Early onset scoliosis

Early-onset scoliosis (EOS) is defined as a curvature of the spine in children >10° with onset before age 10 years. Young children with EOS are at risk for impaired pulmonary function because of the high risk of progressive spinal deformity and thoracic constraints during a critical time of lung development.

A retrospective case-match analysis consisting of 12 cases of EOS treated with the Dual Growing Rods (DGR) + apical control convex pedicle screws (ACPS) technique (group A) from 2010 to 2020, and matched with TDGR case (group B) at a ratio of 1:1 by age, sex, curve type, major curve degree, and apical vertebral translation (AVT). Clinical assessment and radiological parameters were measured and compared.

Results: Demographic characteristics, preoperative main curve, and AVT were comparable between groups. The correction ability of the main curve, AVT, and apex vertebral rotation was better in group A at index surgery ($P < .05$). The increase in T1-S1 and T1-T12 height was large in group A at index surgery ($P = .011$, $P = .074$). The annual increase in spinal height was slower in group A, but without significant difference. The surgical time and estimated blood loss were comparable. Six complications occurred in group A, and 10 occurred in group B.

Conclusion: In this preliminary study, ACPS seems to provide better correction of apex deformity, while attaining the comparable spinal height at 2-year follow-up. Larger cases and longer follow-up are needed to achieve reproducible and optimal results [1)].

Magnetically controlled growing rods (MCGR) were developed as an outpatient distraction system for EOS, allowing to avoid multiple surgeries.

A systematic review was conducted according to the PRISMA guidelines. PubMed, Google Scholar, Embase and Scopus were accessed in May 2022. All the clinical trials which investigate the role of MCGR for early-onset scoliosis were accessed. Only studies reporting data in patients younger than 10 years with a preoperative Cobb Angle greater than 40° were eligible. The following data were extracted at baseline and at last follow-up: mean kyphosis angle, overall mean Cobb angle, and mean T1-S1 length. Data from complications were also collected.

Data from 23 clinical studies (504 patients) were included in the present study. 56% (282 of 504) were females. The average length of the follow-up was 28.9 ± 16.0 months. The mean age of the patients was 8.7 ± 1.9 years old. The mean BMI was 17.7 ± 7.6 kg/m2. The mean kyphosis angle had reduced by the last follow-up ($P = 0.04$), as did the overall mean Cobb angle ($P < 0.0001$), while the overall T1-S1 length increased ($P = 0.0002$). Implant-associated complications, followed by spinal alignment failure, wound healing ailments, pulmonary complications, progressive trunk stiffness, persistent back pain, and fracture.

The management of EOS remains challenging. The current evidence indicates that MCGR may be effective to distract the spine and modeling the curve in EOS [2)].

Growing instrumentation procedures in EOS are associated with a low risk for post-operative shunt complications in patients with ventriculoperitoneal shunts. There were no shunt revision procedures performed in the first 2 years following rib-based device insertion. Sixteen percent of patients went on to require a shunt revision at some point during their follow-up, which is comparable to the baseline rate of shunt revision in non-EOS patients. [3)].

3: Matsumoto H, Fano AN, Ball J, Roye BD, George A, Garg S, Erickson M, Samdani A, Skaggs D, Roye DP, Vitale MG; Pediatric Spine Study Group. Uncorrected Pelvic Obliquity Is Associated With Worse Health-related Quality of Life (HRQoL) in Children and Their Caregivers at the End of Surgical Treatment for Early Onset Scoliosis (EOS). J Pediatr Orthop. 2022 Apr 1;42(4):e390-e396. doi: 10.1097/BPO.0000000000002096. PMID: 35142714.

4: Xu AL, Marrache M, Hardesty CK, Groves ML, Erickson MA, Murphy RF, Thompson GH, Sponseller PD; Pediatric Spine Study Group. Baclofen Pump Use: Complications After Growth-friendly Instrumentation for Early-onset Scoliosis. J Pediatr Orthop. 2022 Feb 1;42(2):77-82. doi: 10.1097/BPO.0000000000002035. PMID: 34882588.

5: Stuecker S, Mladenov K, Kunkel P, Hagemann C, Freiwald E, Stuecker R. Vertebral column growth in children with early onset scoliosis treated with magnetically controlled growing rods - Effects of distraction on vertebral and disc morphology. Surgeon. 2021 Sep 6:S1479-666X(21)00132-3. doi: 10.1016/j.surge.2021.07.007. Epub ahead of print. PMID: 34503893.

6: Marrache M, Suresh KV, Miller DJ, Hwang S, Schorry EK, Rios JJ, Sponseller PD. Early-Onset Spinal Deformity in Neurofibromatosis Type 1: Natural History, Treatment, and Imaging Surveillance. JBJS Rev. 2021 Jul 23;9(7). doi: 10.2106/JBJS.RVW.20.00285. PMID: 34297709.

7: Cali E, Dominik N, Manole A, Houlden H. Riboflavin Transporter Deficiency. 2015 Jun 11 [updated 2021 Apr 8]. In: Adam MP, Mirzaa GM, Pagon RA, Wallace SE, Bean LJH, Gripp KW, Amemiya A, editors. GeneReviews® [Internet]. Seattle (WA): University of Washington, Seattle; 1993–2022. PMID: 26072523.

8: Özcan Ç, Polat Ö, Alataş İ, Çamur S, Sağlam N, Uçar BY. Clinical and radiological results of kyphectomy and sliding growing rod surgery technique performed in children with myelomeningocele. J Orthop Surg Res. 2020 Dec 1;15(1):576. doi: 10.1186/s13018-020-02099-2. PMID: 33261632; PMCID: PMC7708111.

9: Lundkvist Josenby A, Westbom L. No support that early selective dorsal rhizotomy increase frequency of scoliosis and spinal pain - a longitudinal population-based register study from four to 25 years of age. BMC Musculoskelet Disord. 2020 Nov 27;21(1):782. doi: 10.1186/s12891-020-03782-5. PMID: 33246436; PMCID: PMC7697382.

10: Urbański W, Tucker S, Ember T, Nadarajah R. Single vs dual rod constructs in early onset scoliosis treated with magnetically controlled growing rods. Adv Clin Exp Med. 2020 Oct;29(10):1169-1174. doi: 10.17219/acem/126289. PMID: 33064377.

11: Garg B, Mohapatra S, Mehta N. Is routine intraoperative neuromonitoring necessary in growing rod lengthening procedures? A retrospective, observational study. Spine Deform. 2020 Dec;8(6):1369-1374. doi: 10.1007/s43390-020-00163-9. Epub 2020 Jun 24. PMID: 32583349.

12: Klyce W, Mitchell SL, Pawelek J, Skaggs DL, Sanders JO, Shah SA, McCarthy RE, Luhmann SJ, Sturm PF, Flynn JM, Smith JT, Akbarnia BA, Sponseller PD. Characterizing Use of Growth-friendly Implants for Early-onset Scoliosis: A 10-Year Update. J Pediatr Orthop. 2020 Sep;40(8):e740-e746. doi: 10.1097/BPO.0000000000001594. PMID: 32467421.

13: Tabibkhooei A, Sadeghipour A, Fattahi A. Thoracolumbar pilomyxoid astrocytoma concomitant with spinal scoliosis: A case report and literature review. Surg Neurol Int. 2019 Dec 6;10:235. doi: 10.25259/SNI_548_2019. PMID: 31893136; PMCID: PMC6911671.

14: Jeszenszky D, Kaiser B, Meuli M, Fekete TF, Haschtmann D. Correction to: Surgical growth guidance with non-fused anchoring segments in early-onset scoliosis. Eur Spine J. 2019 Oct;28(10):2434. doi: 10.1007/s00586-019-06125-8. Erratum for: Eur Spine J. 2019 Jun;28(6):1301-1313. PMID: 31463537.

15: Noureldine MHA, Shimony N, Jallo GI, Groves ML. Scoliosis in patients with Chiari malformation type I. Childs Nerv Syst. 2019 Oct;35(10):1853-1862. doi: 10.1007/s00381-019-04309-7. Epub 2019 Jul 24. PMID: 31342150.

16: Voirin-Hertz M, Carvajal Alegria G, Garrigues F, Simon A, Feydy A, Reijnierse M, van der Heijde D, Loeuille D, Claudepierre P, Marhadour T, Saraux A. Associations of lumbar scoliosis with presentation of suspected early axial spondyloarthritis. Semin Arthritis Rheum. 2020 Feb;50(1):48-53. doi: 10.1016/j.semarthrit.2019.06.008. Epub 2019 Jun 13. PMID: 31277929.

17: Miękisiak G, Kołtowski K, Menartowicz P, Oleksik Z, Kotulski D, Potaczek T, Repko M, Filipovič M, Danielewicz A, Fatyga M, Latalski M. The titanium-made growth-guidance technique for early-onset scoliosis at minimum 2-year follow-up: A prospective multicenter study. Adv Clin Exp Med. 2019 Aug;28(8):1073-1077. doi: 10.17219/acem/102269. PMID: 31237121.

18: Chen ZX, Kaliya-Perumal AK, Niu CC, Wang JL, Lai PL. In Vitro Biomechanical Validation of a Self-Adaptive Ratchet Growing Rod Construct for Fusionless Scoliosis Correction. Spine (Phila Pa 1976). 2019 Nov 1;44(21):E1231-E1240. doi: 10.1097/BRS.0000000000003119. PMID: 31181015.

19: Richter JE Jr, Samreen A, Vadlamudi C, Helmi H, Mohammad AN, Wierenga K, Hines S, Atwal PS, Caulfield TR. Genomic Observations of a Rare/Pathogenic SMAD3 Variant in Loeys–Dietz Syndrome 3 Confirmed by Protein Informatics and Structural Investigations. Medicina (Kaunas). 2019 May 15;55(5):137. doi: 10.3390/medicina55050137. PMID: 31096651; PMCID: PMC6571799.

20: Expert Panel on Pediatric Imaging:, Jones JY, Saigal G, Palasis S, Booth TN, Hayes LL, Iyer RS, Kadom N, Kulkarni AV, Milla SS, Myseros JS, Reitman C, Robertson RL, Ryan ME, Schulz J, Soares BP, Tekes A, Trout AT, Karmazyn B. ACR Appropriateness Criteria® Scoliosis-Child. J Am Coll Radiol. 2019 May;16(5S):S244-S251. doi: 10.1016/j.jacr.2019.02.018. PMID: 31054751.

21: Jeszenszky D, Kaiser B, Meuli M, Fekete TF, Haschtmann D. Surgical growth guidance with non-fused anchoring segments in early-onset scoliosis. Eur Spine J. 2019 Jun;28(6):1301-1313. doi: 10.1007/s00586-019-05934-1. Epub 2019 Mar 8. Erratum in: Eur Spine J. 2019 Aug 28;: PMID: 30848364.

22: Iyer S, Duah HO, Wulff I, Osei Tutu H, Mahmud R, Yankey KP, Akoto H, Boachie-Adjei O; FOCOS Spine Research Group. The Use of Halo Gravity Traction in the Treatment of Severe Early Onset Spinal Deformity. Spine (Phila Pa 1976). 2019 Jul 15;44(14):E841-E845. doi: 10.1097/BRS.0000000000002997. PMID: 30817734.

23: Liu J, Wu N; Deciphering Disorders Involving Scoliosis and COmorbidities (DISCO) study, Yang N,

Takeda K, Chen W, Li W, Du R, Liu S, Zhou Y, Zhang L, Liu Z, Zuo Y, Zhao S, Blank R, Pehlivan D, Dong S, Zhang J, Shen J, Si N, Wang Y, Liu G, Li S, Zhao Y, Zhao H, Chen Y, Zhao Y, Song X, Hu J, Lin M, Tian Y, Yuan B, Yu K, Niu Y, Yu B, Li X, Chen J, Yan Z, Zhu Q, Meng X, Chen X, Su J, Zhao X, Wang X, Ming Y, Li X, Raggio CL, Zhang B, Weng X, Zhang S, Zhang X, Watanabe K, Matsumoto M; Japan Early Onset Scoliosis Research Group, Jin L, Shen Y, Sobreira NL, Posey JE, Giampietro PF, Valle D; Baylor-Hopkins Center for Mendelian Genomics, Liu P, Wu Z, Ikegawa S, Lupski JR, Zhang F, Qiu G. TBX6-associated congenital scoliosis (TACS) as a clinically distinguishable subtype of congenital scoliosis: further evidence supporting the compound inheritance and TBX6 gene dosage model. Genet Med. 2019 Jul;21(7):1548-1558. doi: 10.1038/s41436-018-0377-x. Epub 2019 Jan 14. PMID: 30636772; PMCID: PMC6659397.

24: Margalit A, Sponseller PD, McCarthy RE, Pawelek JB, McCullough L, Karlin LI, Shirley ED, Schwend RM, Samdani AF, Akbarnia BA; Children's Spine Study Group, and the Growing Spine Study Group. Growth-Friendly Spine Surgery in Escobar Syndrome. J Pediatr Orthop. 2019 Aug;39(7):e506-e513. doi: 10.1097/BPO.0000000000001315. PMID: 30628977.

25: Cheung JPY, Yiu K, Kwan K, Cheung KMC. Mean 6-Year Follow-up of Magnetically Controlled Growing Rod Patients With Early Onset Scoliosis: A Glimpse of What Happens to Graduates. Neurosurgery. 2019 May 1;84(5):1112-1123. doi: 10.1093/neuros/nyy270. PMID: 30102378.

26: Beauchamp EC, Anderson RCE, Vitale MG. Modern Surgical Management of Early Onset and Adolescent Idiopathic Scoliosis. Neurosurgery. 2019 Feb 1;84(2):291-304. doi: 10.1093/neuros/nyy267. PMID: 30016462.

27: Hosseini P, Akbarnia BA. Commentary: Mean 6-Year Follow-up of Magnetically Controlled Growing Rod Patients With Early Onset Scoliosis: A Glimpse of What Happens to Graduates. Neurosurgery. 2019 May 1;84(5):E267-E268. doi: 10.1093/neuros/nyy318. PMID: 30010954.

28: Wu OC, Kasliwal MK. Commentary: Mean 6-Year Follow-up of Magnetically Controlled Growing Rod Patients With Early Onset Scoliosis: A Glimpse of What Happens to Graduates. Neurosurgery. 2019 May 1;84(5):E266. doi: 10.1093/neuros/nyy282. PMID: 29982674.

29: Shaw KA, Fletcher ND, Devito DP, Murphy JS. Complications following lengthening of spinal growing implants: is postoperative admission necessary? J Neurosurg Pediatr. 2018 Jul;22(1):102-107. doi: 10.3171/2018.2.PEDS1827. Epub 2018 Apr 27. PMID: 29701559.

30: Oates EC, Jones KJ, Donkervoort S, Charlton A, Brammah S, Smith JE 3rd, Ware JS, Yau KS, Swanson LC, Whiffin N, Peduto AJ, Bournazos A, Waddell LB, Farrar MA, Sampaio HA, Teoh HL, Lamont PJ, Mowat D, Fitzsimons RB, Corbett AJ, Ryan MM, O'Grady GL, Sandaradura SA, Ghaoui R, Joshi H, Marshall JL, Nolan MA, Kaur S, Punetha J, Töpf A, Harris E, Bakshi M, Genetti CA, Marttila M, Werlauff U, Streichenberger N, Pestronk A, Mazanti I, Pinner JR, Vuillerot C, Grosmann C, Camacho A, Mohassel P, Leach ME, Foley AR, Bharucha-Goebel D, Collins J, Connolly AM, Gilbreath HR, Iannaccone ST, Castro D, Cummings BB, Webster RI, Lazaro L, Vissing J, Coppens S, Deconinck N, Luk HM, Thomas NH, Foulds NC, Illingworth MA, Ellard S, McLean CA, Phadke R, Ravenscroft G, Witting N, Hackman P, Richard I, Cooper ST, Kamsteeg EJ, Hoffman EP, Bushby K, Straub V, Udd B, Ferreiro A, North KN, Clarke NF, Lek M, Beggs AH, Bönnemann CG, MacArthur DG, Granzier H, Davis MR, Laing NG. Congenital Titinopathy: Comprehensive characterization and pathogenic insights. Ann Neurol. 2018 Jun;83(6):1105-1124. doi: 10.1002/ana.25241. PMID: 29691892; PMCID: PMC6105519.

31: Chotai S, Basem J, Gannon S, Dewan M, Shannon CN, Wellons JC, Bonfield CM. Effect of Posterior Fossa Decompression for Chiari Malformation-I on Scoliosis. Pediatr Neurosurg. 2018;53(2):108-115. doi: 10.1159/000485254. Epub 2018 Jan 4. PMID: 29298440.

32: Chen Z, Li S, Qiu Y, Zhu Z, Chen X, Xu L, Sun X. Evolution of the postoperative sagittal spinal profile in early-onset scoliosis: is there a difference between rib-based and spine-based growth-friendly instrumentation? J Neurosurg Pediatr. 2017 Dec;20(6):561-566. doi: 10.3171/2017.7.PEDS17233. Epub 2017 Oct 6. PMID: 28984540.

33: Vivas AC, Hwang SW, Pahys JM. Insertion of magnetically controlled growing rods in a patient with a diaphragmatic pacemaker: case report. Neurosurg Focus. 2017 Oct;43(4):E14. doi: 10.3171/2017.7.FOCUS17356. PMID: 28965446.

34: Yılmaz B, Ekşi MŞ, Işik S, Özcan-Ekşi EE, Toktaş ZO, Konya D. Magnetically Controlled Growing Rod in Early-Onset Scoliosis: A Minimum of 2-Year Follow-Up. Pediatr Neurosurg. 2016;51(6):292-296. doi: 10.1159/000448048. Epub 2016 Aug 6. PMID: 27497928.

35: Ridderbusch K, Rupprecht M, Kunkel P, Hagemann C, Stücker R. Preliminary Results of Magnetically Controlled Growing Rods for Early Onset Scoliosis. J Pediatr Orthop. 2017 Dec;37(8):e575-e580. doi: 10.1097/BPO.0000000000000752. PMID: 27182837.

36: Jayaswal A, Kandwal P, Goswami A, Vijayaraghavan G, Jariyal A, Upendra BN, Gupta A. Early onset scoliosis with intraspinal anomalies: management with growing rod. Eur Spine J. 2016 Oct;25(10):3301-3307. doi: 10.1007/s00586-016-4566-5. Epub 2016 Apr 12. PMID: 27072552.

37: Jones CS, Stokes OM, Patel SB, Clarke AJ, Hutton M. Actuator pin fracture in magnetically controlled growing rods: two cases. Spine J. 2016 Apr;16(4):e287-91. doi: 10.1016/j.spinee.2015.12.020. Epub 2015 Dec 17. PMID: 26707076.

38: Auerbach JD, Kean K, Milby AH, Paonessa KJ, Dormans JP, Newton PO, Song KM, Lonner BS. Delayed Postoperative Neurologic Deficits in Spinal Deformity Surgery. Spine (Phila Pa 1976). 2016 Feb;41(3):E131-8. doi: 10.1097/BRS.0000000000001194. PMID: 26571164.

39: Desai SK, Sayama C, Vener D, Brayton A, Briceño V, Luerssen TG, Jea A. The feasibility and safety of using sublaminar polyester bands in hybrid spinal constructs in children and transitional adults for neuromuscular scoliosis. J Neurosurg Pediatr. 2015 Mar;15(3):328-37. doi: 10.3171/2014.9.PEDS1468. Epub 2015 Jan 2. PMID: 25555118.

40: Ramirez N, Flynn JM, Smith JT, Vitale M, Sturm PF, D'Amato C, Samdani A, Machiavelli R, El-Hawary R. Use of the S-hook for Pelvic Fixation in Rib-Based Treatment of Early-Onset Scoliosis: A Multicenter Study. Spine (Phila Pa 1976). 2015 Jun 1;40(11):816-22. doi: 10.1097/BRS.0000000000000443. PMID: 24921843.

41: Mesquita RC, D'Souza A, Bilfinger TV, Galler RM, Emanuel A, Schenkel SS, Yodh AG, Floyd TF. Optical monitoring and detection of spinal cord ischemia. PLoS One. 2013 Dec 16;8(12):e83370. doi: 10.1371/journal.pone.0083370. PMID: 24358279; PMCID: PMC3865183.

42: El-Hawary R, Sturm PF, Cahill PJ, Samdani AF, Vitale MG, Gabos PG, Bodin ND, d'Amato CR, Harris C, Howard JJ, Morris SH, Smith JT. Sagittal Spinopelvic Parameters of Young Children With Scoliosis. Spine Deform. 2013 Sep;1(5):343-347. doi: 10.1016/j.jspd.2013.07.001. Epub 2013 Sep 25. PMID: 27927390.

43: Ha Y, Maruo K, Racine L, Schairer WW, Hu SS, Deviren V, Burch S, Tay B, Chou D, Mummaneni PV, Ames CP, Berven SH. Proximal junctional kyphosis and clinical outcomes in adult spinal deformity surgery with fusion from the thoracic spine to the sacrum: a comparison of proximal and distal upper instrumented vertebrae. J Neurosurg Spine. 2013 Sep;19(3):360-9. doi: 10.3171/2013.5.SPINE12737. Epub 2013 Jul 12. PMID: 23848349.

44: Kunes J, Thompson GH, Manjila S, Poe-Kochert C, Cohen AR. Idiopathic intracranial hypertension following spinal deformity surgery in children. Neurosurg Focus. 2011 Oct;31(4):E20. doi: 10.3171/2011.7.FOCUS11160. PMID: 21961865.

45: Murans G, Gustavsson B, Saraste H. One-stage major spine deformity correction surgery: comparison between groups with and without additional neurosurgical intervention, with more than 24 months of follow-up. Clinical article. J Neurosurg Spine. 2010 Dec;13(6):666-71. doi: 10.3171/2010.5.SPINE08690. PMID: 21121742.

46: Geiger F, Rauschmann M. Dynamische Verfahren bei der juvenilen Skoliose [Dynamic instrumentation techniques in early-onset scoliosis]. Orthopade. 2009 Feb;38(2):122-4, 126-30. German. doi: 10.1007/s00132-008-1368-4. PMID: 19130042.

47: Lew SM, Kothbauer KF. Tethered cord syndrome: an updated review. Pediatr Neurosurg. 2007;43(3):236-48. doi: 10.1159/000098836. PMID: 17409793.

48: Benli IT, Uzümcügil O, Aydin E, Ateş B, Gürses L, Hekimoğlu B. Magnetic resonance imaging abnormalities of neural axis in Lenke type 1 idiopathic scoliosis. Spine (Phila Pa 1976). 2006 Jul 15;31(16):1828-33. doi: 10.1097/01.brs.0000227256.15525.9b. PMID: 16845359.

49: Hamlat A, Adn M, Ben Yahia M, Morandi X, Brassier G, Guegan Y. Gowers intrasyringal hemorrhage. Case report and review of the literature. J Neurosurg Spine. 2005 Dec;3(6):477-81. doi: 10.3171/spi.2005.3.6.0477. PMID: 16381211.

50: Ouvrier RA, McLeod JG, Morgan GJ, Wise GA, Conchin TE. Hereditary motor and sensory neuropathy of neuronal type with onset in early childhood. J Neurol Sci. 1981 Aug;51(2):181-97. doi: 10.1016/0022-510x(81)90097-6. PMID: 6268756.

1)
Zhao Y, Du Y, Yang Y, Lin G, Shen J, Wu N, Zhuang Q, Wang S, Zhang J. Dual Growing Rods Combined With the Apical Convex Control Pedicle Screw Technique Versus Traditional Dual Growing Rods for the Surgical Treatment of Early-Onset Scoliosis: A Case-Matched 2-Year Study. Neurosurgery. 2023 Mar 3. doi: 10.1227/neu.0000000000002431. Epub ahead of print. PMID: 36867052.

2)
Migliorini F, Chiu WO, Scrofani R, Chiu WK, Baroncini A, Iaconetta G, Maffulli N. Magnetically controlled growing rods in the management of early onset scoliosis: a systematic review. J Orthop Surg Res. 2022 Jun 11;17(1):309. doi: 10.1186/s13018-022-03200-7. PMID: 35690867.

3)
Johnson MA, Lott C, Kennedy BC, Heuer GG, Cahill PJ, Anari JB. Risk of ventriculoperitoneal shunt malfunction in operatively treated early onset spinal deformity. Spine Deform. 2022 Jun 6. doi: 10.1007/s43390-022-00527-3. Epub ahead of print. PMID: 35661994.