

Magnetically Controlled Growing Rods' Use for Early-Onset Scoliosis Management: A Single-Center Experience

Monerah M. Annaim^{1,2}, Ali A. Alhandi^{1,2}, Abdullellah A. Alsheddi^{1,2}, Samir Alsayegh^{1,2,3}, Sami I. Aleissa^{1,2}

¹Department of Surgery, Division of Orthopedic Surgery, King Abdulaziz Medical City-Riyadh, Ministry of National Guard - Health Affairs, ²King Abdullah International Medical Research Center, ³Department of Orthopedic, King Abdullah Specialist Children Hospital, Ministry of National Guard - Health Affairs, Riyadh, Saudi Arabia

ABSTRACT

Objectives: The challenge in treating early-onset scoliosis (EOS) lies behind the nature of the disease and the technical difficulties. Magnetically controlled growing rods (MCGR) provide a noninvasive option of distraction in EOS. This study reports a single-center experience with the system, assessing hardware-related complications, radiological improvement of curves, and need for revision surgeries. **Methods:** This was a retrospective study of patients who underwent MCGR placement in a single center with a minimum of 2-year follow-up. Patient demographic data, etiology, and pre/postoperative sagittal and coronal plane images were reviewed. **Results:** Ten patients were analyzed. The mean age at surgery was 5.1 years. The average preoperative coronal curves were 22.9° in upper thoracic, 71.9° in thoracic, and 47.9° in lumbar, and the mean sagittal curves were 20.9 ± 26.6 in thoracic and 41.3 ± 28.1 in lumbar. The mean follow-up was 3.8 years. The average of progression in all planes was monitored in follow-ups, 15.1° (upper thoracic coronal), 41.0° (thoracic coronal), 24.7° (lumbar coronal), 30.8° (thoracic sagittal), and 18° (lumbar sagittal). The mean percentage of improvement was 47% in the main curve. Seven patients had complications, including, three rod malfunction, four screw pullout that was prominent in two patients. Three patients had revisions due to suspected infection and failure of expansion. **Conclusions:** In this study, MCGR showed promising results where it enabled growth and showed acceptable improvement in the coronal plane with considerably fewer operations and complications. However, all patients had an alteration in the sagittal plane.

Keywords: Early-onset scoliosis, growing rods, magnetically controlled growing rods, pediatrics, scoliosis, spine

INTRODUCTION

Scoliosis is a three-dimensional deformity that has anatomical lateral, anteroposterior, and rotational components. Early-onset scoliosis (EOS) accounts for 80% of all cases; males and females are equally affected with a female predominance in severe-to-moderate curves.^[1] EOS is a description of curves that are more than 10° in pediatric patients younger than 10 years of age.^[2-5] The aim of treatment in EOS is to prevent the progression, allow growth, and achieve stability. Therefore, the treatment depends on the type, age, degree of curvature, and the presence of Risser sign.^[6,7] Spinal implants were used in the last decade and became the preferred treatment method. Growth friendly spinal implants have been the gold standard surgical treatment in EOS as they provided internal bracing, delayed spinal fusion, and allowed growth.^[6,8] It was purposely developed to overcome the limitations of EOS's traditional management modalities.^[8] Traditional growing rods (TGR), vertical expandable prosthetic titanium ribs, and magnetically controlled growing rods (MCGR) are all currently used as distraction-based implants.^[2] The TGR

procedure will require patients to undergo distraction surgeries every 6 months under general anesthesia to lengthen the rods, sometimes reaching 15–18 operations until the final fusion at puberty.^[6,8] This objectively high number of surgical interventions carries a surgical and anesthetic risk, and not to mention possible wound complications. General anesthesia risk on developing brains has been addressed in the literature, and warnings have been raised by the Food and Drug Administration; For children <4 years of age, recommendation against receiving general anesthesia or for children to have repeated procedures and those that would last for >3 h.^[9,10] Furthermore, socioeconomic

Address for correspondence: Dr. Samir Alsayegh,
King Abdullah Specialist Children Hospital, Ministry of National
Guard - Health Affairs, Alrimayah, Riyadh 14611, Saudi Arabia.
E-mail: drsamiralsayegh@gmail.com

Received: 08-05-2020

Revised: 14-06-2020

Accepted: 08-07-2020

Published Online: 31-07-2020

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Annaim MM, Alhandi AA, Alsheddi AA, Alsayegh S, Aleissa SI. Magnetically controlled growing rods' use for early-onset scoliosis management: A single-center experience. *J Musculoskelet Surg Res* 2020;4:199-204.

Access this article online

Quick Response Code:



Website:
www.journalmsr.com

DOI:
10.4103/jmsr.jmsr_50_20

and psychological burdens on both the affected children and their parents cannot be understated.^[8] MCGR are, as the name indicates, controlled magnetically with an external device; they are placed initially in the same method as the traditional growing system. However, they provide a noninvasive option of distraction that can be done in an outpatient setting.^[6,8] Distraction can be done in fewer intervals and with conscious neurological monitoring during lengthening.^[8] This new system was able to correct the deformities and enable the growth of children with fewer complications, pain, cost, and time compared to the traditional system.^[6-8] The magnetic system is currently recommended by the National Institute for Health and Care Excellence guidelines due to its effectiveness and benefit to childhood scoliosis treatment when compared to the traditional rod systems, although the system is not free from drawbacks, as increased radiation exposure during distraction is cited in the literature.^[7] This study reports a single-center experience with the MCGR system, including assessing hardware-related complications, radiological improvement of curves, and need for revision surgeries.

MATERIALS AND METHODS

A retrospective cohort of ten pediatric patients who underwent MCGR placement as a treatment of EOS was included in the study. All included patients were skeletally immature with flexible curves and required no additional magnetic resonance imaging. The surgeries were done by two board-certified orthopedic spine surgeons in a single tertiary center. All patients followed the same protocol of clinic rod distraction, which was at 3-month intervals. Each visit, the rods were distracted by 2–3 mm depending on the targeted growth and patients' radiographic status. Patients who had <2 years of follow-up were excluded from the study.

Data from 2011 to 2018 were reviewed, and a total of ten patients who underwent MCGR placement surgery met the inclusion criteria. Patient demographics, etiology, and preoperative, postoperative, and last clinic visit of sagittal and coronal plane radiographs and spinal growth measurements were collected. Patients' follow-up data such as the number of distractions, hardware length reached, postoperative complications, and the

need for revision surgeries were all collected and reported. All images used for measurements were standing radiographs and were reviewed by a senior author (SS).

After acquiring the proper institutional review board approval, patients' data were collected from the hospital's database. Quantitative variables from patients' data were described using mean, standard deviation, and frequency. The analysis was done using Microsoft Excel (Microsoft corporation, Redmond, WA, USA) and the Statistical Package for the Social Sciences (SPSS) version 23 (SPSS Inc., Chicago, IL, USA). Student's *t*-test was used to compare pre- and postoperative Cobb angle improvement with a confidence interval of 95%, and $P \leq 0.05$ was considered statistically significant.

RESULTS

The ten patients included in the study were seven females and three males. The mean age at diagnosis was 50 ± 25.9 months. Two patients had idiopathic scoliosis, three had syndromic, four had neuromuscular, and one had congenital scoliosis. All patients were treated primarily with MCGR except one who had a conversion from TGR. All patients had dual growing rods; the instrumentation was done using proximal and distal screws except for two patients, in which proximal hooks were used. One patient had one rod removed after 2 years due to suspected infection. Two patients have completed the treatment course of MCGR placement, and the final fusion surgery was performed. The mean age at the initial surgery was 5.1 ± 2.1 years, the mean height preoperatively was 99.4 ± 17.4 cm, and the mean weight was 81.3 ± 14.7 kg.

Pre- and postoperative angle results in the coronal and sagittal planes are detailed in Tables 1-3. On the coronal plane, the mean percentage of improvement was 47% in the main curve at the last visit [Table 1]. Immediate postoperative angles were significantly improved for the upper thoracic and lumbar sections of the curve $P \leq 0.01$, whereas for the last follow-up, curve improvement was only statistically significant for the thoracic and lumbar sections of the curve $P < 0.01$ [Table 2]. The sagittal plane results showed a statistically significant improvement only in the thoracic spine on the last follow-up $P = 0.01$ [Table 2].

Table 1: Major curve change percentages for each patient shown in the coronal plane

Patient	Major curve preoperatively	Major curve postoperatively	Major curve last follow-up	Percentage of improvement
1	91	52	50	45.1
2	73	35	65	11
3	67	46.9	40	40.3
4	77	75	37	52
5	84	50	26	69
6	50	30	26	48
7	60	26	21	65
8	100	33	45	55
9	74	25	46	37.8
10	73	40	36	50.7
Mean	74.9	41.2	39.2	47.4

The mean follow-up was 15.3 ± 5.4 visits over 3.8 ± 1.8 years; the mean lengthening per visit was 2.4 ± 1.0 mm in the right (RT) rod and 2.4 ± 0.8 mm lengthening in the left (LT) rod [Table 3].

Patient number 1 had poor follow-up where her first clinic visit was 1 year after MCGR placement. At the time, her thoracic kyphosis worsened to 66° (from 47° preoperatively). She eventually reached 22° in the last follow-up visit, which is in

the acceptable range for kyphosis. Patient number 2 [Figure 1] had her growth spurt in the period of the final fusion surgery arrangement, which led to marginal improvement in her kyphosis from -11° to -3° and further straightening of her lumbar spine from -1° to -6° . Patient number 3 [Figure 2] also showed straightening of her spine with lumbar lordosis measured at 71° preoperatively to 3° at her last visit. A similar trend was seen with patient number 9 [Figure 3] with thoracic kyphosis straightening from 20° to 1° only at the final visit [Table 4].

Table 2: Preoperative, postoperative, and last follow-up spinal curve changes in the coronal plane for all patients

Patient	Curve progression in the coronal plane								
	Preoperative			Immediate postoperative			Last follow-up		
	Upper thoracic	Thoracic	Lumbar	Upper thoracic	Thoracic	Lumbar	Upper thoracic	Thoracic	Lumbar
1	12	91	72	5	52	37	0	50	38
2	30	73	54	24	35	30	52	65	56
3	57	67	33	25	46.9	20	27	40	20
4	0	47	77	0	25	75	0	55	37
5	25	84	52	9	50	22	9	26	15
6	22	50	23	15	30	6	26	26	1
7	35	60	0	19	26	0	10	21	0
8	13	100	83	8	33	27	10	45	41
9	0	74	56.7	0	25	8	0	46	29
10	35	73	28	27	40	12	17	36	10
Mean	22.9	71.9	47.8	13.2	36.2	23.7	15.1	41	24.7
P*				0.01	2.63	<0.01	5.37	<0.01	<0.01

*P value was considered significant if <0.05

Table 3: The follow-up data throughout treatment

	Follow-up data		Minimum
	Mean \pm SD	Maximum	
Number of follow-ups	15.3 \pm 5.4	27	9
Lengthening in the right rod in mm	2.4 \pm 1.0	4	1
Lengthening in the left rod in mm	2.4 \pm 0.8	4	1

SD: Standard deviation

Table 4: Preoperative, postoperative, and last follow-up spinal curve changes in the sagittal plane for all patients

Patient	Curve progression in the sagittal plane					
	Preoperative		Postoperative		Last follow-up	
	Thoracic	Lumbar	Thoracic	Lumbar	Thoracic	Lumbar
1	47	52	20	50	22	63
2	-11	-1	1	-3	3	-6
3	-3	71	16	10	21	3
4	47	53	30	30	34	34
5	55	41	14	30	23	28
6	2	29	12	56	17	53
7	21	73	25	40	15	46
8	-15	-4	-5	10	9	19
9	20	29	31	39	1	33
10	46	70	25	38	35	35
Mean	20.9	41.3	16.9	30	30.8	18
P*			0.55	0.26	0.01	0.21

*P value was considered clinically significant if <0.05

Seven patients had complications, including, three rod malfunction, four screw pullout that was prominent in two patients. Three patients had revisions due to suspected infection and failure of expansion. Four patients had screw pullout, two patients complained of hardware prominence, and three patients had revision surgeries due to suspected infection and failure of expansion.

The mean height in the last follow-up was 121.4 ± 18.2 cm. The spinal growth over the years of treatment is demonstrated in Table 5. The first patient had a growth spurt with poor follow-up, and her curve worsened after the 1st year postoperatively. Three patients reached maturity during follow-up, and two had their final fusion surgery. Changes in the sagittal plane for the two patients that underwent their fusion surgery are shown in Table 6 (kyphosis and lordosis).

Table 5: Patients' spinal growth throughout the treatment

Age	Instrumentation	Patient growth							
		T1-S1 length in cm							
		Preoperative	Postoperative	Year 1	Year 2	Year 3	Year 4	Last follow-up	
1	6	T3-T4/L3-L4	25.6	28		31.5	34.4	33.7	33.7
2	7	T2-T3/L3-L4	36.2	39.8	40.9		42.3		42.3
3	2	L3-L2/T3-T2	23.9	25.8	27.7	28.7			28.7
4	5	T2T3/L4-L5	28.4	30.4	29.1	31.7			31.7
5	6	T5-T4/L3-4	23.8	25.5	26	27.2	29	30.9	30.9
6	8	T2-T3/L2-L3	34.6	35	36	42.3			42.3
7	4	T3-T5/L3-L4	26.5	30.6		32.2		32.6	32.6
8	7	T2-3/L4-L5	28.5	30.4	32.2		32.2		32.2
9	4	T2*-T2*/L2-L3	26	28.4	30	31.6			31.6
10	2	T2*-T3/L4-L5	18.5	22	23.2	25			25
Mean	5.1		27.2	29.6	30.2	32.2	34.8	34.8	33.1

*Used T2 hooks

Table 6: Changes noted in thoracic kyphosis and lumbar lordosis in the sagittal plane after the final fusion for the two patients that underwent final fusion

Final fusion	Patient number 2 preoperative angles	Patient number 2 postoperative angles	Patient number 8 preoperative angles	Patient number 8 postoperative angles
Thoracic kyphosis	3	5	9	12
Lumbar lordosis	-6	-5.6	19	1

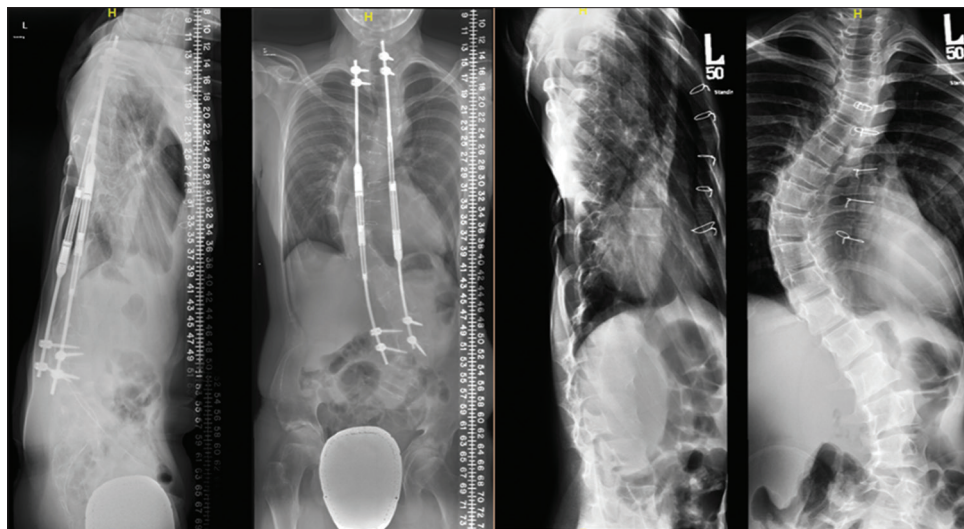


Figure 1: Patient No. 2 had her growth spurt in the period of the final fusion surgery arrangement, which lead to marginal improvement in her kyphosis from -11° to 3° and further straightening of her lumbar spine from -1° to -6°

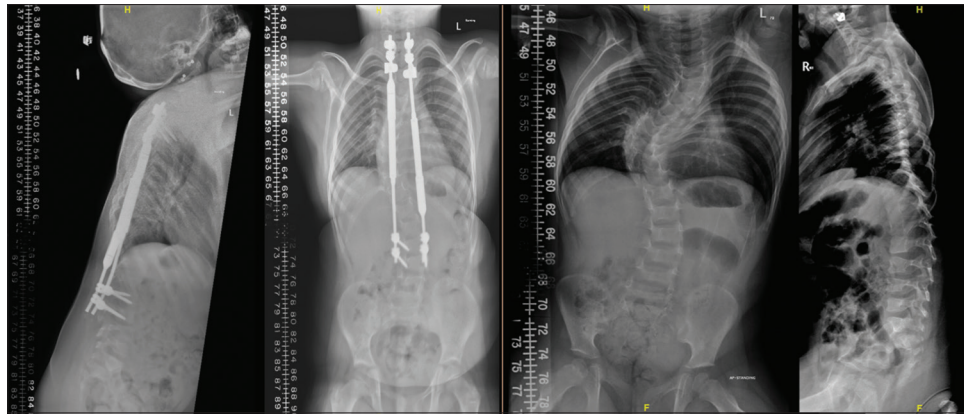


Figure 2: Patient No.3 also showed straightening of her spine with lumbar lordosis measured at 71 preoperatively to 3° at her last visit

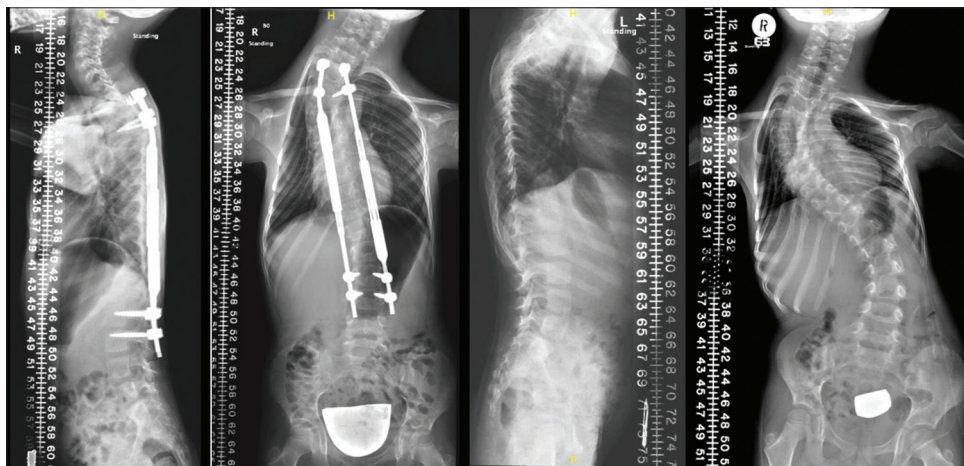


Figure 3: A similar trend seen with patient No.9 with thoracic kyphosis straightening from 20° to 1° only at the final visit

DISCUSSION

The challenge in the treatment of EOS mainly lies behind the nature of the disease and the technical difficulties. The treatment must target the deformity itself, maintain a balanced spine, and allow growth at the same time. Not to forget that the deformity is tridimensional, and the currently available treatment methods only target one or two dimensions at most. In this study, patients showed good improvement in their coronal plane of the major curve, with a mean of 47.4% improvement. Akbarnia *et al.* found in a comparative study between MCGR and TGR use that the coronal improvement in the last follow-up was 32% with MCGR and 31% in TGR.^[11] Similarly, Thompson *et al.* reviewed 19 patients over a mean of 22-month period, and the coronal improvement was 29.6% at the final follow-up.^[12] The primary placement of MCGR and secondary placement results of clinical improvement have been studied by Wimmer *et al.*, and they found that the coronal improvement was 51.3% and 16%, respectively.^[13] Furthermore, Keskinen *et al.* studied the difference between primary and conversion procedures; they found that the patients who had MCGR as their primary treatment have shown improvement by 38%, whereas the conversion group showed only 14.8% at 1-year follow-up.^[14] MCGR instrumentation showed its effectiveness in the coronal deformity

correction. However, in the sagittal plane, the patients tend to shift into a more straightened spine. This observation was seen in this study's population, as well. The problem has been described by Cheung *et al.*, where the usage of MCGR tends to straighten the spine, and the benefit of contouring can be relatively useful to a certain degree.^[15] Patients in the current study showed some improvement in the thoracic and lumbar sagittal curves. However, this improvement has shifted to a straight curve in some of the patients. Knowing that normal thoracic kyphosis ranges from 20° to 50° and the lumbar lordosis ranges from 31° to 79°,^[16] the sample showed mixed results in the sagittal plane [Tables 4 and 6]. As seen in our population, patient numbers 2, 3, and 9 showed good coronal curve improvements unlike in the sagittal plane. Such observation shows that patients do improve very well in the coronal plane while lagging behind in the sagittal plane. This phenomenon can be explained since the expansion occurs at the posterior column mainly, leading to the unintended straightening of the curve sagittally. Lebon *et al.* reported steady improvement in both the coronal and sagittal planes, and the final follow-up curves were 48° in both thoracic kyphosis and lumbar lordosis.^[17] Skov *et al.* have also reported similar good improvement in the mean sagittal plane; however, they had some outliers, with a range of 6°–65° in thoracic kyphosis and 19°–59° in lumbar lordosis at last follow-up.^[18] Keskinen *et al.* compared the sagittal balance in

patients with conversion surgery to primary MCGR placement in EOS. They found that patients who had conversion surgery had significantly worse results than those who underwent a primary MCGR procedure.^[14]

In this study, 70% of the patients had complications and 30% had revision surgeries. Moreover, 50% of the complications were due to hardware malfunction and screw pullout. These complications had been described in many case series; Figueiredo *et al.* found in a systematic review that the total complication rate in dual rod procedure is 30.9%. Nevertheless, the complications do not hold much of the burden when compared to TGR, since patients will need additional surgery down from multiple ones that have been avoided.^[19] Proximal junctional kyphosis (PJK) has been observed by some authors such as Hickey *et al.*, who reported it at 50% of their population.^[6] Lebon *et al.* had it only in one out of thirty patients.^[17] In our article, the analysis of PJK was not performed.

Patient compliance was a major issue in this population and was reflected in the results. However, the current study remains the first study recording the experience in using MCGR in the Middle East. Further research efforts should address population education and include more strict selection criteria. In addition, the small sample size, heterogeneity in the etiologies, and poor patients' compliance, as well as the functional outcome scores with the psychological outcomes, were not reported in the current study and are acknowledged by the authors as limitations.

CONCLUSIONS

MCGR showed promising results where it enabled growth and showed acceptable improvement in the coronal plane with considerably fewer operations. The study reported the possible complications that come with MCGR. However, most patients had an alteration in the sagittal plane, where it shifted into a more straightened spine. Moreover, patient compliance proved to be monumental for success.

Recommendation

A multicenter study with a larger sample size and proper parent education with more strict selection criteria, addressing rod malfunction, sagittal balance, and spinal growth is needed to better assess MCGR as the gold standard treatment in EOS.

Ethical approval

The ethical approval was obtained from the Institutional Review Board of King Abdullah International Medical Research Center, KAIMRC, Riyadh on 30th October 2017, with reference number IRBC-1475/17.

Acknowledgment

We would like to thank Walaa Abdullah Barnawi for her contributions to data collection.

Financial support and sponsorship

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

There are no conflicts of interest.

Authors' contribution

MMA designed and conducted the study, while AAH with MMA wrote the draft, and SIA with SA critically revised and approved the content. AAS collected, interpreted, and analyzed the data. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

REFERENCES

- Solomon L, Warwick D, Nayagam S, editors. Apley's system of orthopaedics and fractures. CRC press Taylor & Francis 338 Euston Road, London NW1 3BH; 2010.
- Yang S, Andras LM, Redding GJ, Skaggs DL. Early-onset scoliosis: A review of history, current treatment, and future directions. *Pediatrics*. 2016;137:e20150709. Doi: 10.1542/peds.2015-0709.
- Menger RP, Kalakoti P, Pugely AJ, Nanda A, Sin A. Adolescent idiopathic scoliosis: Risk factors for complications and the effect of hospital volume on outcomes. *Neurosurg Focus* 2017;43:E3.
- Beauchamp EC, Anderson RCE, Vitale MG. Modern surgical management of early onset and adolescent idiopathic scoliosis. *Neurosurgery* 2019;84:291-304.
- Cunin V. Early-onset scoliosis: Current treatment. *Orthop Traumatol Surg Res* 2015;101:S109-18.
- Hickey BA, Towriss C, Baxter G, Yasso S, James S, Jones A, *et al.* Early experience of MAGEC magnetic growing rods in the treatment of early onset scoliosis. *Eur Spine J* 2014;23 Suppl 1:S61-5.
- Jenks M, Craig J, Higgins J, Willits I, Barata T, Wood H, *et al.* The MAGEC system for spinal lengthening in children with scoliosis: A NICE Medical Technology Guidance. *Appl Health Econ Health Policy* 2014;12:587-99.
- Cheung KM, Cheung JP, Samartzis D, Mak KC, Wong YW, Cheung WY, *et al.* Magnetically controlled growing rods for severe spinal curvature in young children: A prospective case series. *Lancet* 2012;379:1967-74.
- Wilder RT, Flick RP, Sprung J, Katusic SK, Barbaresi WJ, Mickelson C, *et al.* Early exposure to anesthesia and learning disabilities in a population-based birth cohort. *Anesthesiology* 2009;110:796-804.
- Andropoulos DB, Greene MF. Anesthesia and developing brains-implications of the FDA Warning. *N Engl J Med* 2017;376:905-7.
- Akbarnia BA, Pawelek JB, Cheung KM, Demirkiran G, Elsebaie H, Emans JB, *et al.* Traditional growing rods versus magnetically controlled growing rods for the surgical treatment of early-onset scoliosis: A case-matched 2-year study. *Spine Deform* 2014;2:493-7.
- Thompson W, Thakar C, Rolton DJ, Wilson-MacDonald J, Nnadi C. The use of magnetically-controlled growing rods to treat children with early-onset scoliosis: Early radiological results in 19 children. *Bone Joint J* 2016;98-B:1240-7.
- Wimmer CS, Pfandlsteiner T, Siam AE. Preliminary results of treatment of early onset scoliosis using magnetic growing rods. *Ann Orthop Rheumatol* 2017;5:1077.
- Keskinen H, Helenius I, Nnadi C, Cheung K, Ferguson J, Mundis G, *et al.* Preliminary comparison of primary and conversion surgery with magnetically controlled growing rods in children with early onset scoliosis. *Eur Spine J* 2016;25:3294-300.
- Cheung JP, Cahill P, Yaszay B, Akbarnia BA, Cheung KM. Special article: Update on the magnetically controlled growing rod: Tips and pitfalls. *J Orthop Surg (Hong Kong)* 2015;23:383-90.
- Roussouly P, Nnadi C. Sagittal plane deformity: An overview of interpretation and management. *Eur Spine J* 2010;19:1824-36.
- Lebon J, Batailler C, Wargny M, Choufani E, Violas P, Fron D, *et al.* Magnetically controlled growing rod in early onset scoliosis: A 30-case multicenter study. *Eur Spine J* 2017;26:1567-76.
- Skov ST, Wijedicks SPJ, Büniger C, Castelein RM, Li H, Kruyt MC. Treatment of early-onset scoliosis with a hybrid of a concave magnetic driver (magnetic controlled growth rod) and a contralateral passive sliding rod construct with apical control: Preliminary report on 17 cases. *Spine J* 2018;18:122-9.
- Figueiredo N, Kananeh SF, Siqueira HH, Figueiredo RC, Al Sebai MW. The use of magnetically controlled growing rod device for pediatric scoliosis. *Neurosciences* 2016;21:17-25.