbers would be required to confirm this finding.

Previous analyses of patients that were converted to MCGR from VEPTR constructs or TGR have found a comparable growth rate during treatment but less distraction of the spine at the index procedure.[24,25] We found similar growth rates in our cohort of five converted patients, which was accompanied with an increased rate of proximal foundation failures when compared with those not converted.

It has been established that MCGR treatment shows an appreciable rate of complication and unplanned return to the operating theatre. Thakar *et al*[7] concluded their systemic review by showing a mean complication rate of 44.5% and a rate of unplanned surgery of 33% at an average follow up of 2.4 years. In our cohort, the complication rate reached 66% (31 patients had at least one complication) leading to 21 unplanned surgeries. The higher complication rate may be attributed to the longer follow up and the complexity of the patients within our cohort (only 21% idiopathic patients). We also observed that patients with thoracic kyphosis greater than 40° prior to MCGR implantation showed a higher rate of complication and unplanned surgeries, in contrast to those with less sagittal deformity. Interestingly, this does not appear to be due to a significant increase in either proximal junctional or implant failure. That resembles previously published information on TGR.[26]

Complications can categorized as either implant or non-implant related. In our cohort 31.5% of the patients had implant related complications (21% rod breakage, 10.5% slippage, and failure to distract). These findings are similar to previous literature with comparable follow up.[17,27] Half of the patients with CS broke their rods, and although not statistically significant, this is a trend which we were unable to identify in any previous reports, although similar findings were reported in a series of patients with CS treated with TGR followed for an average of 4 years where five broken rods were identified amongst eight patients.[28] Moreover, a trend towards increased rate of rod breakage with the 4.5 mm rods when compared with the 5.5 mm rods was found, and though this was not statistically significant, suggests that rod diameter may be an independent risk factor for complications.

Metallosis should be discussed cautiously because its significance in pediatric spine surgery is not clear. Recent reports regarding the occurrence of metallosis and the elevation of metal ions concentration in blood samples from treated patients have created understandable concern.[11–13,29] 47% of the patients in our cohort showed metallosis at their final surgery, although we hypothesize that it is under-reported as the rate of metallosis described by each center ranged from 0% to 100%.

Limitations

There are limitations to this study. The consistency of data reporting may have been variable across the included centers and there is potential bias in reporting metallosis. Furthermore, this consecutive group of patients represents the earliest patients treated with the new technology, so there is a possibility that we are observing a learning curve.

The strength of our study beyond the number of patients involved and the long-term follow up is the inclusion of MCGR treatment to its conclusion with posterior fusion.

CONCLUSION

In this study, patients treated with MCGR for deformity in the growing spine were followed to definitive fusion. The cohort showed control of deformity and ongoing growth of the thoracic spine. We have defined the rate of surgical and implant related complications and identified a correlation between rod breakage and both rod diameter and congenital scoliosis. Patients who were converted from other growth compatible systems showed a higher rate of proximal foundation failure but were otherwise comparable. We recommend the use of 5.5 mm rods, close radiographic observation, and counselling patients that revision surgery is needed in 45% of cases. The treatment with MCGR eliminated the need for repeated planed surgeries but the overall complication rate, deformity control, and growth gains are comparable to TGR.

➢ Key Points

- ❑ Treatment with MCGR helped maintaining thoracic spine growth in the developing spine.
- ❑ MCGR treated patients to conclusion of growth demonstrated significant spine flexibility at their final fusion.
- ❑ Long-term follow up with MCGR revealed significant number of complications and unplanned returns to the operating theatre.
- ❑ The treatment with MCGR eliminated the need for repeated planed surgeries but the overall complication rate, deformity control, and growth gains are comparable to the previously used TGR's.

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