Review Article

Strategies for Treating Scoliosis in Early Childhood

Karsten Ridderbusch, Alexander S. Spiro, Philip Kunkel, Benjamin Grolle, Ralf Stücker, Martin Rupprecht

Summary

Background: Scoliosis in early childhood is defined as abnormal curvature of the spine of any etiology that arises before age 10. The affected children are at high risk of developing restrictive pulmonary dysfunction. The treatment presents major challenges because of the complexity and high morbidity of the disease.

Methods: This article is based on pertinent articles retrieved by a selective literature search, and on the results of a retrospective study by the authors.

Results: In addition to conservative treatment methods including physiotherapy, casts, and corsets, progressive scoliosis usually requires early surgical intervention. In recent years, many different so-called non-fusion techniques have been developed for the surgical treatment of early childhood scoliosis. The goal of this new strategy is to avoid early fusion procedures and to enable further growth of the rib cage, lungs, and spine in addition to correcting the scoliosis. The authors also present their own intermediate-term results with a novel growth-preserving spinal operation that exploits magnet technology.

Conclusion: Because of the low prevalence and heterogeneous etiology of early childhood scoliosis, the literature to date contains no randomized controlled therapeutic trials concerning this small group of high-risk patients. For the treatment to succeed, it is essential for specialists from all of the involved medical disciplines to work closely together. Conservative measures such as physiotherapy, casts, and corsets can delay the (frequent) need for surgery or even make surgery unnecessary, particularly in the idiopathic types of early childhood scoliosis. The new non-fusion techniques enable continued growth of the spine, rib cage, and lung in addition to correcting the scoliosis.

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Department of Pediatric Orthopedics, Altona Children's Hospital, Hamburg: Dr. med. Karsten Ridderbusch, PD Dr. med. Alexander S. Spiro, Prof. Dr. med. Ralf Stücker, Prof. Dr. med. Martin Rupprecht

Department of Orthopedics, University Medical Center Hamburg-Eppendorf (UKE), Hamburg: Dr. med. Karsten Ridderbusch, PD Dr. med. Alexander S. Spiro, Prof. Dr. med. Ralf Stücker, Prof. Dr. med. Martin Rupprecht

Department of Pediatric Neurosurgery, Altona Children's Hospital, Hamburg: Dr. med. Philip Kunkel

Department of Pediatrics, Altona Children's Hospital, Hamburg: Dr. med. Benjamin Grolle

Early-onset scoliosis (EOS) is defined as a curvature of the spine of any etiology, occurring before the age of 10 years (1, 2). The magnitude of scoliosis is assessed on an anteroposterior (AP) radiograph of the spine, using the Cobb method. Scoliosis is defined as a spinal curve angle (Cobb angle) greater than 10 degrees. To treat scoliosis, comprehensive knowledge of its causes, the normal development of chest and spine, and the natural course of scoliosis is required. Children under the age of 10 years with progressive EOS are during the critical phase of the development of the lungs at high risk of developing restrictive lung disease as the result of the thoracic cage deformity caused by the scoliosis (3). Muirhead et al. estimated the risk of moderate and severe ventilation impairment associated with infantile and congenital EOS to be 34% (4). The therapeutic spectrum for EOS extends from clinical monitoring, physiotherapy, serial casting, and bracing to growth-sparing surgical techniques. Today, the first-line surgical treatment of EOS relies on the placement of implants allowing for further growth of the spine. This approach has replaced early fusion surgery which is now obsolete.

The current aim of the treatment of early-onset scoliosis is to control scoliosis progression, while allowing for further growth of the spine and thorax.

Prevalence and etiology

The exact prevalence of EOS is unknown. For adolescent idiopathic scoliosis >10 degrees, the prevalence is reported to be 2–3% (5). Treatment of EOS is very complex due to the inhomogeneity of the conditions and the diverse comorbidities. Due to the variety of underlying factors, scoliosis has no general pathophysiological pathway.

Progression of EOS varies widely according to severity and etiology. It is distinguished between

- congenital malformations,
- neuromuscular disease, such as spinal muscle weakness or meningocele,
- scoliosis-associated syndromes, such as Marfan syndrome or Ehlers–Danlos syndrome,
- neurofibromatosis, and
- idiopathic scoliosis.

Congenital scoliosis with innate vertebral body malformations or complex malformations, including thoracic dysplasia or spondylocostal dysplasia (Jarcho–Levin syndrome) require specific and early treatment (*eTable*).

Figure: Scoliosis as the result of an unclear myopathy in a six-year-old girl

Idiopathic scoliosis is described as infantile idiopathic scoliosis if it presents in patients up to 3 years of age and as juvenile idiopathic scoliosis if it presents in patients 4 to 9 years of age (*Box*). Two types of infantile idiopathic scoliosis are distinguished: resolving, which takes a benign course with spontaneous remission (in up to 80% of cases), and malignant progressive (6). If left untreated, the course of infantile progressive scoliosis is unfavorable with high morbidity and mortality from cardiopulmonary complications (7). Boys and girls are equally affected (8). Based on the scoliosis curve type, the course of the disease is categorized as either benign or malignant. While a flexible harmonic c-shaped curve is typically benign, short structural abnormalities are often malignant/progressive in nature (6). As a general rule, whole spine magnetic resonance imaging (MRI) should be performed in all patients with progressive scoliosis and a Cobb angle of >20 degrees. In their study on 504 cases with infantile or juvenile scoliosis who were scanned with MRI, Zhang et al. found in 18.7% of patients intraspinal abnormalities, such as Arnold–Chiari, tethered-cord, syrinx and split-cord malformations (9).

Pulmonary problems, thoracic and spinal growth

In EOS, pulmonologists are especially concerned about the functional integrity of the lung parenchyma which translates into physiological gas exchange. The basic requirement for this is an undisturbed pre- and especially postnatal lung development. The formation of the alveoli, i.e. the differentiation from the primary to the secondary septa, starts at 36 weeks' gestation and

ends by age 3 years; consequently, at the time of birth only about one third of the later number of alveoli are functional. The lungs have developed adult morphology only by age 3 years; the mature lungs then enter into a period of “simple” growth (10, 11). The thoracic volumes in the newborn, by age 5 years and at age 10 years are 6%, 30% and 50%, respectively, of the final thoracic volume at skeletal maturity (12). Thus, if the thoracic cage configuration is compromised by, for example, early-onset scoliosis or early spinal fusion surgery, both the structural maturation and the quantitative development of lung parenchyma are affected (13). Especially during the first 5 years after birth, the spine from S1 to T1 grows at a very fast rate of 2 cm/year. It then plateaus between 5 and 10 years after birth (1 cm/year), followed by another acceleration (1.8 cm/year) during the growth spurt in puberty (12).

Indication for surgery

The decision whether surgical treatment is indicated in a patient with EOS should be based on scoliosis progression and/or the development of a chest wall deformity, rather than solely relying on the Cobb angle. However, surgery is generally indicated in patients with progressive scoliosis >50 degrees (14–16).

Primary spinal fusion surgery, i.e. spondylodesis, should not be performed early in childhood as it will impede or even halt the remaining spinal and thoracic growth (6, 17–21).

Discussion

Both conservative and surgical treatment of scoliosis in early childhood are challenging because of the impact of growth and the heterogeneity of the condition. The three columns of conservative treatment of EOS are physiotherapy, serial casting, and bracing. For the surgical treatment of early-onset scoliosis, growth-sparing procedures have become indispensable (*Box*).

Physiotherapy

From our point of view, the use of specific physiotherapy strategies is a crucial element of conservative scoliosis treatment and should be initiated when mild deformities (Cobb angle <20 degree) are present. However, the available evidence for EOS is weak. Small studies on adolescent idiopathic scoliosis (AIS) with short follow-up periods evaluating patients with mild scoliosis showed some degree of efficacy (22–24). The goals of physiotherapy are to stabilize the spine and the trunk muscles and to prevent secondary functional impairments.

Serial casting

Among the various etiologies of EOS, idiopathic EOS is most responsive to casting. Derotating and elongating plaster casting is applied on a special casting table (Risser table) under general anesthesia. Correct use does not result in additional deformation of the thoracic cage. The goal of serial casting is to achieve derotation and straightening of the curve. Altogether, the cast is changed three times and each cast brace is to be worn

BOX

Excursus: Distraction-based magnetically controlled growing rods for the treatment of early-onset scoliosis

Introduction

Conventional growing rod systems have to be surgically distracted every six months until skeletal maturity. Thanks to the new technique of magnetically controlled telescopic rods which can be distracted transcutaneously, patients no longer need to undergo these surgical lengthening procedures.

Material and methods

In a retrospective study with a postoperative follow-up (FU) period of at least 24 months, altogether 22 patients (15 female, 7 male) with early-onset scoliosis (EOS) underwent implantation of magnetically controlled growing rods (MCGR). Inclusion criteria comprised exhaustion of conservative treatment options, preoperative risk evaluation, and progressive Cobb angle >40 degrees.

Magnetically controlled growing rods, surgical technique, distraction

The MCGR system features a telescopic mechanism which can be distracted transcutaneously using an external electromagnet. The technique of MCGR implantation is comparable to the one used with conventional growing rods. The rods are advanced in the submuscular plane and anchored at the spine and/or pelvis using pedicle screws or lamina hooks. Every 4 months, transcutaneous distraction is performed without anesthesia, based on spinal growth curves (12, 18). In the *Figures*: pre- and postoperative radiographs (A, B) and radiographs taken 12 and 36 months after distraction, respectively (C, D).

Results

At the time of surgery, the average age of the pediatric patients was 8.8 ± 2.5 years (4.6–14.3). The most common conditions were syndromic ($n = 7$) and neuromuscular ($n = 5$) scoliosis. Of these patients, 91% ($n = 20$) had thoracic, 4.5% ($n = 1$) thoracolumbar, and 4.5% ($n = 1$) lumbar scoliosis. The mean duration of FU was 31 ± 7 months (24–46) and at least 6 distractions were performed on an outpatient basis at 4-month intervals (8 ± 2 ; 6–11).

Postoperative radiographic evaluation

The mean Cobb angles improved from 61 ± 14 degrees (range 40–96) by 54% to immediately postoperative 28 ± 19 degrees (range 11–53) after MCGR implantation ($n = 22$; $p < 0.001$). The Cobb angle after the so far last FU was 26 ± 18 degrees (11–64; $n = 22$; $p = 0.54$). As the result of MCGR implantation, the thoracic height (T1–T12) increased by 11% from 18.3 ± 2.5 cm (range 13.1–23.4) to 20.4 ± 2.6 cm (range 15.2–25.9; $p < 0.001$); at the time of the last FU, the mean thoracic height was 22.5 cm (range 17.4–28.2; $p < 0.001$). The spinal height S1–T1 increased on average by 13% from 29.6 ± 4.3 cm (range 21.7–37.7) to 33.3 ± 4.3 cm (range 26.1–41.5) ($p < 0.001$). At the time of the last measurement, the mean spinal height was 35.9 cm on average (range 28.6–44.4). This corresponds to normal growth of 1 mm/months.

Adverse events

So far, no intraoperative adverse events have occurred. Over time, 4 patients developed a kyphosis above the instrumentation, referred to as a high thoracic junctional kyphosis. In 3 cases, revision surgery had to be performed to correct this kyphosis. In 1 patient, loosening of the proximal screw anchoring was observed, while in another patient the curve below the instrumentation increased ("adding on"). So far, no neurological adverse events or rod breakage have occurred. In all children, intraoperative neuromonitoring was performed.

Discussion

The available data show that the technique of percutaneous distraction-based magnetically controlled growing rods enables normal spinal growth, besides correction of the scoliosis (12). In contrast to earlier conventional methods, this is achieved without the need for repeated surgical distraction procedures. In our single-center study, we achieved a primary correction of the scoliosis with the initial surgery which was by 10 degrees (Cobb angle) greater compared to results from similar studies (39, 40). In our opinion, this is explained by the exclusive use of the double rod technique. During the distraction period, the outcomes tend to stabilize, with a trend to further reduction. When properly indicated, the MCGR technique represents a new treatment option in the management of early-onset scoliosis (38–40). The greatest advantage it offers is non-invasive extracorporeal distraction, allowing the spine and thoracic cage to continuously grow along. This reduces not only the adverse event rate and revision rate (31, 32), but also the hospitalization rate, postoperative pain, and psychological distress for the children (33).

KEY MESSAGES

- As they are growing, children with early-onset scoliosis are at an increased risk of developing severe deformities with restrictive lung function.
- Various conservative strategies, such as physiotherapy, casting and bracing, play a major role in the management of EOS.
- Due to the low prevalence and etiological heterogeneity of early-onset scoliosis, evidence-based data on the various treatment strategies are scarce.
- The management of progressive early-onset scoliosis requires a broad interdisciplinary diagnostic workup (spinal MRI, pulmonary function tests, among others) prior to the start of treatment.
- New distraction-based magnetically controlled implants allow lengthening of the spine in the growing child without the need for surgical distraction procedures.

for one month. Once this series is completed, the patient will receive brace treatment. Serial casting can usually be applied in children up to age 5 years. Especially in children who do not have a syndrome, complete correction of the scoliosis can be achieved with this treatment approach. The techniques of serial casting described by Mehta (25) are well documented and achieve impressive results in the conservative treatment of idiopathic early-onset scoliosis.

Bracing

As the third column, bracing plays an important role in the conservative treatment of idiopathic EOS. Besides the individually fitted brace, the basic requirement for successful bracing treatment is the multidimensional follow-up by the treating physicians, orthopedic technicians, and physiotherapists. Especially in young children, the horizontally aligned ribs are very soft so that inadequate pressure exerted by an ill-fitted brace can cause thoracic deformities by itself. Thus, bracing treatment should be performed according to the principles of Mehta (25) in EOS patients with a Cobb angle >20 degrees. The goal of bracing should be to reduce the primary curve by 50%. With regard to the various types of braces, the modified Chêneau brace and the Boston brace have been proven to be effective; this explains their widespread use (26). Apart from the correct fit of the brace, good patient guidance plays a key role, because treatment success mostly depends on acceptance and wearing duration. Solid evidence is available to support the use of brace treatment for idiopathic adolescent scoliosis (patients >10 years of age) (27). Katz et al. showed that if the brace is worn >12 h/day, 82% of patients experienced no further scoliosis progression (28). The prospective randomized level-1 BraIST study demonstrated the efficacy of bracing in adolescent idiopathic scoliosis relative to watchful waiting alone. Brace treatment was successful in 75% of patients in the bracing group compared to 42% of patients in the group with watchful waiting alone. Successful treatment was defined as scoliosis with a Cobb angle <50 degrees at skeletal maturity.

Furthermore, the clear relationship between daily wear time of the brace and the efficacy of the treatment was confirmed. Wear times of 0–6 h/day resulted in improvements in 41% of patients, while the success rates with wear times >12.9 h/day were 90–93% (29).

Non-fusion techniques

In pediatric patients, spinal fusion surgery leads to disproportionate growth with shorter trunk length and the associated secondary effects on chest wall development and the development of the lungs. Karol et al. showed that the number of fused spinal segments is closely correlated with reduced vital capacity. In order to prevent restrictive lung function in adulthood, thoracic height (T1–T12) should not be below 22 cm at skeletal maturity (30). Thus, spinal fusion surgery, the standard of care for major adolescent scoliosis, should no longer play a role in the management of EOS in early childhood scoliosis or, if indispensable, should only be performed over a short length, as, for example, during resection of half the vertebral body. Various distraction-based “grow-along” non-fusion techniques, such as the Vertical Expandable Prosthetic Titanium Rib (VEPTR) or the conventional growing rod technique, have been developed. However, repeated surgical distractions had to be performed to ensure that these implants can “grow along”. Distraction surgery is typically performed every 6 months. It is associated with a significant adverse event rate and considerable psychological stress for the children (31–33).

With the Shilla growth guidance technique, certified since 2012, the primary curve of the scoliosis is instrumented with pedicle screws and corrected using rods. Proximally and distally of the deformity, the rods are guided by multi-axial sliding screws, designed to enable further spinal growth along the rods (34). Further techniques include anterolateral tethering and the use of staples; however, so far these procedures have only been evaluated in very small patient populations (35). These techniques involve the placement of staples in the convex side of the vertebral bodies. The resulting epiphysiodesis effect, which has also been used successfully to control the growth of extremities, straightens the curve with growth without spinal fusion.

The most advanced non-fusion technique is the magnetically controlled growing rod. These growing rods are surgically anchored in the spine cranially and caudally of the scoliosis. In contrast to conventional growing rod systems, these rods can be transcutaneously distracted using electromagnets. These distractions are usually performed every 4 months on an outpatient basis without anesthesia (36), sparing these children from repeated surgical lengthening procedures (37), postoperative pain, and inpatient stays (*Box*).

Besides choosing an appropriate non-fusion technique, careful preoperative decision-making as to whether the procedure is indicated as well as the

assessment and evaluation of the risks of surgery and anesthesia are essential. Once skeletal maturity is reached, implant removal with subsequent spinal fusion surgery is required to prevent future progression of the deformity. Over the course of the disease, clinical and radiographic follow-up assessments are required.

Conclusion

Due to the etiological diversity of early-onset scoliosis combined with its low prevalence, randomized controlled studies evaluating this small high-risk patient population are scarce in the literature. Thus, successful management of EOS depends on good and close multidisciplinary cooperation of all healthcare professionals involved. Conservative strategies, such as physiotherapy, casting and bracing, can delay the time of surgical correction which is often required. However, especially in idiopathic early-onset scoliosis, conservative treatment alone may achieve satisfactory outcomes. In patients who experience progression of scoliosis despite conservative treatment (Cobb angle >50 degrees), comprehensive interdisciplinary assessment of the child as a basis for risk evaluation is required. Besides the correction of the curve, new non-fusion techniques ensure the further growth of the spine, thoracic cage, and lungs. With this approach, early spinal fusion surgery on the growing child can be avoided (38–40).

Conflict of interest statement

Dr. Ridderbusch received reimbursement of travel and accommodation expenses from Orthovative. He received fees for preparing continuing medical education events from Nuvasive.

Prof. Stücker received fees for conference participation and reimbursement of travel and accommodation expenses from Nuvasive. He also received fees from Nuvasive for preparing continuing medical education events.

Dr. Kunkel received fees for preparing continuing medical education events from Nuvasive.

Dr. Spiro, Dr. Grolle, and Prof. Rupprecht declare that no conflict of interest exists.

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References

1. Akbarnia BA, El-Hawary R: Letter to the editor, early onset scoliosis: time for consensus. *Spine Deform* 2015; 3: 105–6.
2. Skaggs DL, Guillaume T, El-Hawary R, et al.: Early onset scoliosis consensus statement, SRS Growing Spine Committee. *Spine Deform* 2015; 3: 107.
3. Stücker R: The growing spine: normal and abnormal development. *Orthopäde* 2016; 45: 534–9.
4. Muirhead A, Conner AN: The assessment of lung functions in children with scoliosis. *J Bone Joint Surg (Br)* 1985; 67B: 699–702.
5. Weinstein SL: Natural history. *Spine* 1999; 24: 2592–600.
6. Lloyd-Roberts GC, Pilcher MF: Structural idiopathic scoliosis in infancy: a study of the natural history of 100 patients. *J Bone Joint Surg Br* 1965; 47: 520–3.
7. Pehrsson K, Larsson S, Oden A, Nachemson A: Long-term follow-up of patients with untreated scoliosis. A study of mortality, causes of death, and symptoms. *Spine* 1992; 17: 1091–6.
8. Trobisch P, Suess O, Schwab F: Idiopathic scoliosis. *Dtsch Arztebl Int* 2010; 107: 875–83.

9. Zhang W, Sha S, Xu L, et al.: The prevalence of intraspinal anomalies in infantile and juvenile patients with „presumed idiopathic“ scoliosis: a MRI-based analysis of 504 patients. *BMC Musculoskelet Disord* 2016; 17: 189.
10. Burri PH: Structural aspects of prenatal and postnatal development and growth of the lung. In: McDonald J (ed.): *Lung growth and development*. Dekker, New York 1997: 1–35.
11. Koumbourlis AC: Chest wall abnormalities and their clinical significance in childhood. *Paediatric Respiratory Rev* 2014; 15: 246–54.
12. Dimeglio A, Canavese F, Charles YP: Growth and adolescent idiopathic scoliosis: when and how much? *J Pediatr Orthop* 2011; 31 (Suppl 1): 28–36.
13. Mehta HP, Snyder BD, Baldassari SR, et al.: Expansion thoracoplasty improves respiratory function in a rabbit model of postnatal pulmonary hypoplasia: a pilot study. *Spine* 2010; 35: 153–61.
14. Edgar M, Mehta M: Long-term follow-up of fused and unfused idiopathic scoliosis. *J Bone Joint Surg* 1988; 70B: 712–6.
15. Weinstein SL: Idiopathic scoliosis. Natural history. *Spine* 1986; 11: 780–3.
16. Weinstein SL, Ponseti IV: Curve progression in idiopathic scoliosis. *J Bone Joint Surg* 1983; 65A: 447–55.
17. McMaster MJ, Macnicol MF: The management of progressive infantile idiopathic scoliosis. *J Bone Joint Surg (Br)* 1979; 61-B: 36–42.
18. Sponseller PD, Yazici M, Demetracopoulos C, Emans JB: Evidence basis for management of spine and chest wall deformities in children. *Spine* 2007; 32 (Suppl 19): 81–90.
19. Fernandes P, Weinstein SL: Natural history of early onset scoliosis. *J Bone Joint Surg Am* 2007; 89 (Suppl 1): 21–33.
20. Campbell RM, Smith MD, Mayes TC, et al.: The characteristics of thoracic insufficiency syndrome associated with fused ribs and congenital scoliosis. *J Bone Joint Surg (Am)* 2003; 85-A: 399–408.
21. Campbell RM, Smith MD: Thoracic insufficiency syndrome and exotic scoliosis. *J Bone Joint Surg (Am)* 2007; 89-A (Suppl): 108–22.
22. Rigo M, Quera-Salvá G, Villagrasa M, et al.: Scoliosis intensive outpatient rehabilitation based on Schroth method. *Stud Health Technol Inform* 2008; 135: 208–27.
23. Weiss HR, Klein R: Improving excellence in scoliosis rehabilitation: a controlled study of matched pairs. *Pediatr Rehabil* 2006; 9: 190–200.
24. Schreiber S, Parent E, Moez E, et al.: The effect of Schroth exercises added to the standard of care on the quality of life and muscle endurance in adolescents with idiopathic scoliosis—an assessor and statistician blinded randomized controlled trial: “SOSORT 2015 Award Winner” *Scoliosis* 2015; 10: 24.
25. Mehta MH: Growth as a corrective force in the early treatment of progressive infantile scoliosis. *J Bone Joint Surg Br* 2005; 87: 1237–47.
26. Weinstein SL, Dolan LA, Wright JG, et al.: Design of the Bracing in Adolescent Idiopathic Scoliosis Trial (BrAIST). *Spine* 2013; 38: 1832–41.
27. Helfenstein A, Lankes M, Ohlert K, et al.: The objective determination of compliance in treatment of adolescent idiopathic scoliosis with spinal orthoses. *Spine* 2006; 31: 339–44.
28. Katz DE, Herring JA, Browne RH, Kelly DM, Birch JG: Brace wear control of curve progression in adolescent idiopathic scoliosis. *J Bone Joint Surg Am* 2010; 92: 1343–52.
29. Weinstein SL, Dolan LA, Wright JG, Dobbs MB: Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med* 2013; 369: 1512–21.
30. Karol LA, Johnston C, Mladenov K, Schochet P, Walters P, Browne RH: Pulmonary function following early thoracic fusion in non-neuromuscular scoliosis. *J Bone Joint Surg (Am)* 2008; 90: 1272–81.
31. Bess S, Akbarnia BA, Thompson GH, et al.: Complications of growing-rod treatment for early-onset scoliosis: analysis of one hundred and forty patients. *J Bone Joint Surg (Am)* 2010; 92: 2533–43.
32. Sankar WN, Acevedo DC, Skaggs DL: Comparison of complications among growing spinal implants. *Spine* 2010; 35: 2091–6.
33. Flynn JM, Matsumoto H, Torres F, Ramirez N, Vitale MG: Psychological dysfunction in children who require repetitive surgery for early onset scoliosis. *J Pediatr Orthop* 2012; 32: 594–9.

34. Wilkinson JT, Songy CE, Bumpass DB, et al.: Curve modulation and apex migration using shilla growth guidance rods for early-onset scoliosis at 5-year follow-up. *J Pediatr Orthop* 2017 [Epub ahead of print].
35. Boudissa M, Eid A, Bourgeois E, et al.: Early outcomes of spinal growth tethering for idiopathic scoliosis with a novel device: a prospective study with 2 years of follow-up. *Childs Nerv Syst* 2017; 33: 813–8.
36. Ridderbusch K, Rupprecht M, Kunkel P, Stücker R: Non-fusion techniques for treatment of pediatric scoliosis. *Orthopäde* 2013; 42: 1030–7.
37. 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; 37: e575–80.
38. Cheung KM, Cheung JP, Samartzis D, et al.: Magnetically controlled growing rods for severe spinal curvature in young children: a prospective case series. *Lancet* 2012; 379: 1967–74.
39. Akbaria BA, Cheung K, Noordeen H, et al.: Next generation of growth-sparing technique: preliminary clinical results of a magnetically controlled growing rod (MCGR) in 14 patients with early onset scoliosis. *Spine* 2013; 38: 665–70.
40. Dannawi Z, Altaf F, Harshavardhana NS, Elsebaie H, Noordeen H: Early results of a remotely operated magnetic growth rod in early-onset scoliosis. *Bone Joint J* 2013; 95-B: 75–80.

Corresponding author

Dr. med. Karsten Ridderbusch
Abteilung für Kinderorthopädie
Altonaer Kinderkrankenhaus
Bleickenallee 38
22763 Hamburg, Germany
karsten.ridderbusch@kinderkrankenhaus.net

► **Supplementary material**

eTable:
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CLINICAL SNAPSHOT

Intractable Postoperative Lymphatic Fistula with Impaired Wound Healing

A 76-year-old man underwent the excision of an aneurysm of the common femoral artery with implantation of an ilio-femoral Dacron bypass graft. Postoperatively, an inguinal lymphatic fistula with impaired wound healing developed and was treated with a vacuum-sealed dressing. Superficial microbiological cultures were negative, good granulation was seen at the wound edges, and the wound was closed secondarily 24 days after the original procedure, but lymphatic secretion persisted thereafter. 10 days later, transpedal lymphangiography was performed with the aim of selectively obliterating the fistula. Over the ensuing three days, lymphatic secretion stopped completely, and the patient was discharged home with a partially healed wound. Full healing was documented on outpatient follow-up one month later.

Intractable lymphatic fistulae arise after up to 30% of operations

in the groin. These can be treated successfully with transpedal lymphangiography: the iodinated oil leads to selective blockage of the afferent lymphatic vessels as well as sterile inflammation at the fistula site, which causes it to heal with a scar.

PD Dr. med. Christof M. Sommer, Christina Goerig, Prof. Dr. med. Götz M. Richter, Klinik für Diagnostische und Interventionelle Radiologie, Klinikum Stuttgart, cmsommer@gmx.com

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Selective contrast study of lymphatic vessels and the intractable lymphatic fistula (*) after transpedal lymphangiography with iodinated oil. Left: plain x-ray. Right: computed tomography.

Supplementary material to:

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eTABLE

Demographic characteristics and adverse events

Patient/ sex	Age at surgery (months)	Diagnosis	Primary curve	Interval to FU (months)	Distractions (n)	Adverse events
1/f	70	Unclear myopathy	Thoracic	39	8	None
2/f	55	Prader–Willi syndrome	Thoracolumbar	39	10	None
3/f	92	Loeys–Dietz syndrome	Thoracic	42	11	Loosening of the anchoring / PJK
4/f	113	Spinal muscular atrophy type III	Lumbar	46	11	None
5/f	74	Unclear myopathy	Thoracic	37	9	None
6/m	68	Dandy–Walker syndrome	Thoracic	37	8	Pull out
7/m	99	Neurofibromatosis type I	Thoracic	37	9	None
8/f	91	Neurofibromatosis type I	Thoracic	36	9	None
9/f	102	Nemaline myopathy	Thoracic	29	7	None
10/f	145	Rib fusions	Thoracic	29	7	PJK
11/f	110	Infantile cerebral palsy	Lumbar	28	7	None
12/f	117	Prader–Willi syndrome	Thoracic	28	7	PJK
13/m	105	Hamartomas	Thoracic	28	7	None
14/f	126	Infantile	Thoracic	28	6	None
15/f	123	Marfan syndrome	Thoracic	27	7	None
16/m	172	Infantile	Thoracic	27	7	None
17/f	130	Infantile	Thoracic	26	5	None
18/m	71	Neurofibromatosis type I	Thoracic	25	5	None
19/f	97	Neurofibromatosis type I	Thoracic	25	6	None
20/f	127	Chromosome translocation	Thoracic	24	6	Increase in secondary curve
21/m	80	Infantile	Thoracic	24	6	None
22/m	154	DiGeorge syndrome	Thoracic	24	6	PJK
M 15f; 7m	106			31	7.5	
SD	30			7	2	

f, female; FU, follow-up; m, male; M, mean; PJK, proximal junctional kyphosis; SD, standard deviation