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Welcome to NSDS 2019

Dear colleagues and guests of NSDS 2019. It is with great honor we welcome you all to this year’s meeting in Bergen.

The meeting venue is located at the Radisson Blue Royal Hotel at Bryggen – which is a Unesco World Heritage Site. Bryggen was built on the foundations of buildings from the 12th century. Bryggen has been a center for trade and commerce for several hundred years and was an important trade port for the Hanseatic league.

Several museums, galleries and medieval buildings are within walking distance of the hotel. The Leprosy museum where the famous Dr. Armauer Hansen discovered the lepra bacillus is 10 minutes’ walk from the hotel. Fløibanen funicular is close by, and for those looking for physical exercise we can recommend a hike up the 722 steps in Stoltzekleiven. Please don’t hesitate to contact us locals if you need information on things to do in Bergen.

We have the pleasure to present four invited speakers, both international and domestic, with lectures of individual selected topics. We do hope you will enjoy the scientific part of the program. Our own well respected mentor, Per Torgeir Nilsen, will deliver the Alf Nachemson memorial lecture.

The contribution from the society’s members with abstract presentations and plenum discussions is invaluable.

Thursday evening we are boarding the old steamboat Stord 1 at Bryggen. While enjoying dinner onboard, Stord 1 will take us around the Bergen archipelago. The official conference dinner Friday evening will be at the hotel with entertainment afterwards.

Please remember to visit our partners from the industry at their exhibitions.

On behalf of the organizing committee

Thomas Natvik and Maria Rieber-Mohn
GENERAL INFORMATION

Name Badges
The participant name badge will be provided at the registration desk. Please wear the badge at all times during the conference and social events.

Hotel
Check in from 14:00 on Thursday 22nd August.
Check out no later than 11:00 on Saturday 24th August.
Mini-bar or other payable services are not included in the conference fee and must be settled separately at the hotel reception upon departure.

Meals
Breakfast for overnight guests is served in the hotel restaurant on 1st floor
Weekdays from 06.30 to 10.00
Weekend from 07.00 to 11.00

The conference lunch is served in the same restaurant
Coffee Breaks with snacks is served in the exhibition area

Climate
The weather in Bergen in August is normally pleasant, but bring an umbrella or a waterproof jacket!

Please visit www.yr.no for the weathercast.

Abstract information
All abstracts will be printed in the final program.

Abstract and presentation must be in English. Each presentation is 15 minutes: oral presentation 8-10 minutes, questions from the audience and change of speaker 5 minutes.

All speakers must hand in their presentation at registration.
SCIENTIFIC PROGRAMME

THURSDAY 22.AUGUST

09.00 -13.00  Registration
12.00 -13.00  Lunch

13.00 -13.15  Welcome NSDS 2019
  Randi-Luise Møgster, Deputy CEO Helse-Bergen
  Thomas Natvik, Maria Rieber-Mohn

13.15 -14.00  Growth-friendly surgery in young children with crooked spines:
  Is it more trouble than it’s worth?
  Muharrem Yazici, Ankara

14.00 -14.30  MAGEC – the Oslo experience.
  Kjetil Kivle, Oslo

14.30 -15.00  Pause/ Visit exhibition

15.00 -16.15  Free papers. Moderators Ilkka Helenius and René Castelein

1.  Health Related Quality of Life and Physical Activity during Treatment with Magnetic Controlled Growing Rods or Casting- Preliminary Results. Molland, RS.

2.  Health Related Quality of Life and Physical Activity after Multiple surgeries in Patients with Early Onset Scoliosis. Kibsgård TJ.

3.  Back Pain and Quality of Life after Surgical Treatment for Adolescent Idiopathic Scoliosis at 5-year Follow-up. Comparison with Healthy Controls and Patients with Untreated Idiopathic Scoliosis. Helenius I.


5.  Compensatory Curves in Congenital Scoliosis also show Anterior Overgrowth, located in the Disc. de Reuver S.

16.15 -17.00  Adolescent idiopathic scoliosis
  John Hutchinson, Bristol

18.00-  SOCIAL PROGRAMME – Boat trip
FRIDAY 23.AUGUST

08.30 -09.45  Free papers. Moderators Marinus de Kleuver and Paul Gerdhem


7. Preoperative MRI and Intraoperative Monitoring reduce Neurophysiological Incidences in IS surgery, while Curves >70° increase the risk. *Schizas N.*

8. Concomitant Low-Grade Isthmic L5-Spondylolisthesis Does Not Affect the Course of Adolescent Idiopathic Scoliosis. *Schlenzka D.*

9. Could Roussouly type distribution be part of the explanation of curve location in AIS population? *Genevois KA.*

10. Surgical treatment of congenital spinal deformity in young children. *Gerdhem P.*

09.45 -10.15  Break / Visit exhibition

10.15 -11.00  Neuromuscular vs. idiopathic spine deformities: Can we apply general pediatric deformity principles to neuromuscular deformities? *Muhtarrem Yazici, Ankara*

11.00 -12.00  Free papers. Moderators Thomas Andersen and Thomas Kibsgård

11. Treatment of adolescent idiopathic scoliosis with Providence nighttime brace at Haukeland University Hospital. *Natvik T.*

12. Effectiveness of Providence Night-time Bracing compared to Full-time Boston Bracing for Adolescent Idiopathic Scoliosis. A matched cohort Study. *Simony A.*

13. Preliminary results from a cohort of Juvenile Idiopathic Scoliosis patents, treated with Providence Brace. *Simony A.*

14. Results from a prospective cohort with AIS treated with the Gensingen brace (GBW). *Wied PW.*

12.00 -13.00  Lunch

13.00 -13.45  Neurofibromatosis: how we learn and keep on learning. *John Hutchinson, Bristol*
13.45 -15.00  Free papers. *Moderators Kariman Abelin Genevois and Ivar Rossvoll*

15. Magnetic resonance imaging findings of the lumbar spine, back symptoms and physical function among adult male patients with Scheuermann’s disease. *Ristolainen L.*

16. The influence of arm position during imaging on the sagittal profile of the spine. *Genevois KA.*

17. Radiological and pulmonary outcomes in 41 patients treated with growth friendly spinal implants. *Sydnes KS.*

18. Validation of Ultrasound Imaging in Adolescent Idiopathic Scoliosis. *de Reuver S.*

19. Comparison between Augmented Reality navigation and free-hand technique for pedicle screw placement: a matched-control study. *Gerdhem P.*

15.00 -15.30  Break /Visit exhibition

15.30 -16.00  Alf Nachemson Memorial Lecture

*Per Torgeir Nilsen, Bergen*

16.00 -16.15  Coffee break

16.15 -16.30  Introducing NSDS 2020

16.30 -17.30  General assembly

19.00  SOCIAL PROGRAMME - Conference dinner
SATURDAY 24.AUGUST

08.30 -10.00 Free papers. Moderators Ane Simony and Andreas Seip


21. Spring Distraction System to Correct Early Onset Scoliosis: 2 Year Follow-up Results from 17 Patients. Lemans JVC.

22. Comparison of Complication Profile Between the Magnetically Controlled Growing Rod and the Spring Distraction System in the Treatment of Early Onset Scoliosis. Lemans JVC.

23. The 22q11.2 Deletion syndrome is a confounder in the association between congenital heart disease and scoliosis. de Reuver S.

24. Cervical Spine Anomalies within the 22q11.2 Deletion Syndrome: Risk and Screening. R.M. Castelein

25. The changing position of the center of mass of the thorax during growth in relation to pre-existent vertebral rotation. de Reuver S.

10.00 -10.30 Break / Visit exhibition

10.30 -11.00 Patient selection and surgical treatment of degenerative deformity of the spine. Christian Hellum, Oslo.
11.00 -12.00  Free papers. *Moderators Ivar Austevoll and Frode Rekeland*

**26.** The concept of spinal lordosis. How is the lumbar lordosis organized in the normal population. *Genevois KA.*

**27.** Indication and treatment of adult kyphoscoliosis (INTRAKS study) 
- A retrospective cohort study at Oslo university hospital. *Nooman A.*

**28.** Indication and Treatment of adult kyphoscoliosis (INTRAKS study) 
- Study protocol of a prospective multicenter observational effectiveness study. *Hansen VB.*

**29.** Is the domestic pig (Sus scrofa domesticus) curled tail, a form of Scoliosis? *Simony A.*

12.00  Stig Willner award (best presentation)

12.10  Closing remarks

12.30  Lunch and departure
Muharrem Yazici
Professor of Orthopaedics at the Hacettepe University in Ankara, Turkey, clinical practice involving pediatric orthopaedics and spine problems. His researches are focusing on the treatment of early onset pediatric spine deformities. He edited two international textbooks and published more than 140 research articles in peer review international journals.

Served as president for European Pediatric Orthopaedic Society (2012-2013) and Board of Director (2012-2014), Chair of Growing Spine (2007) and Program Committees (2017) for Scoliosis Research Society. He is currently vice president of SRS.

John Hutchinson
Consultant Spinal Surgeon in Bristol, England. He has an adult practice at Southmead Hospital and a paediatric practice at the Bristol Royal Children’s Hospital.

Accredited as an orthopaedic consultant in 1999 and trained in spinal surgery at Heartshill, Oswestry, Nottingham and Adelaide.

Examiner to the four Royal Colleges of Great Britain and Ireland for 10 years until 2017.

Published articles in peer reviewed journals and written book chapters and been an invited lecturer or visiting professor to 27 countries around the world.

He is a member of the British Association of Spinal Surgeons, the British Scoliosis Society and is currently on the faculty or chairing courses teaching consultant spinal surgeons in sagittal balance; complex anterior approaches; emergencies in spinal surgery; osteotomies and operative techniques for deformity.
Christian Hellum
Consultant spine surgeon at Oslo University Hospital. In his clinical practice he preformes surgery in the thoracolumbar spine on trauma patients, adult deformity and degenerative conditions. With his extensive research background and is currently supervising 5 PhD candidates. Scientific leader of the NORDSTEN study, a randomized study comparing different surgical techniques in patients with spinal stenosis and spondylolisthesis. He is currently also in the scientific board of a randomized multicenter study comparing antibiotic treatment with placebo in patients with chronic low back pain and Modic changes, and have started collaboration with Malmø and Kyoto University Hospital on patients with adult spinal deformity.

Doctoral thesis from 2013: Patients with chronic low back pain and degenerative disc: effects of surgery with disc prosthesis versus rehabilitation, predictors of treatment outcome and health economic considerations.

Member of the board of the Norwegian quality registry for spinal surgery.

Yearly educating spine surgeons in the EduWeek of Eurospine to be Certified as spine surgeons.

Kjetil Kivle
Consultant orthopaedic spine surgeon at Oslo University Hospital, Norway. In 2005, he graduated from Oslo University where he was trained in spinal surgery at Oslo University Hospital and accredited as an ortopaedic surgeon in 2015.

Specialises in paediatric and adolescent spinal deformities, with a particular focus in early onset spinal deformities. He has published articles in peer reviewed journals and is working on his PhD.

Member of the Norwegian Orthopaedic Association and the Norwegian Association of Spinal Surgeons.
Per Torgeir Nilsen
Educated in Vienna and Oslo -1974. Diploma of Tropical Medicine an Hygiene, Liverpool 1978

Served 5 years in Pingtung Christian Hospital, Taiwan, from 1979 and participated in rehabilitation program for children suffering from sequelae after poliomyelitis infection, with extremity- and spine surgery (scoliosis). Specialist in General surgery 1990 and Orthopedic surgery 1991, after training in hospitals in Hammerfest (-74-75), Oslo (76), Ålesund (1977-78) and Bergen. Consultant at Haukeland University Hospital, Bergen, from 1994 and responsible for neuroorthopaedic surgery and spinal deformities. Did also general orthopaedic- and pediatric orthopaedic surgery.

In charge of spine surgery at the same hospital from 2007 until achieved retirement 2017.

Attached to rehabilitation program for victims of polio in Changsu province in China between 1994 and 2004 and cooperated at scoliosis-surgery with colleagues there.

Shorter visits to hospitals in DR Congo and Ethiopia. Member of NSDS from 1990
We will enjoy an evening trip with an old-fashioned steamer built in 1913, restored in 2005 and now used for social events.

**Meeting point:** We will meet in the reception/entrance at the conference hotel, and walk together to the steam boat. It’s a 2 minutes’ walk.

**Schedule:**
- Meeting point: 17.55
- Departure hotel: 18.00
- Departure Stord 1: 18.30
- Arrival Bergen/hotel: 22.30

**Menu:**
- Seafood buffet
- Aperitif + 2 units per person (wine, beer, mineral water)

**Dress code:** Casual
The steam boat is spacious and everyone can stay inside if the weather is bad, but bring a warm jacket.

**Contact:** Henriette Alsaker +47 980 00 979
FRIDAY 23. AUGUST
Official Conference Dinner

Welcome to the conference dinner at the hotel

**Schedule:**
- Aperitif in the exhibition area  19.00
- Conference dinner  19.30
- Partyband “Oh Snap!” will play after dinner

**Menu:**
- 3 course served dinner
- 2 units per person (wine, beer, mineral water)

**Dress code:** Formal
THE BERGEN SPINE TEAM
ABSTRACTS
1. Health Related Quality of Life and Physical Activity during Treatment with Magnetic Controlled Growing Rods or Casting- Preliminary Results

Molland, RS., Kivle, K., Kibsgård, T

Oslo University Hospital, Rikshospitalet

**Background:** Serial casting and magnetic controlled growing rods are commonly used treatments of early onset scoliosis. These interventions are extensive and one should believe that these treatments in early age would decrease children’s activity and well-being. The aim of the study was to measure children’s health related quality of life (HRQOL) and physical activity before and after the first casting and index surgery.

**Method:** In the period from 2017-2019 patients were included consecutively. Only children that were able to use a waist bearing accelerometer to measure weekly physical activity were included. Early onset scoliosis 24-item questionnaire was used to measure HRQOL. Data collection was performed before treatment, at 6 and 12 months.

**Results:** Three patients treated with casting (mean age 2.5y) and three patients treated with magnetic rods (mean age 7.7y) were included. The HRQOL was reduced in all children after they got their first cast. The total EOSQ score was reduced by mean of 12 points at one year follow-up. The children treated with magnetic rods had a mean of 12 point increase in EOSQ at one year follow-up.

<table>
<thead>
<tr>
<th></th>
<th>Total EOSQ score</th>
<th>Physical activity (counts/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Diff pre-6m</td>
</tr>
<tr>
<td><strong>Casting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pat nr 1</td>
<td>88</td>
<td>-14</td>
</tr>
<tr>
<td>Pat nr 2</td>
<td>67</td>
<td>-20</td>
</tr>
<tr>
<td>Pat nr 3</td>
<td>80</td>
<td>-9</td>
</tr>
<tr>
<td><strong>Magnetic Rods</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pat nr 1</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>Pat nr 2</td>
<td>78</td>
<td>16</td>
</tr>
<tr>
<td>Pat nr 3</td>
<td>84</td>
<td>2</td>
</tr>
</tbody>
</table>

Total physical activity level among the casted children decreased during 12 months. Two of the children treated with magnetic rods increased their weekly activity during one year in treatment, while one patient demonstrated a small reduction.

**Conclusion:** Serial casting and magnetic controlled growing rods may impact children’s physical activity and HRQOL in different manners. While casted children tended to have a reduction in HRQOL and activity during treatment, children treated with magnetic rods had a similar improvement.
2. Health Related Quality of Life and Physical Activity after Multiple-surgeries in Patients with Early Onset Scoliosis

Molland, RS, Brox, JI, Stuge, B, Holm, I, Riise, RB, Kibsgård, TJ

Oslo University Hospital, Rikshospitalet

Background: Severe early onset scoliosis (EOS) is a heterogenic group of patients with deformity of the spine. Some of these patients may require multiple-surgeries during childhood. Surgical and radiological outcomes have mainly been used to monitor surgical success. Little is reported of the well-being of the patients. Patient related outcomes have been developed with focus on health related quality of life (HRQOL) and patient activity following surgical procedures. Our aim was to measure health related quality of life and physical activity in children with EOS treated with multiple-surgeries.

Method: Daily activity was measured by a waist bearing accelerometer in children with independent walking ability. All participants answered question regarding habitual physical activity. HRQOL was measured by use of Early Onset Scoliosis 24-item Questionnaire (EOSQ-24) (<16 years) or Scoliosis Research Society 22-item Questionnaire (≥16 years).

Results: Thirty-nine patients participated. The mean age was 13 years, 41% were boys. 54% had undergone graduation (final surgical procedure with fusion of instrumented spine). Accelerometer data showed similar amount of activity as healthy, Norwegian peers, but at a lower intensity. All children of idiopathic or congenital etiology were independent walkers, and reported highest total EOSQ-24 score (mean score 74, CI 68 to 80). Among children of syndromic or neuromuscular etiology, EOSQ-24 total score decreased with decreasing walking abilities, from independent (mean score 58, CI 32 to 84) to reduced (mean score 48, CI 37 to 59), and non-walking ability (mean score 43, CI 31 to 55) (p≤0.01). Self-reported physical activity was highest among children with idiopathic or congenital etiology (mean 4.4 h/w, CI 3 to 6) (p=0.002). Syndromic or neuromuscular scoliosis children with reduced walking abilities reported lowest level (mean 0.9h/w, CI -1 to 2), also lower than children in same etiology groups with independent (mean 2.2 h/w, CI -1 to 6) or without (mean 1.7 h/w, CI 0 to 3) walking abilities (p=0.007).

Conclusion: Children without independent walking ability and children of syndromic or neuromuscular etiology had lower HRQOL and physical activity than children with independent walking abilities and children of idiopathic or congenital etiology.
3. Back Pain and Quality of Life after Surgical Treatment for Adolescent Idiopathic Scoliosis at 5-year Follow-up. Comparison with Healthy Controls and Patients with Untreated Idiopathic Scoliosis

Linda Helenius, MD,1,2 Elias Diarbakleri, PT, MSc,3,4 Anna Grauers, MD, PhD,3,5 Markus Lastikka, MD,2 Hanna Oksanen, RN,2 Olli Pajulo, MD, PhD,2 Eliisa Löyttyniemi, MSc,6 Tuula Manner, MD, PhD,1 Paul Gerdhem, MD, PhD,3,4 and Ilkka Helenius, MD, PhD2
From the 1Department of Anesthesia and Intensive care, University of Turku and Turku University Hospital, Finland; 2Department of Paediatric Orthopaedic Surgery, University of Turku and Turku University Hospital, Finland; 3Department of Clinical Science, Intervention and Technology (CLINTEC), Karolinska Institutet, Stockholm, Sweden; 4Department of Reconstructive Orthopaedics, Karolinska University Hospital; 5Department of Orthopaedics, Sundsvall and Härnösand County Hospital, Sundsvall, Sweden; 6Department of Biostatistics, University of Turku, Turku, Finland

Background: Posterior spinal fusion with pedicle screws represents the golden standard treatment for adolescent idiopathic scoliosis. However, it remains unclear whether this improves back pain and health related quality of life in the long-term as compared with untreated patients. The aim of our study was to evaluate back pain and quality of life at minimum five-year follow-up as compared with untreated patients and healthy population.

Methods: Fifty-five consecutive adolescents (mean age at surgery 15.6 years) undergoing posterior pedicle screw instrumentation for adolescent idiopathic scoliosis by a single orthopedic surgeon were prospectively enrolled and had a 100% clinical and radiographic data at 2-year follow-up. At a minimum of 5-year follow-up, 49 patients completed SRS-24 questionnaire and data on reoperation was available in all 55 patients. Pain and quality of life parameters were compared to 49 age and gender matched individuals with untreated adolescent idiopathic scoliosis and 49 healthy controls.

Results: Major curve averaged 53° preoperatively and 12° at 2-year follow-up. One reoperation (pedicle screw removal) was needed due to a new neurological deficit (transient). The SRS-24 pain, self-image, function, and total scores improved significantly from preoperative to 5-year follow-up (p≤0.016). The pain score improved from 4.1 to 4.3 at 5-year follow-up (p=0.003). There was no correlation between the pain scores and preoperative major curve, instrumentation below L1 or postoperative rib hump. Surgically treated patients had significantly better scores in the pain, activity, and self-image domains of the SRS-24 questionnaire at 5-year follow-up as compared to untreated patients (p≤0.01), and their scores of pain, self-image, and activity approximated the scores of healthy controls, except for function score which was significantly lower (p<0.001).

Conclusion: Posterior spinal fusion with pedicle screws improves back pain and health related quality of life as compared to patients with untreated adolescent idiopathic scoliosis. Health-related quality of life is at similar level as in the healthy controls except for function which is significantly lower.
4. Patient Specific Designed and Manufactured Rods for AIS Surgical Correction: Applying The Principles Of The New AIS Sagittal Classification

Pierre Grobost MD, Davide Sassi MD, Stephane Verdun PhD, Kariman Abelin Genevois MD, PhD

Spine Unit, Department of Orthopedic Surgery, Centre des Massues, Lyon (France)

Hypothesis: Guidelines given by the new AIS sagittal classification using patient-specific rods leads to predictable restoration of sagittal alignment.

Design: Prospective monocentric study on AIS patients candidate to surgery to test the applicability of sagittal AIS classification guidelines in terms for pre operative 3D planification and rod contouring in order to optimize sagittal correction.

Introduction: AIS surgical treatment aims at improving spinal alignment while improving trunk cosmesis. In order to prevent mechanical complication and early degenerative changes, sagittal realignment according to spino pelvic parameters and TK restoration have been shown to be essential.

Methods: Corrections applied through the simulation mode in order to approach a normalized spine: TK > 20° (ideally 34°), neutral TL junction (T10L2 < 10°, ideally 0 +/- 5°), to adapt inflexion point. A computerized simulation of sagittal correction was performed by surgeon, before guidelines were transmitted to the rod manufacturer with surgical details (diameter and material of the rod, levels of fusion, estimated correction rate) and AP and lateral calibrated X-rays.

Results: A total of 49 AIS patients were prospectively included. All rods were implanted without modifications. Mean Cobb 54 +/- 10 degrees corrected average 21 +/- 8 degrees (62%). No changes occurred in terms fo PI, while PT initially increased similarly to planification as some cases presented with an anteverted pelvis. However PT was comparable to preoperative values at 6 months FU. All patients maintained in their Roussouly shape. TK and LL increased from preoperative to last FU. L4S1 ratio initially decreased but was again comparable between preoperative and last FU (66%). T10L2 angle distribution has been refined from 0,9 +/- 13,3 to 0,06 +/- 8,9 degrees. Improvement of TK was strictly identical to preoperative planning from 19,9 +/- 13 preoperatively to 29,6 +/- 8,3 at last FU (simulation TK value : 30,7 +/- 10,1), p<001.

Conclusion: All patients with a pathological sagittal alignment were changed into a sagittal type 1 by restoring proper length and magnitude of thoracic kyphosis.
Compensatory Curves in Congenital Scoliosis also show Anterior Overgrowth, located in the Disc

Steven de Reuver1, Rob C. Brink1, Jelle F. Homans1, Ludvig Vavruch2, Hans Tropp2, Moyo C. Kruyt1, Marijn van Stralen3, René M. Castelein1

From the 1Department of Orthopedic Surgery, University Medical Center Utrecht, Utrecht, the Netherlands; 2Department of Clinical and Experimental Medicine, Linköping University, Sweden and the 3Imaging Division, University Medical Center Utrecht, Utrecht, the Netherlands.

Background: Relative anterior spinal overgrowth (RASO) was proposed as a generalized growth disturbance and a potential initiator of adolescent idiopathic scoliosis (AIS). However, the same phenomenon was also observed in neuromuscular (NM) scoliosis, and was restricted to the apical areas and located in the intervertebral discs. This suggests that the anterior-posterior length discrepancy is not a generalized active growth phenomenon nor the cause of AIS, but rather a passive phenomenon that is the result of any scoliotic deformity.

Method: Patients were selected in whom a short segment congenital malformation had led to a long thoracic compensatory curve without any underlying bony abnormality. In this latter curve, of each vertebral body and intervertebral disc, the anterior and posterior length was measured on computed tomography scans in the exact mid-sagittal plane, corrected for deformity in all three planes. The anterior-posterior length discrepancy (AP%) was calculated for the total compensatory curve, and for the vertebral bodies and the intervertebral discs separately. Positive values indicated that the anterior side was longer than the posterior side.

Results: In total, 18 congenital scoliosis patients (mean Cobb angle: 42.3°±14.9°) were included and compared with 30 AIS, 30 NM scoliosis and 30 non-scoliotic control patients. The total AP% of the compensatory curve in congenital scoliosis showed lordosis (+1.8%) that was comparable to AIS (+1.2%) and NM scoliosis (+0.5%), and differed from the kyphosis in non-scoliotic controls (-3.0%; p<0.001). The vertebral body AP% showed kyphosis (-3.2%), similar to AIS (-2.5%), NM scoliosis (-4.5%), and non-scoliotic controls (-3.4%; p≥0.151). However, the disc AP% showed lordosis (+24.3%), as was found for AIS (+17.5%) and NM scoliosis (+20.5%), which sharply contrasts to the kyphotic discs of controls (-1.5%; p<0.001).

Conclusion: ‘Anterior overgrowth’ is part of the 3D deformity in all types of scoliosis and is located in the intervertebral discs. The bony vertebral bodies maintain their kyphotic shape, which indicates that there is no active bony overgrowth, in contrast to what the term RASO implies. The anterior-posterior length discrepancy is most likely a passive result of any scoliotic deformity, rather than the cause of AIS.
5. Compensatory Curves in Congenital Scoliosis also show Anterior Overgrowth, located in the Disc

*Steven de Reuver*¹, Rob C. Brink², Jelle F. Homans³, Ludvig Vavruch², Hans Tropp², Moyo C. Kruyt¹, Marijn van Stralen³, René M. Castelein¹

From the ¹Department of Orthopedic Surgery, University Medical Center Utrecht, Utrecht, the Netherlands; ²Department of Clinical and Experimental Medicine, Linköping University, Sweden and the ³Imaging Division, University Medical Center Utrecht, Utrecht, the Netherlands.

**Background:** Relative anterior spinal overgrowth (RASO) was proposed as a generalized growth disturbance and a potential initiator of adolescent idiopathic scoliosis (AIS). However, the same phenomenon was also observed in neuromuscular (NM) scoliosis, and was restricted to the apical areas and located in the intervertebral discs. This suggests that the anterior-posterior length discrepancy is not a generalized active growth phenomenon nor the cause of AIS, but rather a passive phenomenon that is the result of any scoliotic deformity.

**Method:** Patients were selected in whom a short segment congenital malformation had led to a long thoracic compensatory curve without any underlying bony abnormality. In this latter curve, of each vertebral body and intervertebral disc, the anterior and posterior length was measured on computed tomography scans in the exact mid-sagittal plane, corrected for deformity in all three planes. The anterior-posterior length discrepancy (AP%) was calculated for the total compensatory curve, and for the vertebral bodies and the intervertebral discs separately. Positive values indicated that the anterior side was longer than the posterior side.

**Results:** In total, 18 congenital scoliosis patients (mean Cobb angle: \(42.3°\pm14.9°\)) were included and compared with 30 AIS, 30 NM scoliosis and 30 non-scoliotic control patients. The total AP% of the compensatory curve in congenital scoliosis showed lordosis (+1.8%) that was comparable to AIS (+1.2%) and NM scoliosis (+0.5%), and differed from the kyphosis in non-scoliotic controls (-3.0%; \(p<0.001\)). The vertebral body AP% showed kyphosis (-3.2%), similar to AIS (-2.5%), NM scoliosis (-4.5%), and non-scoliotic controls (-3.4%; \(p\geq0.151\)). However, the disc AP% showed lordosis (+24.3%), as was found for AIS (+17.5%) and NM scoliosis (+20.5%), which sharply contrasts to the kyphotic discs of controls (-1.5%; \(p<0.001\)).

**Conclusion:** ‘Anterior overgrowth’ is part of the 3D deformity in all types of scoliosis and is located in the intervertebral discs. The bony vertebral bodies maintain their kyphotic shape, which indicates that there is no active bony overgrowth, in contrast to what the term RASO implies. The anterior-posterior length discrepancy is most likely a passive result of any scoliotic deformity, rather than the cause of AIS.

**Jelle F. Homans, MD¹, Moyo C. Kruyt, MD PhD¹, Tom P.C. Schlösser, MD PhD¹, Dino Colo, MD³
Kenneth Rogers, PhD ATC², Suken A. Shah, MD², John M. Flynn, MD³, René M. Castelein, MD PhD¹, Saba Pasha, PhD³**

¹Department of Orthopaedic Surgery, University Medical Center Utrecht, Utrecht, The Netherlands; ²Department of Orthopaedic Surgery, Nemours/Alfred I. DuPont Hospital for Children, Wilmington, Delaware, USA; ³Division of Orthopaedic Surgery, The Children’s Hospital of Philadelphia (CHOP), Philadelphia, Pennsylvania, USA

**Background:** The development of proximal junctional kyphosis (PJK) after posterior spinal fusion in adolescent idiopathic scoliosis (AIS) is a major problem. Changes in the global sagittal parameters as they relate to PJK have been reported after surgery, however the relationships between the changes in the upper-instrumented vertebra (UIV) during and after surgery and development of PJK have not been quantified.

**Method:** Sixty AIS patients (with at least one year follow-up) who underwent posterior spinal surgery were included retrospectively. Global spinal parameters were calculated using three-dimensional (3D) models of the spine, additional parameters (PJK angle (PJKA), cervical lordosis angle (CL)) were measured manually before surgery and at three post-operative follow-ups. The 3D position of the vertebral body centroids was calculated for T1, UIV, and LIV at all time-points. The sagittal position of T1, UIV and LIV were correlated to the CL, PJKA, lumbar lordosis, and pelvic tilt.

**Results:** The PJKA increased significantly from pre-operative to first erect (FE) and the increase continued during the consecutive follow-ups. The position of T1 and UIV were significantly more anterior at (FE) for patients who developed PJK. The posterior shift of UIV at last follow-up as compared to the pre-operative position was significant in both the PJK and non-PJK cohort. A larger anterior shift in UIV at FE correlated with a larger T1 and UIV posterior shift at last follow-up. At the last follow-up a more posterior position of the UIV correlated with a larger angle of PJKA, p<0.05. The lumbar lordosis decreased from pre-operative to FE and increased significantly between FE and all the consecutive follow-ups.

**Conclusion:** Both a larger anterior shift of UIV between pre-operative and FE and a more posterior position of UIV at the last follow-up was correlated with a higher PJKA. A larger anterior shift in the position of the UIV after surgery was associated with a higher posterior shift of UIV at the last follow-up. The surgically induced changes in the UIV are an important parameter associated with development of PJK.
7. **Preoperative MRI and Intraoperative Monitoring reduce Neurophysiological Incidences in IS surgery, while Curves >70° increase the risk**

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**Background:** Idiopathic scoliosis (IS) represents approximately 80% of all scoliosis cases. Patients undergo preoperative MRI screening to identify possible anomalies in the neural axis. Previous studies have shown an incidence rate of 4.2-14.7%, most commonly Chiari malformation, tethered cord, filum terminale lipoma and syrinx. Additionally, intraoperative neurophysiological monitoring is used to protect the integrity of spinal cord and contributes in avoiding serious complications. However, it is quite unclear whether MRI findings are correlated to neurophysiological incidences and whether other factors (e.g. curve’s size) are associated with the occurrence of such incidences.

**Aim:** To investigate the role of preoperative MRI and intraoperative neurophysiological monitoring in the prevention of correction-related complications in IS.

**Method:** We conducted a retrospective case study of 129 patients with juvenile and adolescent IS. All patients were operated between 2005-2018 in Uppsala Akademiska Hospital. Data from MRI imaging, intraoperative neurophysiological monitoring and postoperative follow-up were collected. The patients were divided into groups, depending on Lenke’s classification, sex, major curve (MC) size and debut age. Statistical analyses were performed with SPSS.

**Results:** Patients with juvenile IS were operated in average one year earlier and had a larger MC of 4.5° than adolescent IS (p=0.001 and p=0.004 respectively). Eight patients (6.1%) had intraspinal pathologies and two of them (1.5%) underwent decompression surgery prior to correction. Neurophysiological incidences were reported in ten patients (7.8%) while nine of them had no signs of intraspinal pathology in the MRI. Six patients (4.7%) had transient incidences, however, in four patients (3.1%) it was required an intervention for the normalization of action potentials. Three out of the last four patients had a MC of greater than 70 degrees and that was statistically significantly higher from the expected value according to standardized residuals.

**Conclusion:** The observations in our study suggest the continuation of MRI screening preoperatively and most importantly the use of perioperative neurophysiological monitoring. In three cases with no signs of pathology in the MRI, intraoperative monitoring prevented possible neurological injuries. MCs greater that 70 degrees should be considered as a risk factor for the occurrence of neurophysiological deficiencies that require action to be normalized.
Background:
Scoliosis with concomitant spondylolisthesis was described in 4.4-48%. No information on clinical impact or outcome is available.

Purpose:
Purpose of the study was to determine the prevalence of this double pathology in a significant series of patients with adolescent idiopathic scoliosis (AIS) and to investigate whether the presence of spondylolisthesis affects the course and/or the outcome of the scoliosis.

Methods:
A retrospective comparative study using patients’ records, radiographs, the National Inpatient Registry (NIR), and Patient-rated outcome measures (PROM): Oswestry disability index (ODI), modified SRS-24 questionnaire, WHO Quality of life index (WHOQoL), and Numerical rating scale (NRS) for pain.
Clinical follow-up time 4.4(4.3) yrs., follow-up rate 95%. PROM follow-up time 26.4(2.8) yrs. \( \chi^2 \) statistics and t-tests were applied. Significance threshold was set at \( P < 0.05 \).

Results:
Out of 1531 consecutive Caucasian AIS patients, aged 13.9(1.8) yrs, primary curve 29.2(11.5) drs., 120 (7.8%) had low-grade isthmic L5-slip of mean 15.0(8.3)% (Study group = S). The distribution of the curve types in the Study group was comparable to the remaining 1411 patients with AIS only. In comparison to a pair-matched Control group (C) at admission, back pain interfering with activities of daily living (ADL) had 4.2% of the Study group and 1.7% of the Control group, at clinical follow-up 2.6/4.2% resp.(n.s.).
Between the groups (S/C), there was no significant difference concerning scoliosis treatment: observation 38.3/45.8%, bracing 48.3/46.6%, surgery 10.8/10.2%. Results of scoliosis treatment (bracing, surgery) were equal in both groups.
Long-term outcomes were comparable. ODI: 5.6/6.2%; modified SRS-24: 93.9/91.9; WHOQoL: Physical 81.0/78.5; Psychological 75.2/71.5; Social 76.3/75.0; Environment 81.9/78.7; NRS-back pain 2.6/2.1, leg pain 1.3/1.4 (n.s.).
Of the Study group, 13/120 (10.8%) patients had fusion for spondylolisthesis.

Conclusions:
The prevalence of low-grade isthmic L5- spondylolisthesis in 1531 consecutive AIS patients was 7.8%. The presence of low-grade isthmic spondylolisthesis did not influence the curve type of AIS nor did it affect the course or long-term outcome. Both pathologies can be treated separately according to generally accepted rules as proposed by Goldstein et al (1976).
9. Could Roussouly type distribution be part of the explanation of curve location in AIS population?

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Summary: Radiographic analysis of 141 AIS surgical patients with a specific insight into spine pelvic alignment and Roussouly shape showed specific associations between Roussouly types and the location of the main structural curve. While AIS etiology is still unclear, it seems that Roussouly sagittal types may be part of the explanation of scoliosis curve location occurrence.

Hypothesis: Sagittal alignment is an important component of AIS deformity. We hypothesize that scoliosis curve type is favored by the spino pelvic alignment given by Roussouly type.

Design: Radiographic analysis on consecutive AIS patients prospectively followed on a single center surgical database.

Introduction: AIS is a three dimensional deformity of the spine occurring in otherwise healthy adolescents. Curve location can vary from thoracic, thoraco lumbar or lumbar spine. Despite recent growing evidence for genetic etiopathogenesis, no risk factor has been related to the location of scoliotic curves occurrence.

Methods: We conducted a radiographic study on 141 consecutive AIS candidate to surgery in order to determine the sagittal Roussouly types within each Lenke type. Sagittal parameters were measured (T1T12, T4T12, global sagittal thoracic angle, T10L2, L1S1, global sagittal lumbar angle, PI, SS, PT). GSTA and GSLA were calculated with regard to the position of the inflexion point (limit where curves transition). Patients were categorized according to Lenke and Roussouly classifications.

Results: Lenke types repartition was as follow: 78 Lenke 1 or 2 (55%), 24 Lenke 3 (17%), 22 Lenke 5C (16%) and 17 Lenke 6C (12%). We found no statistical difference in terms of pelvic parameters. Global lumbar lordosis was longer in thoracic scoliosis (5,5 vertebrae vs 4,6 in TL/L, p<0,001). Having classified these cases using Roussouly classification, we found that Lenke 1 or 2 were mainly Roussouly type 3 or 4, with more anteverted pelvis than in TL/L scoliosis (30,6% in Lenke 1 or 2, 20,8% in Lenke 3, 23% in Lenke 6C versus 13,6% in Lenke 5C). Roussouly type 2 (low PI) was mainly observed in TL/L scoliosis (Lenke 5C 36,4%, 23,5% in Lenke 6C versus 12,5% in Lenke 3C and 9% in thoracic Lenke 1 or 2). Thoracolumbar kyphosis (T10L2>10) was rare and all had a low PI, corresponding to Roussouly type 1, and were retrieved in the TL/L scoliosis types.

Conclusion: Thoracic scoliosis are mainly Roussouly type 3 or 4 and are more likely to have an anteverted pelvis. In contrary, TL/L curves may express Roussouly type 1 or 2.
# 10. Surgical treatment of congenital spinal deformity in young children

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**Background:** Most cases with congenital vertebral malformations may be left untreated. Some deteriorate to the point in which surgery is attempted to reduce the deformity. Due to its relative rarity, data on outcome in children are scarce. The aim was to describe the outcome after surgical treatment for congenital scoliosis before the age of 10.

**Methods:** We identified patients treated for congenital spinal deformity in the Swedish Spine registry. Included were individuals treated until the age of 10 years. Surgical methods and complications were assessed in the registry, radiographs and surgical files. Vertebral malformations were classified independently by the authors according to Kawakami et al (2009), and any discrepancies were solved in consensus. Patient reported outcomes were assessed with EQ-5D.

**Results:** 72 individuals were identified, and index surgical treatment was undertaken at a mean (SD) age of 5.6 (2.6) years. 43 (60%) were females. The congenital vertebral malformations were distributed as follows; solitary simple (type 1) in 17 individuals, multiple simple (type 2) in 5 individuals, complex (type 3) in 44 individuals, segmentation failure (type 4) in 3 individuals, and another 3 individuals were unclassifiable. In 48 (67%) individuals the vertebral malformation engaged the thoracic spine. 9 (12%) individuals had a known syndrome, and 33 (46%) individuals had organ malformations. Surgical treatment was performed by posterior fusion (n=37), anterior fusion (n=2), posterior and anterior fusion combined (n=4), growth friendly instrumentation (n=23), or other (n=4). In 36 (50%) individuals the surgical procedure was combined with osteotomy or vertebrectomy. Unplanned additional surgery was performed in 16 individuals (22%). Median EQ-5D-index (IQR) was available 5 (3) years postoperative in 54 individuals and was 0.80 (0.31).

**Conclusion:** In this nationwide study of children treated surgically for congenital spinal deformity before the age of 10 years, we found that fusion was the dominant method of treatment. The co-existence of other organ malformations was common, while known syndromes were uncommon, indicating the complexity and variability of congenital spinal deformity. Postoperative health related quality of life was lower than normative data.
11. Treatment of adolescent idiopathic scoliosis with Providence nighttime brace at Haukeland University Hospital.

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**Background:** Our institution has used Providence nighttime brace as standard brace treatment of AIS since 2004. The present study reports the results from patients treated at our department between 2004 and 2015.

**Method:** Clinical data and radiological findings were collected from the medical journal and radiological system. Approval to collect data was obtained from the hospital’s ethical board. We decided to adhere to the SRS committees inclusion criteria in this study and included patients with initial age 10 years or older, Cobb angle of major curve between 20° and 40°, Risser sign 0-2 and no prior treatment. We used the endpoints described by the SRS committee on Bracing and Nonoperative management for assessment of effectiveness. In addition, we added curve progression to 50° or more as an indication of treatment failure. Surgical rate was recorded at 2 year follow-up.

**Results:** 125 patients were treated with Providence brace from March 2004 until end of June 2015. We excluded 36 patients with initial curve >40°, or Risser sign >2 or unknown. 2 patients were lost to follow-up. 87 patients were included in the analysis. Average age 13.5 years. 64% of the patients were Risser 0. Mean initial Cobb angle was 32.5°, and mean final Cobb angle was 41.6°. 31 (36%) patients has had surgery or had surgery recommended. 63% had a curve less than 45° and 76% had a curve less than 50° at the end of brace treatment. 55% progressed more than 5°. Patients with an initial curve of 35° or less had better results than those with larger curves.

<table>
<thead>
<tr>
<th>Initial curve(n)</th>
<th>Final curve</th>
<th>Final curve&lt;45°</th>
<th>Final curve&lt;50°</th>
<th>Progression&gt;5º</th>
<th>Surgery 2 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤35°(63)</td>
<td>38°</td>
<td>78%</td>
<td>89%</td>
<td>46%</td>
<td>22%</td>
</tr>
<tr>
<td>36°-40°(24)</td>
<td>51°</td>
<td>25%</td>
<td>42%</td>
<td>79%</td>
<td>71%</td>
</tr>
</tbody>
</table>

**Conclusion:** Treatment with Providence brace was effective when treating moderate curves with initial Cobb angle 35° or lower. Overall results are similar to the BRAIST trial when comparing progression to surgical threshold 50°. The Providence brace seems ineffective in treating curves with initial Cobb angle more than 35°.
12. Effectiveness of Providence Night-time Bracing compared to Full-time Boston Bracing for Adolescent Idiopathic Scoliosis. A matched cohort Study.

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1 Sector for Spine Surgery & Research, Middelfart Hospital
2 Department of Orthopedic Surgery, University Hospital Odense.

Background: Providence Night-time Bracing (PNB) is an alternative nonsurgical method to Full time Boston Bracing (FBB) for AIS Patients. Recent studies have shown a dose response curve with the FBB, that is longer brace wear is more effective at preventing curve progression. However, due to limitations with daily function, a night time brace may increase compliance. The aim of the study was to compare the outcomes between PNB and FBB in a matched cohort of AIS patients.

Methods: 71 consecutive AIS patients received treatment, with PNB. Treatment was administered according to the SRS criteria. The clinical outcome of PNB was determined 2 years after brace weaning. The patients treated with PNB was then matched according to age, sex, curve type, apex and Cobb prior to treatment with a cohort of AIS patients, treated with FBB.

Results: 71 consecutive PNB patients, 61 females and 10 males where matched, with 71 patients treated with FBB. The demographics were similar between the two cohorts. The Cobb angle after completion of treatment and the amount of curve correction was similar between the two groups. However, 6 patients in the PNB had surgery, 2 for cosmesis and 4 for curve progression.

<table>
<thead>
<tr>
<th></th>
<th>Boston Mean</th>
<th>NightTime Mean</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CobbStart</td>
<td>33,31°</td>
<td>32,75°</td>
<td>0,617</td>
</tr>
<tr>
<td>CobbEnd</td>
<td>32,51°</td>
<td>30,15°</td>
<td>0,121</td>
</tr>
<tr>
<td>Cobb_Diff</td>
<td>0,80°</td>
<td>2,59°</td>
<td>0,157</td>
</tr>
<tr>
<td>Correction</td>
<td>0,22%</td>
<td>8,36%</td>
<td>0,012</td>
</tr>
<tr>
<td>Surgery</td>
<td>0</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion: Curve progression after PNB was comparable to FBB. Night time bracing seems effective in the treatment of AIS and might reduce the psychological stress of the AIS patients during puberty. The difference seen in the rate of surgery between the 2 groups, reflects the change in surgical management from 1990 to 2018, where surgery is indicated at 40°.
13. Preliminary results from a cohort of Juvenile Idiopathic Scoliosis patients, treated with Providence Brace.

_Ane Simony MD, PhD^1_, Stig Mindedahl Jespersen^2_, Mikkel Andersen^1_.

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^2^ Department of Orthopedic Surgery, University Hospital Odense.

**Background:** Providence Night-time Bracing (PNB) is an alternative to Full time Boston Bracing (FBB) for Scoliosis Patients. Recent studies have shown excellent results preventing curve progression in Adolescent Idiopathic Scoliosis patients, and PNB has also been introduced in the treatment of Juvenile idiopathic Scoliosis (JIS). This study reports the preliminary results in a cohort of JIS patients.

**Methods:** 22 consecutive JIS patients received treatment, with PNB. Brace treatment was initiated in patients with Cobb > 10° and curve progression. Patient where treated with the Providence Night-time Brace and all patients had an initial curve correction of > 70% in the brace. The evaluation was performed on standing radiographs in all the patients. Patients referred to surgery or patients who progressed > 5°, was considered failures.

**Results:** 22 consecutive PNB patients participated in the study, 3 patients were excluded. 1 patient presented with neuromuscular symptoms and 2 patients were lost to follow up. 13 females and 3 males mean age 7.9 years (5-10 years) were included in the results. Mean Cobb before treatment 29° (12-44°), Mean Cobb at termination of the study 38° (12-70°).

8 patients progressed > 40 ° and was referred to surgery, 3 progressed >5° during treatment, 2 remained stable during the treatment and 6 patients achieved curve correction.

**Conclusion:** Previous reports by Weinstein et al 2018 reports a 34 % success rate treating JIS patients with TLSO or Milwaukee Brace on a full-time schedule. This preliminary study reports a 42 % success rate of Providence Nighttime Bracing, treating 7-8 hours at night. The rate off progression in JIS patients are high and the treatment time long, but the preliminary results from this study supports night-time bracing which is less stress-full to the patient’s mental health.
14. Results from a prospective cohort with AIS treated with the Gensingen brace (GBW)

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Background: Today there are numerous studies on brace treatment of patients with AIS. In the US, UK, Scandinavia and some countries in Asia the Boston brace is used widely. The purpose of this paper is to present the first end results from a prospective cohort started in 2011 treated with a CAD based Chêneau derivate and compared to the published results, as achieved with the Boston Brace.

Materials and Methods: Inclusion criteria were the SRS inclusion criteria for studies on bracing (Girls only, Age 10 – 14 years, Risser 0 -2, Cobb angle 25 – 40°) except the range of Cobb angles was extended to curvatures of up to 45° in order to increase the amount of patients in the study. 28 patients from our prospective cohort (12.5 years; Risser 0.8; Cobb 32.6°) have been weaned off their CAD Chêneau style brace. The results of this cohort have been compared with the BRAIST study by Weinstein et al. with the help of the z-test. Failure in both studies was defined as a Cobb angle reaching or exceeding 50° Cobb.

Results: The average in brace correction was 51,4%. Two of the 28 patients (7.1%) from this group reached or exceeded 50° at final follow-up making a success rate 92,9%. This was compared to the success rate of 72% in the BRAIST study. The differences were highly significant in the z-test (z = 2,58, t = -3,42, p = 0,01).

Conclusions: The results as achieved with the GBW are significantly better than the results as achieved with the Boston brace. Therefore, the standards should change from symmetric compression to asymmetric high correction braces allowing a standardized classification based corrective system for most of the possible curve patterns.
15. Magnetic resonance imaging findings of the lumbar spine, back symptoms and physical function among adult male patients with Scheuermann’s disease

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**Background:** Knowledge of magnetic resonance imaging (MRI) findings in lumbar spine on untreated (no brace or surgical treatment) Scheuermann’s is limited. Our aim was to clarify lumbar MRI findings, symptoms and function in Scheuermann patients and compare with population based control group.

**Method:** Twenty-two male adult Scheuermann’s (mean age 64.7 years [SD] 6.4) and 26 males (mean age 59.7 years [SD] 7.4, p=0.015) from a national health survey were included. Mean height of vertebral bodies, intervertebral discs, spondylolisthesis, Modic changes (MC) and high intensity zone values (HIZ) were registered from both groups. Disc changes were classified according to Pfirrmann among Scheuermann’s. Self-reported general health, quality of life, and back pain symptoms was obtained, and physical function measured.

**Results:** More Scheuermann patients had at least one MC compared to control group at the level L1/L2 (50% vs. 4%, p<0.001), at the level L3/L4 (36% vs. 4%, p=0.005) and at the level L5/S1 (77% vs. 40%, p=0.010). The mean sagittal diameter of the dura sac at L4-L5 disc level was smaller (10.9 mm vs.12.6 mm, p=0.049) and the mean area of the dura sac (L3-L4) was larger (201 mm² vs. 152 mm², p=0.017) in the Scheuermann’s than control group. Among Scheuermann’s 77% of the L5 discs were Pfirrmann 4 or 5. Age-adjusted Scheuermann’s had more commonly constant back pain (p=0.015) and they had also more difficulties in walking up one floor without resting (p=0.049) than control group. MC at L5 level associated nearly with constant back pain among Scheuermann’s (p=0.051). At L4 level, they associated with constant back pain among control group (p=0.009). Constant back pain (p=0.013) and constant ischial pain (p=0.002) were associated with difficulties in walking up one floor without resting among Scheuermann’s. Constant ischial pain was associated with difficulties in carrying 5-kg load at least 100 m (p=0.014), with walking steps (p<0.001) and walking speed during 6.1 meters (p=0.001) among Scheuermann’s.

**Conclusion:** Modic changes on lumbar MRI, back pain and physical function restrictions seem more prevalent among Scheuermann patients than in the general population.
16. The influence of arm position during imaging on the sagittal profile of the spine

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Background: The sagittal spinal alignment is an important aspect for clinicians to consider in the evaluation and treatment of patients. However, in the natural standing position (i.e. hands at the side) the arms inhibit adequate visualization of the spine. It is currently unclear which of the (numerous) arms positions as described in literature, approaches most adequately the natural position. If radiography is performed with the, increasingly available, biplanar radiography (EOS®), patients stand on a small platform during the radiography, which hampers the number of positions that can be used. Moreover, using EOS® technology a new position has been introduced with the patients standing with their hands and forearms against the wall, which enables simultaneous visualisation of maturation aspects of the bones of the hand. Using three-dimensional ultrasound, it is possible to test which position corresponds most adequately with the natural standing position.

The goal of this study is to compare the hands-on-cheek and hands-on-wall position with the natural standing position and to determine which position provides the most “functional representation” of the natural standing position.

Method: A cross-sectional study, with the arms in natural, hands-on-cheek and hands-on-wall position was performed. The main study parameters were the thoracic and lumbar sagittal angles and overall statistical shape modelling (SSM) of the spine.

Results: Sixteen volunteers (female: male ratio 1:1) were included. Both the hands-on-cheek and hands-on-wall positions gave an underestimation of the thoracic kyphosis (38.9±6.5, 38.3±7.8° respectively), as compared to the natural position (43.5±7.4°), p=0.004. SSM showed the largest difference between the control and hands-on-wall position (natural, cheek and wall position: 0.48, -0.16 and -0.33 respectively (p≤0.002)).

Conclusion: This is the first study to describe the sagittal alignment in healthy volunteers using 3D ultrasound. The sagittal spinal alignment differs between the different positions that are used during radiography. Based on SSM, the hands-on-cheek position resembles the natural position the most and we therefore recommend to use this position for lateral radiography of the spine.
17. Radiological and pulmonary outcomes in 41 patients treated with growth friendly spinal implants

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Institute of Clinical Medicine, University of Oslo, Oslo Norway

Background
Severe Early Onset Scoliosis (EOS) has been treated with growth friendly implants the last 15 years. The patients are a heterogeneous group and most will develop pulmonary deficit. The goals of the treatment are to control and correct spinal deformity and allow spinal growth. The aim of this study was to examine if the surgical goals of curve correction and spinal growth were achieved. Secondly, we examined the pulmonary function and tested if there were any correlation between radiological data and pulmonary function.

Method
This is a retrospective study of 41 surgically treated patients with EOS treated with growth friendly spinal implants between 2000 and 2016 (28 graduated and 13 under active treatment). During 2016-2017, 18 patients with final fusion and 7 patients with growth implants had pulmonary examination and data are presented as percentage of predicted value. Correlation between pulmonary function and radiological values were tested.

Results
The mean age at index surgery was 5.8 (range 10 months-9.9 years). The mean age at final fusion was 12.4 years (range 8-17 years). Including final fusion a mean of 14 procedures was performed on each patient (range 4-26). Radiological data is presented in the table below. Twenty out of the 28 graduated patients had T1-T12 length above 18 cm.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>After index surgery</th>
<th>Before final fusion</th>
<th>After final fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobb (SD)</td>
<td>76(21)</td>
<td>51(16)</td>
<td>58(21)</td>
<td>43(22)</td>
</tr>
<tr>
<td>T1-T12 height (SD)</td>
<td>149(33)</td>
<td>166(35)</td>
<td>196(44)</td>
<td>207(46)</td>
</tr>
<tr>
<td>T1-S1 height (SD)</td>
<td>249(52)</td>
<td>280(58)</td>
<td>330(60)</td>
<td>347(59)</td>
</tr>
<tr>
<td>SAL ratio</td>
<td>0.85</td>
<td>0.93</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td>Apex distance</td>
<td>55</td>
<td>40(18)</td>
<td>49(25)</td>
<td>40(22)</td>
</tr>
</tbody>
</table>

The 25 patients with spirometry scored Forced Vital Capacity mean 52% (SD 18), Forced Expiratory Volume mean 54% (SD 19), Peak Expiratory Flow mean 71% (SD 17). FVC was found to have significant reverse correlation to apex distance (r=-.0664, p<0.001) and Cobb angle (r=-.457, p=0.22). We did not find any correlation between any of the pulmonary variables and T1-T12 height.

Conclusion
When lengthening devices are used the major correction was achieved during index surgery and during graduation. Our use of lengthening implants controlled and improvement curve angles and height. The pulmonary function is reduced and it correlated with the severity of the deformity, but not with T1-T12 height.
18. Validation of Ultrasound Imaging in Adolescent Idiopathic Scoliosis

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Background
Patients with adolescent idiopathic scoliosis (AIS) are exposed to 9-10 times more radiation, resulting in a five-fold increased lifetime cancer risk as compared to the general population. Therefore, multiple radiation-free imaging techniques, like ultrasound imaging, have been studied. Several studies observed excellent correlations between spinal ultrasound measurements and the radiographic Cobb angle, however, ultrasound systematically underestimated the Cobb angle. To calculate the expected Cobb angle from the ultrasound angle, a properly developed and validated equation is essential.

Methods
Seventy patients suspected of AIS (10–18 years of age, radiographic Cobb angle range 2°–90°), who received traditional upright anterior-posterior radiography of the total spine as well as standardized upright ultrasound of the spine at the same visit, were included. Patients were split randomly in a 4:1 ratio, resulting in 54 patients in the equation creation group and 16 in the validation group. The relationship was described, for thoracic and lumbar curves separately, as the equation: expected Cobb angle = regression coefficient × ultrasound angle in the creating group. Subsequently, this equation was validated in the validation group.

Results
The linear regression analysis between ultrasound angles and radiographic Cobb angles (thoracic: $R^2=0.968$, lumbar: $R^2=0.923$, p<0.001) in the creation group, resulted in the equations: thoracic Cobb angle = 1.43 × ultrasound angle and lumbar Cobb angle = 1.23 × ultrasound angle. With these equations, the expected Cobb angles in the validation group were calculated and showed an excellent correlation with the radiographic Cobb angles (thoracic: $R^2=0.959$, lumbar: $R^2=0.936$, p<0.001). The mean absolute differences were 6.5°–7.3°, the Bland-Altman plots showed good accuracy of the equation and there was no proportional-bias, i.e. curve severity did not influence the amount of variation between expected and radiographic Cobb angle.

Conclusion
Excellent correlations between ultrasound angles and radiographic Cobb angles were observed and the equation to calculate expected Cobb angles with ultrasound angles was valid and accurate. The validation of the equation supports the possible implementation of ultrasound in AIS clinics, which can lead to less frequent radiography, to reduce the ionizing-radiation in AIS patients.
19. Comparison between Augmented Reality navigation and free-hand technique for pedicle screw placement: a matched-control study

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³Department of Image Guided Therapy Systems, Philips, Best, The Netherlands

Background: Computer-assisted navigation has been reported to improve pedicle screw placement for a wide spectrum of spinal pathologies. The purpose of the study is to determine whether intraoperative 3D image-guided augmented reality (AR) navigation has a superior pedicle screw placement accuracy compared to free-hand technique.

Method: Twenty patients undergoing spine surgery with pedicle screw placement with and 20 patients without augmented reality (AR) navigation. The AR navigation group was prospectively enrolled and treated. The AR technology uses intraoperative 3D cone beam CT (CBCT) imaging from a robotic C-arm for guidance with video cameras integrated into the C-arm x-ray detector (Philips Healthcare, Best, the Netherlands). The study group was matched with a control group of equal patient sample size operated using the free-hand technique, with similar indications for surgery, anatomical spinal levels and complexity as the study group. Three independent reviewers assessed clinical accuracy for all screws using the Gertzbein scale. Screws graded as within the pedicle or breaching the cortex less than 2 mm were considered accurately placed. The screw placement assessment was done based on the intraoperative CBCT and the postoperative CT for the navigation and control groups, respectively. Length of hospital stay and procedure time were measured for comparison between both groups.

Results: No significant difference in gender, age, height, or weight were observed between both groups. Thirteen scoliosis, 2 kyphosis and 5 other clinical indications were matched, with 262 and 288 screws radiologically assessed in the navigation and control group, respectively. The share of thoracic screws was comparable between groups (64% vs 62%, p=0.86). The clinical accuracy of the navigation group was statistically higher (94% vs 90%, p=0.047) with twice the amount of screws entirely within the pedicle (63% vs 31%, p<0.001) and neither group had a screw with more than 4 mm breach. There was no significant difference in length of hospital stay or procedure time.

Discussion: This study is the first clinical study to compare augmented reality navigation with intraoperative 3D imaging with free-hand surgery for pedicle screw placement. AR navigation demonstrated a significantly higher clinical accuracy for pedicle screw placement compared to free-hand technique.

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1University Medical Center Utrecht, Department of Orthopaedic Surgery
2University of Twente, Department of Biomechanical Engineering

Background: Scoliosis is a 3D deformity with a prominent torsional component. Therefore, a derotational force should be given to reduce it. Current growing rod technologies are capable of altering the coronal and sagittal plane, but cannot provide correction in the axial plane. We developed a (non-fusion) scoliosis correction implant that can revert axial rotation with a rotational spring (Figure 1). Since idiopathic scoliosis does not occur naturally in animals, this animal study aims to test the devices’ efficacy by creating the very deformity that it aims to reduce, i.e. an idiopathic-like scoliosis with coronal deformity, relative anterior spinal overgrowth (RASO) and axial rotation. We hypothesize that adding a contralateral torsional implant to a unilateral tether will result in scoliosis that is morphologically more like an idiopathic scoliosis than a tether-induced scoliosis.

Method: Scoliosis was induced in 10 male, 7 month old Göttingen minipigs. One group (N=5) received only a tether spanning 8 vertebrae; T10-L3 (TO; tether only). The other group (N=5) was implanted with both a tether and a torsional spring implant fixed to the apex on the contralateral side (T/R; tether-rotation). Major curve, lordosis, apical rotation, spinal growth, and flexibility were measured radiologically during 12 week follow-up.

Results: Coronal deformation increased during follow-up from 0.5° immediately post-operative to 15.7° at 12 weeks for the TO group and from 3.3° to 20.3° for the T/R group (p=0.39). Lordosis increased from 2.2° to 13.0° for the TO group and from 0° to 10.3° for the T/R group (p=0.68). Axial rotation increased from 1.2° to 2.9° in the TO group and from 7.6° to 19.3° for the T/R group (p<0.01). Mean spinal growth at 12 weeks was 1.5 cm for the TO group and 1.3cm for the T/R group (p=0.22). The T/R group showed a larger increase in RASO during follow-up (-2.0% to 0.3%) compared to the TO group (-0.5% to 0.2%) (p<0.01). All instrumented segments remained mobile.

Conclusion: A torsional, non-fusion device added to a contralateral tether induces a scoliosis in Göttingen minipigs that is morphologically similar to idiopathic scoliosis. This shows the potential of (de)rotational forces on the growing spine.
Figure 1: Torsional Spring Implant
21. Spring Distraction System to Correct Early Onset Scoliosis: 2 Year Follow-up Results from 17 Patients.

Justin V.C. Lemans MD,¹ Sebastiaan P.J. Wijdicks MD,¹ René M. Castelein MD PhD,¹ Moyo C. Kruyt MD PhD¹

¹University Medical Center Utrecht, Department of Orthopaedic Surgery

Background: Early onset scoliosis is usually surgically treated with either Traditional Growing Rods or Magnetically Controlled Growing Rods. Both systems are distracted periodically, either surgically or non-surgically. We developed the Spring Distraction System (SDS), which uses a compressed spring to continuously correct the curve while stimulating spinal growth (Figure 1). It does not have to be periodically lengthened and can be used with any instrumentation system. Due to its novelty, its efficacy is currently tested in a prospective trial. This study aims to establish SDS’ efficacy in curve correction and spinal growth maintenance.

Method: All primary- and revision cases (conversion from failed other systems) who were implanted with SDS and who had ≥18 months of follow-up were included. Data on demographics, surgical parameters and complications were collected. Main coronal curve angle, L1-S1 lordosis, T5-T12 kyphosis, T1-T12-, T1-S1 spinal length (measured as a spline curve through the midpoint of each vertebral endplate) and spring length increase were measured on calibrated radiographs. Length increases (from postoperative to latest follow-up) were expressed in mm/yr.

Results: We included 17 patients (13 primary and 4 revision cases) with a mean of 1.9±0.2 year follow-up. The cohort included 6 boys and 11 girls. There were 4 idiopathic, 4 congenital, 3 syndromic and 6 neuromuscular curves. Mean age at implantation was 8.7±1.9 and 10.8±1.4 years for primary- and revision cases respectively. Results can be found in Table 1. In primary cases, the main coronal curve was reduced from 64°±18 to 32°±12 post-operatively, and was maintained at latest follow-up (31°±15). For revision cases, the main curve decreased from 34°±10 to 28°±4 but increased again during follow-up (35°±12). Lordosis and kyphosis decreased post-operatively, but increased to their pre-operative values during follow-up. In both primary and revision cases, mean spring length increase was 11 mm/year during follow-up. Primary- and revision cases had similar increases in T1-T12 length (primary: 9mm/yr, revision: 8mm/yr) and T1-S1 length (primary: 14mm/yr, revision: 12mm/yr). There were 14 implant-related complications necessitating 9 re-operations.

Conclusion: SDS showed maintenance of curve correction and allowed for spinal growth during follow-up without repetitive distractions. Primary cases did better than revision cases.
**Figure 1: Spring Distraction System**

**Table 1: Radiographic results**

<table>
<thead>
<tr>
<th></th>
<th><strong>Primary cases (N=13)</strong></th>
<th></th>
<th><strong>Revision cases (N=4)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-operative</td>
<td>Post-operative</td>
<td>Latest follow-up</td>
<td>Pre-operative</td>
</tr>
<tr>
<td>Main curve (°)</td>
<td>64 (±18)</td>
<td>32 (±12)</td>
<td>31 (±15)</td>
<td>34 (±10)</td>
</tr>
<tr>
<td>Secondary curve (°)</td>
<td>33 (±14)</td>
<td>21 (±13)</td>
<td>23 (±10)</td>
<td>23 (±8)</td>
</tr>
<tr>
<td>T1T12 length (mm)</td>
<td>195 (±25)</td>
<td>202 (±22)</td>
<td>219 (±29)</td>
<td>226 (±11)</td>
</tr>
<tr>
<td>T1S1 length (mm)</td>
<td>325 (±37)</td>
<td>338 (±33)</td>
<td>364 (±38)</td>
<td>352 (±18)</td>
</tr>
<tr>
<td>Instrumented length (mm)</td>
<td>NA</td>
<td>263 (±64)</td>
<td>282 (±70)</td>
<td>NA</td>
</tr>
<tr>
<td>Spring length increase (mm)</td>
<td>NA</td>
<td>NA</td>
<td>20 (±9)</td>
<td>NA</td>
</tr>
<tr>
<td>L1-S1 lordosis (°)</td>
<td>51 (±15)</td>
<td>42 (±10)</td>
<td>49 (±14)</td>
<td>61 (±9)</td>
</tr>
<tr>
<td>T5-T12 kyphosis (°)</td>
<td>19 (±25)</td>
<td>16 (±15)</td>
<td>25 (±13)</td>
<td>35 (±20)</td>
</tr>
</tbody>
</table>
22. Comparison of Complication Profile Between the Magnetically Controlled Growing Rod and the Spring Distraction System in the Treatment of Early Onset Scoliosis.

Justin V.C. Lemans MD, Casper S. Tabeling BSc, Sebastiaan P.J. Wijdicks MD, René M. Castelein MD PhD, Moyo C. Kruyt MD PhD

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Background: Growing rod surgery is associated with high complication rates, which are attributed to the need for frequent re-operations and high stresses on the instrumentation due to intermittent forceful distractions. Although the need for re-operations can be mitigated by using Magnetically Controlled Growing Rod (MCGR), recent literature shows that complications are still frequent. We developed the Spring Distraction System (SDS), which continuously distracts the spine with a compressed spring. Although it offers a theoretical favourable biomechanical stress profile, its effect on complications has not yet been studied. The current study aims to compare complication rates between MCGR and SDS.

Method: We performed a retrospective cohort study to compare complication rates with the classification system used by Smith et al. [1] between patients who underwent primary implantation with either MCGR or SDS. Patient- and disease-related variables were collected and 2 observers independently scored and graded complications in all included patients. Since follow-up of most SDS patients is around 2 years, we only compared complication rates in both cohorts during the first 2 years of follow-up.

Results: We included 12 MCGR and 9 SDS patients. Mean age at surgery was 8.0±1.6 and 8.9±2.0 years for MCGR and SDS respectively. All complications are shown in Table 1. The MCGR group had 13 complications (1.1/patient), 9 patients (75%) had at least 1 complication. The SDS group had 9 complications (1.0/patient), 6 patients (67%) had at least 1 complication. SDS patients had fewer implant failures (anchor pull-out and failure to lengthen comprised >50% of complications in the MCGR group vs. 22% in the SDS group) and also underwent fewer unplanned re-operations (22%) than patients in the MCGR group (33%). All complications were either grade I or II.

Conclusion: Although total complication rate in the first 2 years follow-up is similar between SDS and MCGR, SDS patients seem to have less instrumentation failure and re-operations compared to patients implanted with MCGR.

Table 1: Complications in MCGR and SDS

<table>
<thead>
<tr>
<th></th>
<th>Complications MCGR (12 patients)</th>
<th>Complications SDS (9 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Device related</td>
<td>Disease related</td>
</tr>
<tr>
<td>Anchor pullout</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Failure to lengthen</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Increased kyphosis/PJK</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Superficial SSI</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Deep SSI</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Implant prominence</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Wound dehiscence</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Swelling/Bursitis</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Persistent pain</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Neuromonitoring change</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12</strong></td>
<td><strong>1</strong></td>
</tr>
</tbody>
</table>
23. The 22q11.2 Deletion syndrome is a confounder in the association between congenital heart disease and scoliosis

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Background: For over four decades, clinicians and researchers have suggested a relationship between congenital heart disease (CHD) and scoliosis, attributed to either the disease itself or to the long term effects of cardiac surgery on the immature thoracic cage. However, no study has yet accounted for 22q11.2 deletion syndrome (22q11.2DS, most common cause of velocardiofacial syndrome and DiGeorge syndrome), which is known for a scoliosis risk of 50% and is the second most common cause of CHD after Down syndrome. The goal of this study is determine whether 22q11.2DS is a confounder in the presumed association between CHD and scoliosis.

Method: We systematically determined the presence of scoliosis (Cobb angle >10 degrees), blind to genetic diagnosis, using thorax radiographs in a well-characterized sample of 315 adults with CHD (primarily tetralogy of Fallot); with (n=86) and without (n=229) 22q11.2DS. Patients were matched by sex and CHD severity and excluded if there was another known syndromic diagnoses.

Results: The prevalence of scoliosis in adults with CHD and 22q11.2DS (n=46, 53.5%) was significantly greater than in those without 22q11.2DS (n=18, 7.9%, p<0.0001). The presence of a 22q11.2 deletion (odds ratio [OR] 25.4, 95% CI 11.2–57.4, p<0.0001), thoracotomy before age 12 years (OR 3.5, 95% CI 1.6–8.1, p=0.0027) and severe CHD (OR 2.3, 95% CI 1.1–4.7, p=0.0196), but not sex, were significant independent predictors of scoliosis. In the 22q11.2DS group, a right-sided aortic arch was associated with a left thoracic scoliotic curve (p=0.036).

Conclusion: The prevalence of scoliosis in the CHD population without a 22q11.2 deletion approximates that of the general population. While in the CHD population with a 22q11.2 deletion, the prevalence of scoliosis approximates that of the general 22q11.2DS population. Paediatric surgical approach and severity of CHD were weaker independent contributors as compared to the 22q11.2 deletion. The results support the importance of a genetic diagnosis of 22q11.2DS to the risk of developing scoliosis in individuals with CHD. This study suggests that the 22q11.2 deletion may represent a common etiopathogenetic pathway for both CHD and scoliosis and thus is a confounder for the presumed association between CHD and scoliosis.
Cervical Spine Anomalies within the 22q11.2 Deletion Syndrome: Risk and Screening

**Jelle F. Homans, MD**¹, Bern-Jan Hogendoorn, BSc¹, Moyo C. Kruyt, MD, PhD¹, Terrence B. Crowley³, Donna M. McDonald-McGinn, MS, LCGC³, Frederik JA Beek, MD PhD², René M. Castelein, MD, PhD¹

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**Background:** The 22q11.2 deletion syndrome (22q11.2DS), previously known as the DiGeorge syndrome or velocardiofacial syndrome, is the most common microdeletion occurring in ~1:3000-6000 children. This deletion results in a variation of clinical features; including congenital cervical spine anomalies. Based on small case series, the prevalence of cervical spine anomalies is 90.5-100% and radiological screening including flexion extension X-rays for all patients with 22q11.2DS is recommended. Yet, the clinical significance of these anomalies and the effect of screenings remains unclear. The objective of this study is to identify the prevalence of cervical spine anomalies in 22q11.2DS in a large cohort including clinical implications.

**Method:** All consecutive patients (at least 5.5 years old) with a confirmed 22q11.2 deletion evaluated between January 2014-November 2018 were included. The cervical spine radiograph reports were reviewed for cervical anomalies. Moreover, the need for cervical MRI was determined. Demographics and associated features were analysed (gender, age, congenital heart defect). The means, standard deviation and Odds Ratios(OR) were calculated.

**Results:** A total of 127 patients with 22q11.2DS were included. The mean age was 10.3 years and 48% were male. Sixty-six percent had at least one cervical spine abnormality. A correlation was found between male patients and congenital cervical spine anomalies (OR: 2.26). Based on the cervical radiographs, four patients (3%) required a cervical MRI; one due to a block-fusion, in order to determine the articulation between C1 and C2 and three because of possible instability. These patients underwent a flexion-extension MRI revealing a stable spine. Nevertheless, one patient that was not thought to have instability developed neurological symptoms without significant trauma, years after initial screening, and required cervical spondylodesis.

**Conclusion:** In this study we found that the majority (66%) of 127 patients with 22q11.2DS had some cervical anomaly. A higher prevalence was found in male patients. The majority of the anomalies can be regarded as insignificant, since they have no clinical implications. In three patients a flexion-extension MRI was considered necessary based on the radiograph which however indicated a stable spine. Unfortunately the radiological screening could not prevent the occurrence of neurological symptoms in one of our patients.
25. The changing position of the center of mass of the thorax during growth in relation to pre-existent vertebral rotation

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From the 1Department of Orthopaedic Surgery, University Medical Center Utrecht, Utrecht, The Netherlands; 2Imaging Division, University Medical Center Utrecht, Utrecht, The Netherlands.

**Background:** The normal, non-scoliotic thoracic spine is known to have a slight vertebral rotation in the transversal plane changes direction during growth; a transition from left-sided towards right-sided rotation with increasing age. This pattern matches the changing curve convexity seen when idiopathic scoliosis develops at different ages. The scoliotic curve thus seems to follow the built-in rotational pattern that is already present to a much smaller degree in the normal spine. The direction of pre-existent rotation was shown to be related to organ orientation; in situs inversus the rotation is opposite to situs solitus. We hypothesize that the eccentric position of the body’s center of mass (COM) determines the direction of this pre-existent rotation of the thoracic spine, and that the position of the COM of the thorax changes position from the right side to the left during growth.

**Method:** Computed tomography (CT) scans of the thorax of infantile (0-4 years, n=40), juvenile (4-10 years, n=53) and adolescent (10-18 years, n=62) children without spinal pathology were included from an existing database. The location of the COM inside the thorax was calculated based on Hounsfield-units, representing tissue mass. The COM offset was defined as the shortest distance to the midsagittal plane.

**Results:** At the infantile age (0-4 years) the COM was 2.5±2.1 mm on the right side of the midsagittal plane, whereas the COM at the adolescent age (10-18 years) was 3.1±2.3 mm on the left side. At juvenile age (4-10 years) the COM was not significantly deviated from the midsagittal plane. The mean COM offset correlated linearly with age (r=0.77, p<0.001). Intraclass correlation coefficients for intra- and interobserver reliability were 0.83 (95%, CI: 0.51-0.94) and 0.88 (95% CI: 0.58-0.96).

**Conclusion:** The COM shifts from slightly on the right side of the thorax at the infantile age, to neutral at juvenile age, to the left at adolescent age. This corresponds to the earlier demonstrated change in direction of pre-existent rotation in the normal spine with age, as well as with the well-known changing direction, from left to right, of thoracic curve convexity in scoliosis at different ages.
26. The concept of spinal lordosis. How is the lumbar lordosis organized in the normal population.

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Department of Orthopedic Surgery, Spine Unit, Centre des Massues, Lyon (France)

Purpose: Instead of Lumbar Lordosis (LL) with arbitrary anatomical limits between L1 and S1, the Spinal Lordosis (SL) described by Berthonnaud is defined by two tangent arcs of circle in the lumbar area: the lower arc extends from S1 to the apex, the upper arc from the apex to the inflexion point where Lordosis transitions in Kyphosis.

The variability of sacral slope (SS) and Pelvic Incidence (PI) in the population explain different morphologies of LL described in the Roussouly classification.

The objective of this study is to establish and describe a ratio between upper (UAL) and lower (LAL) arcs of SL for each sagittal spine alignment on an asymptomatic population.

Methods: A total of 373 adult volunteers had a standing lateral radiograph including spine and pelvis. Sacropelvic parameters, global LL, inflexion point location, and type of Roussouly were described.

As LAL is equal to SS, UAL was obtained by the formula UAL = SL – LAL = SL – SS. The SL ratio = UAL/LAL = (SL – SS)/SS was calculated for each type.

Results: UAL unvariably averaged 20 degrees in any of Roussouly types. PI, SS and LL were respectively 40°, 30° and 51° for type 1; 41°, 30° and 48° for type 2; 45°, 56°, 40° and 60° for type 3; 62°, 49° and 70° for type 4.

LAL increases with PI. SL (UAL/LAL) ratio was 0.52 in all subjects. The lower arc of lordosis LAL accounted for 76% for type 1, 60% for type 2, 49% for type 3 and 41% for type 4.

Discussion: This study demonstrates the reverse proportionality between SL ratio and PI in asymptomatic population. As UAL is almost constant, SL is directly dependent on SS and we may assume that SL=SS+20°.

This angle distribution is fundamental and confirms that surgical restoration of the lumbar lordosis has to be concentrated on the distal lumbar area to correct SS in adequation with PI.

Conclusion: This study gives normal targets by type of Roussouly. When planning spinal fusion, surgeon have to consider this new ratio to restore adapted curves of the spine in order to avoid junctional failures.
27. Indication and treatment of adult kyphoscoliosis (INTRAKS study) - A retrospective cohort study at Oslo university hospital

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2 Department of Orthopedic Surgery, Haukeland University Hospital, Bergen, Norway
3 Faculty of Medicine, University of Oslo

Background: Some consensus already exists on indication and treatment of adult kyphoscoliosis, however it is made unclear due to complexities in both selection and surgery. Symptoms of adult kyphoscoliosis are mainly due to primary degeneration, trauma or may arise after elective surgery of the spine. Correctional surgery of spinal deformities has a lot of complications and disparity. The frequency of such surgery is increasing world wide. The aim of this study was to get an overview of the patients at Oslo University Hospital (OUH) about demographic data, indication for surgery, the primary operation method, perioperative complications and the radiological outcome.

Material and method: Patient journals were examined, as well as operation notes and x-ray images from 74 eligible patients who received spinal corrective surgery at Ullevål, OUH, from the year 2011-2017. Inclusion criteria were 1) age > 25 at operation, along with 2) osteotomy or a fixation of three or more vertebral levels. Trauma patients were excluded.

Results: The mean age of the patients was 62 years old, most of them had ASA-class 2 or 3. 21% of the patients had a major complication, 60% of the complications were due to infection. The type of technique with fewest complications was PLF. 49% had at least one revision surgery. Thoracic to lumbar fixations had a revision rate of 58%. Radiological outcome shows an improvement in sagittal vertical axis (SVA) and lumbar Cobb’s angle. SP-osteotomies had a 25% complication rate. 15% of those who underwent PSO had a complication.

Conclusion: As the complexity of the procedure increases, so does the amount of complications and revisions needed. There seems to be a correlation between the length of the fixations and the revision rate. A more standardized method of follow-up is needed to assess the outcome.

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28. Indication and Treatment of adult kyphoscoliosis (INTRAKS study) - Study protocol of a prospective multicenter observational effectiveness study

Vinjar Brenna Hansen¹,8, Nooman Ahmad⁷, Christian Hellum², Ivar Austevoll⁶,8, Bungo Otsuki³, Norimasa Ikeda³, Takayoshi Shimizu³, Fredrik Strömqvist⁴, Freyr Gauti Sigmundsson ⁵, Ove Furnes¹,8, Stephan Maximillian Röhrl²

Background: Degeneration, iatrogenic-/idiopathic causes and fractures can lead to kyphoscoliotic deformities potentially resulting in pain and loss of function. The surgical strategies rely on surgeon preferences and type of deformity as well as clinical symptoms. The complication rate of surgical treatment is high. The aim of this study is to elucidate the indications for surgical treatment of kyphoscoliosis and evaluate the effectiveness of surgical and non-surgical outcome clinically and radiologically.

Method/design: The study is a prospective multicenter observational effectiveness study. Patients planned for correction of spinal deformity from Haukeland University Hospital and Oslo University Hospital in Norway, Malmö University Hospital in Sweden and Kyoto University Hospital in Japan will be included. The study cohort consists of two treatments groups: 1. (Correction) surgery for kyphoscoliosis (the study group); 2. Non-surgical treatment of kyphoscoliosis (the control group). We will collect baseline- demographic-, surgical-, clinical- and radiological- data. To equalize the distribution of observed baseline characteristics Propensity score matching will be performed. The sample size is calculated to 220 patients anticipating a 10% loss to follow-up and exclusions due to the propensity score matching, resulting in a total of 300 patients. The primary outcome will be the Oswestry disability index (ODI) at 1 year follow-up and 30% improvement in ODI is regarded as treatment success. The study will compare the outcomes between the treatment groups and investigate predictors for success and for complications/side effects.

Discussion: The study will contribute to real-world knowledge of the treatment of kyphoscoliosis and may contribute to improved clinical decision making for the patient groups.

Keywords: prospective, adult kyphoscoliosis, osteotomy, correction surgery of the spine, complications, propensity score matching

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29. Is the domestic pig (Sus scrofa domesticus) curled tail, a form of Scoliosis?

Ane Simony MD, PhD¹, Mark Egelund², Hanne Thomsen², Elisabeth Maersk Moller³, Mikkel Andersen¹.

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**Background:** The etiology of scoliosis has been unsolved for more than a decade. Very few animals develop a rotation of the spine, as part of their natural growth. The domestic pig (Sus scrofa domesticus) has descended from the wild boar (Sus scrofa) which has a short straight tailed. The domestic pig is born with a straight tail but develops a curvature of the tail, within the first 4 weeks of life. The presence of a rotated tail is unique for the domestic pig, since their ancestors the wild boar has the straight tail with is also found among other older breeds of pigs like the Mangalitza (the wool pig). This radiology study is focused on examination the rotation of the pigs tail with x-ray and CT scans and compare the Cobb angel, lordosis and rotation in domestic pigs at 12 weeks age and 6-8 months age.

**Methods:** 5 tails from domestic pigs in the age of 12 weeks and 5 tails from mature pigs age 6-8 months are examined with AP and lateral x-ray and CT scan. The number of vertebrae, the Cobb angel, lordosis and rotation a.m Pedriolle was recorded. Since cutting of the tip of the tail in young piglets is a common practice, Lordosis measurements was performed from in the 5 proximal vertebrae’s. A comparison of the young and mature pigs is performed, to understand the development of rotation in the tail.

**Results:** 3/4 young pigs had scoliosis, with Cobb ranging from 10-30° and spinal rotation. 5/5 old pigs had scoliosis, with Cobb ranging from 15-30°. The lordosis ranged from 55-72° in the young pigs, and 55-68° in the older pigs. No degenerative changes were observed in the older pigs. The radiological parameters seem comparable to scoliosis, and the development off tail rotation and scoliosis occurs from birth to adolescence in pigs.

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