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ORIGINAL ARTICLE

An international consensus on the appropriate evaluation and treatment for adults with spinal deformity

Sigurd H. Berven[1] · Steven J. Kamper[2] · Niccole M. Germscheid[3] · Benny Dahl[4] · Christopher I. Shaffrey[5] · Lawrence G. Lenke[6] · Stephen J. Lewis[7] · Kenneth M. Cheung[8] · Ahmet Alanay[9] · Manabu Ito[10] · David W. Polly[11] · Yong Qiu[12] · Marinus de Kleuver[13] · AOSpine Knowledge Forum Deformity

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Abstract
Purpose Evaluation and surgical management for adult spinal deformity (ASD) patients varies between health care providers. The purpose of this study is to identify appropriateness of specific approaches and management strategies for the treatment of ASD.
Methods From January to July 2015, the AOSpine Knowledge Deformity Forum performed a modified Delphi survey where 53 experienced deformity surgeons from 24 countries, rated the appropriateness of management strategies for multiple ASD clinical scenarios. Four rounds were performed: three surveys and a face-to-face meeting. Consensus was achieved with ≥70% agreement.
Results Appropriate surgical goals are improvement of function, pain, and neural symptoms. Appropriate preoperative patient evaluation includes recording information on history and comorbidities, and radiographic workup, including long standing films and MRI for all patients. Preoperative pulmonary and cardiac testing and DEXA scan is appropriate for at-risk patients. Intraoperatively, appropriate surgical strategies include long fusions with deformity correction for patients with large deformity and sagittal imbalance, and pelvic fixation for multilevel fusions with large curves, sagittal imbalance, and osteoporosis. Decompression alone is inappropriate in patients with large curves, sagittal imbalance, and progressive

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✉ Sigurd H. Berven
bervens@orthosurg.ucsf.edu

1 Department of Orthopaedic Surgery, University of California San Francisco, 500 Parnassus Ave, MU320W, San Francisco, CA 94143-0728, USA

2 Musculoskeletal Division, The George Institute for Global Health, Sydney, Australia

3 Research Department, AOSpine International, Davos, Switzerland

4 Spine Unit, Department of Orthopedic Surgery, Rigshospitalet and University of Copenhagen, Copenhagen, Denmark

5 Department of Neurosurgery and Orthopaedic Surgery, University of Virginia, Charlottesville, VA, USA

6 Department of Orthopedic Surgery, Columbia University College of Physicians and Surgeons, New York, NY, USA

7 Department of Surgery, Toronto Western Hospital, Toronto, ON, Canada

8 Department of Orthopaedics and Traumatology, The University of Hong Kong, Pokfulam Road, Hong Kong, China

9 Faculty of Medicine, Acibadem University, Istanbul, Turkey

10 Department of Orthopedic Surgery, National Hospital Organization Hokkaido Medical Center, Sapporo, Japan

11 Department of Orthopaedic Surgery, University of Minnesota, Minneapolis, MN, USA

12 Department of Spine Surgery, The Affiliated Drum Tower Hospital of Nanjing University Medical School, Nanjing, China

13 Department of Orthopedics, Radboud University Medical Center, Nijmegen, The Netherlands

deformity. It is inappropriate to fuse to L5 in patients with symptomatic disk degeneration at L5–S1.

Conclusions These results provide guidance for informed decision-making in the evaluation and management of ASD. Appropriate care for ASD, a very diverse spectrum of disease, must be responsive to patient preference and values, and considerations of the care provider, and the healthcare system. A monolithic approach to care should be avoided.

Keywords Adult spinal deformity · Surgery · Appropriateness · Consensus · Delphi

Introduction

Spinal deformity in adults is common and has a significant and measurable impact on health-related quality of life (HRQOL) [1]. The burden of adult spinal deformity (ASD) on society and the healthcare system is large and increasing [2]. However, the management of ASD is characterized by significant variability without consensus [3–5]. Indications for surgery, preoperative preparations, intraoperative strategies, and postoperative care vary within the community of physicians who care for patients with ASD [6–8]. The clinical presentations of ASD patients vary, and may include symptoms of pain, functional limitations, neural compromise, and cosmetic problems. Consequently, the patient cohort is heterogeneous and classifications of ASD have included considerations of curve patterns, sagittal plane alignment, and clinical impact of deformity on health status [9–12]. A high level evidence-based approach to the appropriate evaluation and management of ASD patients is not available and may improve management. Achieving consensus on appropriate evaluation and management should encompass the broad range of approaches and strategies available, and be responsive to relevant considerations, including patient values and preference, physician preferences and skills, and cost and value considerations [13, 14]. The appropriate treatment strategy is the approach that leads to the largest improvement in HRQOL with the least risk and cost. Expert panels can help identify appropriateness criteria as decision-making tools to provide actionable guidance for specific clinical scenarios and pathologies [15, 16]. Recommendations that define reasonable and appropriate care, developed by a panel of experienced surgeons from geographically diverse regions with distinct training and specialties, would empower patients and physicians to make informed decisions regarding appropriate care without mandating a monolithic approach. The purpose of this study is to define appropriateness of specific approaches and management strategies for the treatment of ASD patients.

Materials and methods

Design

A modified Delphi survey was performed, similarly to the approach applied by de Kleuver et al. for adolescent idiopathic scoliosis [17]. The scoring system is based upon the RAND/UCLA appropriateness method [15]. The study included three web-based surveys (January to June 2015) and one face-to-face meeting (July 2015).

Panelists

Invitation to participate was sent by email to all AO Spine Members ($n = 5482$). A total of 155 members applied, 53 were selected, and 46 agreed to participate. Eligibility was based on number of years in practice (minimum of 6 years), clinical practice focus (minimum of 35% focus on adult spine), and estimated number of ASD cases examined (minimum of 50 patients) and operated (minimum of 20 patients) per year. Seven members of the AOSpine Deformity Knowledge Forum Steering Committee who also met the above criteria contributed as panelists. The panel consisted of 53 spine deformity surgeons from 24 countries from different geographic locations. All panelists were male, mean age was 50 years, and over 90% had been practicing spine surgery for 10 or more years (Table 1). The research team MdK, SB, SK, NG, BD and CS did not participate as panelists.

Delphi rounds

The study consisted of four rounds: three rounds were web-based surveys and the final round was a face-to-face meeting. Survey questions were divided into four sections: goals of care, preoperative considerations, intraoperative considerations, and postoperative considerations. In each round, panelists answered specific questions and could then provide additional comments and opinions, either through an open text field, which appeared below every survey question or through discussions during the final meeting. After each round, every panelist received a de-identified summary of all responses, along with their individual ratings.

In the first round, panelists reviewed two peer-reviewed manuscripts that defined ASD and were asked to answer a series of questions which required them to rate the appropriateness of various clinical considerations and scenarios for the ASD patient [9, 18].

In the second round, to increase granularity, four patient cases were presented, representing the spectrum of ASD,

Table 1 Demographic profile of panelists

Characteristic	Round			
	1 ($n = 53$)	2 ($n = 51$)	3 ($n = 49$)	4 ($n = 20$)
Age (years)				
30–39	5	5	5	1
40–49	16	14	13	4
50–59	31	31	30	14
60–69	1	1	1	1
Region				
Asia Pacific	18 (34)	18 (35)	18 (37)	7 (35)
Europe	11 (21)	11 (22)	10 (20)	6 (30)
Africa	1 (2)	1 (2)	1 (2)	0 (0)
Middle East	5 (9)	5 (10)	5 (10)	2 (10)
Latin America	5 (9)	4 (8)	3 (6)	1 (5)
North America	13 (25)	12 (24)	12 (24)	4 (20)
Years in practice				
<10	4 (8)	3 (6)	3 (6)	1 (5)
10–19	24 (45)	23 (45)	22 (45)	9 (45)
20–29	18 (34)	18 (35)	17 (35)	7 (35)
30–39	6 (11)	6 (12)	6 (12)	2 (10)
40–49	1 (2)	1 (2)	1 (2)	1 (5)

Values are presented as *N* (%)

from mild to severe. For each case, six hypothetical clinical scenarios were created by combining patient characteristics (e.g., age, osteoporosis, comorbidities) that influence risks and benefits of surgery.

In the third round, questions from the previous rounds which required additional clarification were re-worded. The operative techniques actually performed for the four clinical cases from the second round were also presented and panelists were asked to rate the appropriateness of the selected treatment strategies.

In the final round, 20 panelists met face-to-face, which provided an interactive platform to exchange and express opinions. The research team moderated the discussion. For areas which were ambiguous and required further clarification, questions were developed in real-time. Using an electronic audience response system, anonymous voting was performed.

Rating process and analysis

The goals of care were ranked according to their relative importance; results are presented as mean rank. With respect to the pre-, intra- and postoperative considerations, panelists rated appropriateness of procedures and management strategies according to the RAND/UCLA appropriateness method using the definitions described by Fitch et al. [15]. Procedures and strategies were rated on a nine-point rating scale, collapsed into three categories: 'inappropriate' where the expected negative consequences exceed the expected health benefit such that the procedure should not be performed (scores of 1–3); 'reasonable' where the balance of risk and benefit is unknown, but there is a reasonable chance of benefit with limited risk (4–6); and 'appropriate' where the expected health benefit exceeds the expected negative consequences by a wide margin such that the procedure is worth doing (7–9). For each question, the percentage of responses in each category was calculated. Consensus was defined as $\geq$70% of responses in either the appropriate or inappropriate category for a particular question. Thus, each proposed management strategy was defined; appropriate (consensus achieved), inappropriate (consensus achieved), or no consensus.

Results

All panelists completed the first round and 96% completed the second and third rounds.

Goals of care

The highest ranked goals of care in treating ASD patients were functional improvement (mean rank of 2.1 from a total of 10 options), pain improvement (mean rank of 2.6), and neural improvement (mean rank of 3.5). Radiographic improvement, prevention of deformity progression, or avoidance of complications were the lowest ranked (mean rank ≥6.0) of the options presented. All data are presented in Supplementary Table 1.

Preoperative management

Assessment of risk factors for surgery and poor prognosis

Table 2 summarizes the consensus regarding preoperative assessment. The panel rated as appropriate specific elements of patient history, physical exam, and circumstances for use of preoperative testing including bone health and cardiopulmonary status.

Preoperative imaging

Table 3 summarizes the consensus regarding preoperative imaging, including use of MRI, CT, and myelography.

Intraoperative management

Surgical strategies

Table 4 summarizes the areas of consensus regarding specific surgical strategies for ASD.

Decompression and length of fusion Decompression alone was inappropriate if there was any spinal sagittal imbalance, or proven radiological curve progression, in larger curves. Decompression with limited fusion was inappropriate if the curve was 60°, and with sagittal imbalance. There was no consensus regarding the appropriateness of decompression with limited fusion. Performing a decompression with long fusion in patients with large coronal deformity (>60°), or sagittal imbalance was appropriate, as long as there were no comorbidities (coronary artery disease, osteoporosis). In the presence of comorbidities, there was no consensus.

Lowest instrumented vertebra

L5–S1 fusion When performing a long lumbar fusion from the lower thoracic spine distally to the lumbar spine, it was appropriate not to fuse L5–S1 in conditions of well-maintained sagittal global alignment, non-osteoporotic vertebra, and no disk degeneration at L5–S1. Conversely, if disk degeneration or symptomatic pathology presented at L5–S1, then it was inappropriate to stop at L5, regardless of sagittal balance and bone quality.

L5–S1 interbody support If a long lumbar fusion from T12 or higher is extended to the sacrum, then it was appropriate to perform interbody support (through anterior or posterior approach) at L5–S1.

Pelvic fixation When performing a long lumbar fusion from the lower thoracic spine to the sacrum (e.g., T10–S1), it was appropriate to perform pelvic fixation if the patient is osteoporotic, or if the patient has a severe deformity (coronal trunk shift >4 cm, sagittal vertical axis offset >5 cm). There was no consensus regarding the appropriateness of pelvic fixation in the presence of isolated sagittal imbalance and good bone quality. When performing a shorter lumbar fusion from the upper lumbar spine to the sacrum (e.g., L2–S1), it was appropriate to perform a pelvic fixation if the patient is osteoporotic and with sagittal imbalance.

Upper instrumented vertebra Ending a lumbar fusion in the lower thoracic spine (e.g., T9–12) was appropriate in cases with small thoracic kyphosis (<30°), adequate sagittal balance, and non-osteoporotic bone. If the thoracic kyphosis is larger (>50°), even with sagittal balance, and non-osteoporotic bone, then there was no consensus on where to end the fusion proximally.

Novel techniques

Table 5 summarizes areas of consensus regarding novel techniques including cement augmentation, percutaneous instrumentation, and osteotomies.

Cement augmentation Cement augmentation at the upper instrumented vertebra (UIV) or UIV + 1 is inappropriate in non-osteoporotic patients. There was no consensus for when cement augmentation was appropriate.

Percutaneous instrumentation Percutaneous fixation was inappropriate in patients with severe coronal deformity (>60°) and severe sagittal imbalance (>100 mm). There was no consensus for when percutaneous fixation was appropriate.

Osteotomies It was inappropriate to perform a Ponte osteotomy in patients with a rigid lumbar hypolordosis with an ankylosed anterior column. It was appropriate to perform a pedicle subtraction osteotomy (PSO) in patients with a rigid lumbar hypolordosis, sagittal imbalance, age 40–65 years, with no comorbidities, and with or without coronal imbalance.

Implant materials, grafts, and neuromonitoring

Local autogenous bone graft was appropriate. It was appropriate to use intraoperative neuromonitoring in correction surgery with levels of fusion above the conus. There was no consensus on which implant and rod materials were appropriate in diverse scenarios.

Table 2 Consensus findings for preoperative assessment of risk factors for surgery and poor prognosis for ASD patients

Area	Item	Level of consensus
Patient history	Medication history	Appropriate
Collecting and evaluating	Surgical history (i.e., previous spine operation)	
	Duration of symptoms	
	Level of pain	
	Social support for patients >65 years of age	
	Family history of degenerative adult deformity	No consensus
	Prior hospitalization	
Patient smoking history	Patient's smoking history through patient reporting	Appropriate
Collecting and evaluating	Patient's smoking cessation in patients who smoke >1 pack per day (for elective surgery)	
	Patient's smoking cessation—never inquire	Inappropriate
	Patient's smoking history through urine/blood testing	No consensus
Cardiovascular condition	Significant co-morbidity (i.e., remote myocardial infarction, blood pressure, and cholesterol medications)	Appropriate
Performing a cardiac stress test (chemical or exercised-based) in patients with	History of congestive heart failure	
	No pulmonary complaints (no shortness of breath, good tolerance to walking 3 flights of stairs), healthy, 40–65 years old	No consensus
Pulmonary condition	History of pulmonary co-morbidity (i.e., chronic obstructive pulmonary disease, asthma), $\geq$40 years old	Appropriate
Performing a pulmonary function test with spirometry in patients with	No pulmonary complaints (no shortness of breath, good tolerance to walking 3 flights of stairs), healthy, 40–65 years old	No consensus
Body mass index (BMI)	BMI to stratify risk or to guide treatment	No consensus
Evaluating		
Bone quality	Bone mineral density with DEXA in patients with history of insufficiency fracture (low energy fracture of extremity and spine)	Appropriate
Evaluating	Bone quality/presence of osteoporosis in patients with known risk factors for osteoporosis	
	Bone quality/presence of osteoporosis- Never inquire	Inappropriate
	Bone mineral density with DEXA in a >65 years old female patient with no known history of osteoporosis (no history of fragility fractures)	No consensus
Patient physical exam	Gross motor function and knee and ankle reflexes by performing a neurological exam	Appropriate
Evaluating	Gait (ability to walk)	
	Pelvic tilt (physical assessment of pelvic version)	
	Hip flexion contracture	
	Skin (surgical site, legs for pigmentation and signs of venous stasis and arterial disease)	
	Peripheral pulses	

Postoperative management

Consensus regarding deep venous thrombosis (DVT) prophylaxis and return to activity after surgery is presented in Table 6. Use of postoperative mechanical prophylaxis (i.e., compression stockings, pneumatic compression devices) was appropriate for all patients, and chemical prophylaxis (i.e., low molecular weight heparin, unfractionated heparin) was appropriate for patients with high risk of DVT.

Many postoperative strategies explored by the panel were considered reasonable as approaches, but did not meet the a priori consensus criteria.

Discussion

Goals of care

Literature in ASD surgery supports the goals of care to include radiographic correction of deformity, prevention of

Table 3 Consensus findings for preoperative imaging for ASD patients

Imaging modality	Item	Level of consensus
X-ray	Full standing anterior–posterior and lateral films	Appropriate
	3D full body standing image (e.g., EOS) (if available in your clinic/country)	
MRI of the lumbar spine	Planned lumbar fusion, with or without no neural symptoms	Appropriate
MRI of the thoracic spine	Planned lumbar or thoracic and lumbar fusion, with myelopathy	Appropriate
	Planned lumbar or thoracolumbar fusion, without neural symptoms	No consensus
MRI of the cervical spine	Planned lumbar or thoracic and lumbar fusion, with myelopathy	Appropriate
	Planned lumbar or thoracolumbar fusion, without neural symptoms	No consensus
CT	Previous laminectomy	Appropriate
	No history of previous surgery	No consensus
CT myelogram of the lumbar spine	No history of previous surgery, when preoperative MRI is available	Inappropriate
	No history of previous surgery	No consensus

progression of the deformity, neural decompression, safety, and improvement of HRQOL in domains including pain, function, self-image, and mental health [3, 6, 19, 20]. The panel ranked improvement of function, pain, and neural status to be the most important, and there is good evidence that surgery results in reliable improvement in these domains [5, 21, 22]. Pekmezci et al. reported that baseline functional limitations in daily life were the most important concern for patients choosing surgery over non-operative care [23]. Acaroglu et al. demonstrated that surgery was more effective than non-operative care in improving health-related quality of life measured as quality adjusted life expectancy, and the effect size of surgery is most in patients with greatest preoperative disability [58]. The panel ranked radiographic improvement, prevention of deformity progression, and avoidance of complications as less important goals. Although the ultimate aim is to improve functional status, it has been shown that functional improvement is correlated with radiographic outcomes such as magnitude of radiographic correction in the sagittal and coronal planes and improvement of spinopelvic and global sagittal alignment [24, 25]. Therefore, it is difficult to separate clinical and radiographic goals, and both are considered appropriate in the surgical management of ASD.

Preoperative considerations

Patient-related factors are important for risk assessment and surgical planning in ASD. Age, BMI, and cardiac and pulmonary comorbidities have been shown to be predictors of perioperative complications, readmissions, and mortality in patients undergoing surgery for ASD [26–28]. Hu and Berven identified a comprehensive list of these variables, including medical conditions, prior surgery, and social support networks which should be recognized prior to elective surgery for ASD to optimize patients preoperatively, thereby reducing the risk of surgical complications [29]. Besides comorbidities, smoking is a predictor of poor patient satisfaction and reduced postoperative fusion rates, and smoking cessation for more than 6 months prior to spinal fusion surgery has been shown to reverse these negative effects [26, 30]. Consistent with the literature, the panel reached consensus on the importance of assessing cardiac and pulmonary function, bone density, and comorbidities in all patients with these comorbidities, as well as identifying smoking habits.

Preoperative imaging is important to assess the magnitude of deformity in the coronal, sagittal, and axial planes, and for planning the surgical strategy. The panel reached consensus that it is appropriate for all ASD patients to be evaluated with preoperative full spine standing anterior–posterior and lateral radiographs. This is in agreement with evidence which consistently shows that full-length standing films is critical for accurate preoperative planning and classification, including visualization of C7 and the femoral heads [25, 31, 32].

Intraoperative considerations

The panel recognized the broad spectrum of surgical approaches for ASD patients, and consensus was reached in only a few scenarios. Consensus was more often reached on inappropriate, as opposed to appropriate, surgical approaches. Specifically, decompression alone is inappropriate in curves of 30° with either a progressive deformity or sagittal imbalance. This is supported by the literature which shows that decompression alone is associated with high rates of progressive deformity and poor outcome in patients with segmental instability and deformity [33]. In

Table 4 Consensus findings for surgical procedures for ASD patients

Area	Item or patient scenario	Level of consensus
Decompression alone	Symptomatic stenosis within a 30° lumbar scoliosis	Inappropriate
	Progressive curve, sagittally balanced	
	Stable curve, sagittal imbalance	
	Symptomatic stenosis on the CONVEX or CONCAVE apex of 30° lumbar scoliosis	No consensus
	Stable curve, sagittally balanced	
Decompression with limited fusion	Symptomatic stenosis within a 60° lumbar scoliosis	Inappropriate
	Stable curve, sagittal imbalance	
	Symptomatic stenosis within a 60° lumbar scoliosis and	No consensus
	Stable curve, with trunk shift of 4 cm to the left, sagittally balanced	
	Stable curve, sagittally balanced	
	Symptomatic stenosis within a 30° lumbar scoliosis and	
	Stable curve, sagittal imbalance	
	Stable curve, sagittally balanced	
Decompression with long fusion	Sagittal imbalance, no comorbidities	Appropriate
	Coronal deformity >60°, with trunk shift >4 cm to the left, no comorbidities	
	Sagittal imbalance, osteoporotic, coronary artery disease	No consensus
	Coronal deformity >60°, with trunk shift >4 cm to the left, osteoporotic, coronary artery disease	
Lumbosacral fusion (lowest instrumented vertebra)	With intermediate posterior fusion (lower thoracic spine to L5), sagittally balanced, non-osteoporotic, no disk degeneration at L5–S1	Appropriate
Interbody support at L5–S1	L5 in patients with long fusion (>7 segments) and symptomatic pathology at L5–S1	Inappropriate
	Anterior column support with ALIF or posterior interbody approach to the L5–S1 segment for a long fusion from T12 to S1	Appropriate
Lumbosacral fusion (lowest instrumented vertebra)	Osteoporotic and	Appropriate
Pelvic fixation (T10–S1)	Sagittal plane deformity (>5 cm)	
	Severe deformity (trunk shift >4 cm, sagittal deformity >5 cm)	
	Sagittally balanced	
	Non-osteoporotic and severe deformity (trunk shift >4 cm, sagittal deformity >5 cm)	
	Non-osteoporotic and	No Consensus
	Sagittal plane deformity (>5 cm)	
	Sagittally balanced	
Lumbosacral fusion (lowest instrumented vertebra)	Osteoporotic, sagittal imbalance	Appropriate
Pelvic fixation (L2–S1)	Osteoporotic, sagittally balanced	No consensus
	Non-osteoporotic, sagittally balanced	
	Non-osteoporotic, sagittal imbalance	
Lumbosacral fusion (upper instrumented vertebra)	Thoracic kyphosis (<30°), sagittally balanced, non-osteoporotic	Appropriate
Thoracolumbar junction (T9–L1)	Thoracic kyphosis (>50°), sagittally balanced, non-osteoporotic	No consensus

ALIF anterior lumbar interbody fusion

line with previous literature, decompression with a limited fusion was considered inappropriate for patients with large coronal deformity (>60°), or sagittal imbalance [34].

Regarding the length of fusion, the choice of upper and lower instrumented vertebra, and distal fixation techniques remains controversial.

Distal fusion level and fixation

For long fusions from the thoracic spine to L5, high rates of subsequent advanced degeneration at L5–S1, high revision surgery rates, and worse outcomes have been reported [35]. Conversely, other research has concluded that patients

Table 5 Consensus findings for novel intraoperative techniques for ASD patients

Area	Item or patient scenario	Level of consensus
Cement augmentation	UIV and UIV + 1 in T10–S1, non-osteoporotic	Inappropriate
	UIV and UIV + 1 in T10–S1, osteoporotic	No consensus
Percutaneous fixation	Coronal deformity (>60°), bends to 30°, severe sagittal imbalance (SVA >100 mm)	Inappropriate
	Coronal deformity (>60°), bends to 30°, moderate sagittal imbalance (SVA 50–100 mm)	No consensus
	Coronal deformity (>60°), bends to 30°, sagittally balanced	
	Rigid coronal deformity >30°	
Ponte osteotomy	Rigid lumbar hypolordosis, sagittal imbalance, immobile disks in the anterior column with rigidly fused anterior interbody/ankyloses	Inappropriate
	Mobile anterior column and	No consensus
	Coronal deformity (>60°), severe sagittal imbalance (SVA >100 mm)	
	Coronal deformity (>60°), moderate sagittal imbalance (SVA 50–100 mm)	
	Trunk shift 6 cm with level shoulders, sagittally balanced	
Pedicle subtraction osteotomy	Rigid lumbar hypolordosis, age 40–65 years, no comorbidities, and	Appropriate
	Sagittal imbalance	
	4 cm trunk shift and level shoulders	
	Rigid lumbar hypolordosis, age >65 years, osteoporotic, coronary artery disease, and	No consensus
	Sagittal imbalance	
	4 cm trunk shift and level shoulders	
Vertebral column resection	Rigid thoracic deformity with 4 cm trunk shift to the left and	No consensus
	Level shoulders, age 40–65 years, no comorbidities	
	Level shoulders, age >65 years, osteoporotic, coronary artery disease	
	Right shoulder elevated with a convex right thoracic deformity, age 40–65 years, no comorbidities	
	Right shoulder elevated with a convex right thoracic deformity, age >65 years, osteoporotic, coronary artery disease	

UIV upper instrumented vertebra, *SVA* sagittal vertical axis

fused to S1 have a higher risk of complications than patients fused to L5, and that the latter have an increased risk of developing sagittal imbalance [36, 37]. The panel recommended selection of L5 as a lowest instrumented vertebra as appropriate in patients with intermediate fusions (lower thoracic spine to L5) who have good sagittal balance and good bone stock and have no disk degeneration at L5–S1. In patients with longer fusions (>7 segments) or symptomatic pathology at L5–S1, fusion to S1 is appropriate.

The role of interbody support and pelvic fixation in patients fused to the sacrum is an important consideration. Interbody fusion and pelvic fixation reduce strain on posterior implants, and potentially improve fusion and maintenance of deformity correction [38–41], but there is conflicting evidence regarding the requirement for this strategy [42–44]. The panel found the use of interbody support, through either an anterior or posterior approach at L5–S1, to be appropriate in all fusions extending from T12 or higher to the sacrum. In patients with osteoporosis or with severe deformity (coronal trunk shift >4 cm, sagittal vertical axis offset >5 cm), the panel also found supplemental pelvic fixation to be appropriate in patients undergoing fusion from L2 or above to the sacrum.

Proximal fixation

The choice of an UIV in ASD is thought to impact proximal junctional pathology. The literature provides limited guidance for extension of fusion to the upper thoracic spine [45–48]. The only area of consensus was for a lumbar degenerative scoliosis fusion to the lower thoracic spine (rather than higher) is appropriate in patients who meet the strict criteria of adequate sagittal balance and no evidence of osteoporosis and with a thoracic kyphosis less than 30°.

The role of osteotomies

The use of three-column osteotomies has increased significantly over the past decade. While osteotomies of the spine provide a powerful technique for posterior-based deformity correction [49], osteotomies have been

Table 6 Consensus findings for postoperative management strategies for ASD patients

Area	Item or patient scenario	Level of consensus
DVT prophylaxis Early mobilization	Low risk of DVT	No consensus
DVT prophylaxis Mechanical	Low risk of DVT	Appropriate
DVT prophylaxis	High risk of DVT	Appropriate
Chemical	Low risk of DVT	No consensus
DVT prophylaxis	High risk of DVT	No consensus
Coumadin	Low risk of DVT	
Return to activity	Sedentary work by 3-month postoperative after a short fusion (<5 segments)	Appropriate
	Cycling at 1-year postop	
	Manual labor at 1-month postoperative	Inappropriate
	Contact sports after a long fusion (>7 segments) when the patient is fully healed and there is good bony fusion	
	Manual labor, hiking, dance, yoga, golf, tennis by 1-year postoperative	No consensus
	Sedentary work by 6 months after long fusion	
	Contact sports after a short fusion (<5 segments) when the patient is fully healed and there is good bony fusion	

associated with high rates of complications, including junctional pathology, nonunion, and perioperative complications [50–52]. Specifically, LaMaida et al. demonstrated high rates of complications in elderly ASD patients treated with osteotomies [50], and Smith et al. identified three-column osteotomies as an independent risk factor for major complications [52]. The panel reached consensus that it is appropriate to perform a PSO on patients with sagittal imbalance due to a rigid lumbar hypolordosis if aged 40–65 years, with no comorbidities, with or without coronal imbalance. In contrast, the panel agreed that performing a Ponte osteotomy in a patient with a rigid deformity and ankylosed spine is inappropriate. Other clinical scenarios for when to perform the Ponte, PSO, or vertebral column resection osteotomies did not reach consensus, largely because of the variability in patients.

The use of novel surgical techniques, including cement augmentation of screws and adjacent vertebra, and percutaneous fixation for deformity did not reach consensus for any scenario. There is limited literature to guide an evidence-based approach to novel techniques in spinal deformity surgery.

Postoperative considerations

DVT is a significant postoperative complication related to morbidity and mortality following ASD surgery [53, 54]. The panel achieved consensus that it is appropriate to use mechanical prophylaxis in all surgical ASD patients, and chemical prophylaxis in patients who are at a high risk for DVT. Patients undergoing surgical treatment for adolescent idiopathic scoliosis have been shown to return to full, unrestricted activity including sports by 1 year postoperative without adverse effects [55, 56]. In contrast, there is little evidence to guide time to return to work and recreational activities for adults, and there is substantial variability in reported return-to-activity rates [57].

Clinical relevance and limitations

The strength of this study is that it addressed a broad spectrum of scenarios and decision points that physicians and patients encounter routinely in management of patients with ASD. Many decision points simply cannot be addressed practically with empirical studies or randomized trials, leading to limited evidence in the literature, and significant variability in approaches to care. By employing an international experienced panel, we provided guidance in defining appropriate and inappropriate approaches to care where possible. It turned out that it was very difficult to reach consensus. We believe that this is due not so much to lack of evidence, but due to the complexity of the disease combined with almost endless permutations of confounding comorbidities. Furthermore, patient preference, patient risk aversion, and patient perception of preoperative health status complicate decision-making even more.

Despite providing panelists with multiple realistic scenarios, even this modified Delphi methodology could not take into account this degree of granularity.

The study provides high levels of consensus regarding the appropriate preoperative evaluation of patients, limited consensus on negative recommendations (i.e., consensus on inappropriate care), and very few positive recommendations (i.e., consensus on appropriate care). The majority of surgical approaches, and intraoperative options, are considered as reasonable, without a clear consensus regarding appropriate or inappropriateness. Panel consensus regarding inappropriate care, especially for intraoperative strategies, can function as negative directives and "what not to do". Guidance on what to avoid may be useful as this may help avoid poor outcomes and surgical failures, thereby reducing health care costs, and improving value of care. Acaroglu et al. demonstrated that surgical treatment of adult deformity is associated with significant complications compared with non-operative care, and a decision analysis regarding the appropriateness of surgical care must include consideration of complications of surgery and the expected benefit of surgery on health-related quality of life [59]. The absence of consensus on appropriate approaches to many surgical scenarios, and the predominance of "reasonable" as a response, supports the conclusion that surgeon preference and patient values remain central to decision-making, and a monolithic or dogmatic approach to care (including practice guidelines) should be avoided.

Appropriate care for ASD must be responsive to specific considerations of the patient, the care provider, and the healthcare system. The areas where there is no consensus regarding appropriate approaches may also guide future research to provide an evidence-based treatment.

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Compliance with ethical standards

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References

1. Pellise F, Vila-Casademunt A, Ferrer M, Domingo-Sabat M, Bago J, Perez-Grueso FJ, Alanay A, Mannion AF, Acaroglu E, European Spine Study Group E (2015) Impact on health related quality of life of adult spinal deformity (ASD) compared with other chronic conditions. Eur Spine J 24:3–11. doi:10.1007/s00586-014-3542-1
2. Waldrop R, Cheng J, Devin C, McGirt M, Fehlings M, Berven S (2015) The burden of spinal disorders in the elderly. Neurosurgery 77(Suppl 4):S46–S50. doi:10.1227/NEU.0000000000000950
3. Cho KJ, Kim YT, Shin SH, Suk SI (2014) Surgical treatment of adult degenerative scoliosis. Asian Spine J 8:371–381. doi:10.4184/asj.2014.8.3.371
4. Wang G, Hu J, Liu X, Cao Y (2015) Surgical treatments for degenerative lumbar scoliosis: a meta analysis. Eur Spine J 24:1792–1799. doi:10.1007/s00586-015-3942-x
5. Yadla S, Maltenfort MG, Ratliff JK, Harrop JS (2010) Adult scoliosis surgery outcomes: a systematic review. Neurosurg Focus 28:E3. doi:10.3171/2009.12.FOCUS09254
6. Tribus CB (2003) Degenerative lumbar scoliosis: evaluation and management. J Am Acad Orthop Surg 11:174–183
7. Everett CR, Patel RK (2007) A systematic literature review of nonsurgical treatment in adult scoliosis. Spine (Phila Pa 1976) 32:S130–S134. doi:10.1097/BRS.0b013e318134ea88
8. Liang CZ, Li FC, Li H, Tao Y, Zhou X, Chen QX (2012) Surgery is an effective and reasonable treatment for degenerative scoliosis: a systematic review. J Int Med Res 40:399–405
9. Aebi M (2005) The adult scoliosis. Eur Spine J 14:925–948. doi:10.1007/s00586-005-1053-9
10. Berjano P, Lamartina C (2014) Classification of degenerative segment disease in adults with deformity of the lumbar or thoracolumbar spine. Eur Spine J 23:1815–1824. doi:10.1007/s00586-014-3219-9
11. Faldini C, Di Martino A, De Fine M, Miscione MT, Calamelli C, Mazzotti A, Perna F (2013) Current classification systems for adult degenerative scoliosis. Musculoskelet Surg 97:1–8. doi:10.1007/s12306-013-0245-4
12. Schwab F, Ungar B, Blondel B, Buchowski J, Coe J, Deinlein D, DeWald C, Mehdian H, Shaffrey C, Tribus C, Lafage V (2012) Scoliosis Research Society-Schwab Adult Spinal Deformity Classification: a validation study. Spine (Phila Pa 1976) 37:1077–1082. doi:10.1097/BRS.0b013e31823e15e2
13. Garber AM, Tunis SR (2009) Does comparative-effectiveness research threaten personalized medicine? N Engl J Med 360:1925–1927. doi:10.1056/NEJMp0901355
14. Paulus MC, Kalantar SB, Radcliff K (2014) Cost and value of spinal deformity surgery. Spine (Phila Pa 1976) 39:388–393. doi:10.1097/BRS.0000000000000150
15. Fitch K, Bernstein SJ, Aguilar MD, Burnand B, LaCalle JR, Lazaro P, van het Loo M, McDonnell J, Vader J, Kahan JP (2001) The RAND/UCLA appropriateness method user's manual. RAND Corporation, Santa Monica
16. Shekelle P (2004) The appropriateness method. Med Decis Mak 24:228–231. doi:10.1177/0272989X04264212
17. de Kleuver M, Lewis SJ, Germscheid NM, Kamper SJ, Alanay A, Berven SH, Cheung KM, Ito M, Lenke LG, Polly DW, Qiu Y, van Tulder M, Shaffrey C (2014) Optimal surgical care for adolescent idiopathic scoliosis: an international consensus. Eur Spine J 23:2603–2618. doi:10.1007/s00586-014-3356-1
18. Schwab F, Lafage V, Farcy JP, Bridwell K, Glassman S, Ondra S, Lowe T, Shainline M (2007) Surgical rates and operative outcome analysis in thoracolumbar and lumbar major adult scoliosis: application of the new adult deformity classification. Spine (Phila Pa 1976) 32:2723–2730. doi:10.1097/BRS.0b013e31815a58f2
19. Bradford DS, Tay BK, Hu SS (1999) Adult scoliosis: surgical indications, operative management, complications, and outcomes. Spine (Phila Pa 1976) 24:2617–2629
20. Schwab F, Farcy JP, Bridwell K, Berven S, Glassman S, Harrast J, Horton W (2006) A clinical impact classification of scoliosis in the adult. Spine (Phila Pa 1976) 31:2109–2114. doi:10.1097/01.brs.0000231725.38943.ab
21. Smith JS, Lafage V, Shaffrey CI, Schwab F, Lafage R, Hostin R, O'Brien M, Boachie-Adjei O, Akbarnia BA, Mundis GM, Errico

T, Kim HJ, Protopsaltis TS, Hamilton DK, Scheer JK, Sciubba D, Ailon T, Fu KM, Kelly MP, Zebala L, Line B, Klineberg E, Gupta M, Deviren V, Hart R, Burton D, Bess S, Ames CP, International Spine Study G (2016) Outcomes of operative and nonoperative treatment for adult spinal deformity: a prospective, multicenter, propensity-matched cohort assessment with minimum 2-year follow-up. Neurosurgery 78:851–861. doi:10.1227/NEU.0000000000001116
22. Theis J, Gerdhem P, Abbott A (2015) Quality of life outcomes in surgically treated adult scoliosis patients: a systematic review. Eur Spine J 24:1343–1355. doi:10.1007/s00586-014-3593-3
23. Pekmezci M, Berven SH, Hu SS, Deviren V (2009) The factors that play a role in the decision-making process of adult deformity patients. Spine (Phila Pa 1976) 34:813–817. doi:10.1097/BRS.0b013e3181851ba6
24. Koller H, Pfanz C, Meier O, Hitzl W, Mayer M, Bullmann V, Schulte TL (2016) Factors influencing radiographic and clinical outcomes in adult scoliosis surgery: a study of 448 European patients. Eur Spine J 25:532–548. doi:10.1007/s00586-015-3898-x
25. Smith JS, Klineberg E, Schwab F, Shaffrey CI, Moal B, Ames CP, Hostin R, Fu KM, Burton D, Akbarnia B, Gupta M, Hart R, Bess S, Lafage V, International Spine Study G (2013) Change in classification grade by the SRS-Schwab Adult Spinal Deformity Classification predicts impact on health-related quality of life measures: prospective analysis of operative and nonoperative treatment. Spine (Phila Pa 1976) 38:1663–1671. doi:10.1097/BRS.0b013e31829ec563
26. Andersen T, Christensen FB, Laursen M, Hoy K, Hansen ES, Bunger C (2001) Smoking as a predictor of negative outcome in lumbar spinal fusion. Spine (Phila Pa 1976) 26:2623–2628
27. Schairer WW, Carrer A, Deviren V, Hu SS, Takemoto S, Mummaneni P, Chou D, Ames C, Burch S, Tay B, Sawyer A, Berven SH (2013) Hospital readmission after spine fusion for adult spinal deformity. Spine (Phila Pa 1976) 38:1681–1689. doi:10.1097/BRS.0b013e31829c08c9
28. Worley N, Marascalchi B, Jalai CM, Yang S, Diebo B, Vira S, Boniello A, Lafage V, Passias PG (2016) Predictors of inpatient morbidity and mortality in adult spinal deformity surgery. Eur Spine J 25:819–827. doi:10.1007/s00586-015-4104-x
29. Hu SS, Berven SH (2006) Preparing the adult deformity patient for spinal surgery. Spine (Phila Pa 1976) 31:S126–S131. doi:10.1097/01.brs.0000234760.69549.79
30. Glassman SD, Anagnost SC, Parker A, Burke D, Johnson JR, Dimar JR (2000) The effect of cigarette smoking and smoking cessation on spinal fusion. Spine (Phila Pa 1976) 25:2608–2615
31. Malfair D, Flemming AK, Dvorak MF, Munk PL, Vertinsky AT, Heran MK, Graeb DA (2010) Radiographic evaluation of scoliosis: review. AJR Am J Roentgenol 194:S8–S22. doi:10.2214/AJR.07.7145
32. Bess S, Schwab F, Lafage V, Shaffrey CI, Ames CP (2013) Classifications for adult spinal deformity and use of the Scoliosis Research Society-Schwab Adult Spinal Deformity Classification. Neurosurg Clin N Am 24:185–193. doi:10.1016/j.nec.2012.12.008
33. Frazier DD, Lipson SJ, Fossel AH, Katz JN (1997) Associations between spinal deformity and outcomes after decompression for spinal stenosis. Spine (Phila Pa 1976) 22:2025–2029
34. Houten JK, Nasser R (2013) Symptomatic progression of degenerative scoliosis after decompression and limited fusion surgery for lumbar spinal stenosis. J Clin Neurosci 20:613–615. doi:10.1016/j.jocn.2012.06.002
35. Kuhns CA, Bridwell KH, Lenke LG, Amor C, Lehman RA, Buchowski JM, Edwards C II, Christine B (2007) Thoracolumbar deformity arthrodesis stopping at L5: fate of the L5–S1 disc, minimum 5-year follow-up. Spine (Phila Pa 1976) 32:2771–2776. doi:10.1097/BRS.0b013e31815a7ece
36. Edwards CC 2nd, Bridwell KH, Patel A, Rinella AS, Berra A, Lenke LG (2004) Long adult deformity fusions to L5 and the sacrum. A matched cohort analysis. Spine (Phila Pa 1976) 29:1996–2005
37. Swamy G, Berven SH, Bradford DS (2007) The selection of L5 versus S1 in long fusions for adult idiopathic scoliosis. Neurosurg Clin N Am 18:281–288. doi:10.1016/j.nec.2007.01.010
38. Jain A, Hassanzadeh H, Strike SA, Menga EN, Sponseller PD, Kebaish KM (2015) Pelvic fixation in adult and pediatric spine surgery: historical perspective, indications, and techniques: AAOS exhibit selection. J Bone Jt Surg Am 97:1521–1528. doi:10.2106/JBJS.O.00576
39. Saer EH 3rd, Winter RB, Lonstein JE (1990) Long scoliosis fusion to the sacrum in adults with nonparalytic scoliosis. An improved method. Spine (Phila Pa 1976) 15:650–653
40. Shen FH, Mason JR, Shimer AL, Arlet VM (2013) Pelvic fixation for adult scoliosis. Eur Spine J 22(Suppl 2):S265–S275. doi:10.1007/s00586-012-2525-3
41. Tsuchiya K, Bridwell KH, Kuklo TR, Lenke LG, Baldus C (2006) Minimum 5-year analysis of L5–S1 fusion using sacropelvic fixation (bilateral S1 and iliac screws) for spinal deformity. Spine (Phila Pa 1976) 31:303–308. doi:10.1097/01.brs.0000197193.81296.f1
42. Annis P, Lawrence BD, Spiker WR, Zhang Y, Chen W, Daubs MD, Brodke DS (2014) Predictive factors for acute proximal junctional failure after adult deformity surgery with upper instrumented vertebrae in the thoracolumbar spine. Evid Based Spine Care J 5:160–162. doi:10.1055/s-0034-1386755
43. Barbanti Brodano G, Terzi S, Gasbarrini A, Bandiera S, Simoes C, Boriani S (2013) Do benefits overcome the risks related to surgery for adult scoliosis? A detailed analysis of a consecutive case series. Eur Spine J 22(Suppl 6):S795–S802. doi:10.1007/s00586-013-3031-y
44. Rahman RK, Buchowski JM, Stephens B, Dorward IG, Koester LA, Bridwell KH (2013) Comparison of TLIF with rhBMP-2 versus no TLIF and higher posterolateral rhBMP-2 dose at L5–S1 for long fusions to the sacrum with sacropelvic fixation in patients with primary adult deformity. Spine (Phila Pa 1976) 38:2264–2271. doi:10.1097/BRS.0000000000000045
45. Ha Y, Maruo K, Racine L, Schairer WW, Hu SS, Deviren V, Burch S, Tay B, Chou D, Mummaneni PV, Ames CP, Berven SH (2013) Proximal junctional kyphosis and clinical outcomes in adult spinal deformity surgery with fusion from the thoracic spine to the sacrum: a comparison of proximal and distal upper instrumented vertebrae. J Neurosurg Spine 19:360–369. doi:10.3171/2013.5.SPINE12737
46. Maruo K, Ha Y, Inoue S, Samuel S, Okada E, Hu SS, Deviren V, Burch S, William S, Ames CP, Mummaneni PV, Chou D, Berven SH (2013) Predictive factors for proximal junctional kyphosis in long fusions to the sacrum in adult spinal deformity. Spine (Phila Pa 1976) 38:E1469–E1476. doi:10.1097/BRS.0b013e3182a51d43
47. O'Shaughnessy BA, Bridwell KH, Lenke LG, Cho W, Baldus C, Chang MS, Auerbach JD, Crawford CH (2012) Does a long-fusion "T3-sacrum" portend a worse outcome than a short-fusion "T10-sacrum" in primary surgery for adult scoliosis? Spine (Phila Pa 1976) 37:884–890. doi:10.1097/BRS.0b013e3182376414
48. Fujimori T, Inoue S, Le H, Schairer WW, Berven SH, Tay BK, Deviren V, Burch S, Iwasaki M, Hu SS (2014) Long fusion from sacrum to thoracic spine for adult spinal deformity with sagittal imbalance: upper versus lower thoracic spine as site of upper instrumented vertebra. Neurosurg Focus 36:E9. doi:10.3171/2014.3.FOCUS13541
49. Dorward IG, Lenke LG, Stoker GE, Cho W, Koester LA, Sides BA (2014) Radiographic and clinical outcomes of posterior

column osteotomies in spinal deformity correction. Spine (Phila Pa 1976). doi:10.1097/BRS.0000000000000302

50. La Maida GA, Luceri F, Gallozzi F, Ferraro M, Bernardo M (2015) Complication rate in adult deformity surgical treatment: safety of the posterior osteotomies. Eur Spine J 24(Suppl 7):879–886. doi:10.1007/s00586-015-4275-5
51. Lenke LG, Fehlings MG, Shaffrey CI, Cheung KM, Carreon L, Dekutoski MB, Schwab FJ, Boachie-Adjei O, Kebaish KM, Ames CP, Qiu Y, Matsuyama Y, Dahl BT, Mehdian H, Pellise-Urquiza F, Lewis SJ, Berven SH (2016) Neurologic outcomes of complex adult spinal deformity surgery: results of the prospective, multicenter Scoli-RISK-1 study. Spine (Phila Pa 1976) 41:204–212. doi:10.1097/BRS.0000000000001338
52. Smith JS, Klineberg E, Lafage V, Shaffrey CI, Schwab F, Lafage R, Hostin R, Mundis GM Jr, Errico TJ, Kim HJ, Protopsaltis TS, Hamilton DK, Scheer JK, Soroceanu A, Kelly MP, Line B, Gupta M, Deviren V, Hart R, Burton DC, Bess S, Ames CP, International Spine Study G (2016) Prospective multicenter assessment of perioperative and minimum 2-year postoperative complication rates associated with adult spinal deformity surgery. J Neurosurg Spine 25:1–14. doi:10.3171/2015.11.SPINE151036
53. Dearborn JT, Hu SS, Tribus CB, Bradford DS (1999) Thromboembolic complications after major thoracolumbar spine surgery. Spine (Phila Pa 1976) 24:1471–1476
54. Rojas-Tomba F, Gormaz-Talavera I, Menendez-Quintanilla IE, Moriel-Duran J, Garcia de Quevedo-Puerta D, Villanueva-Pareja F (2016) Incidence and risk factors of venous thromboembolism in major spinal surgery with no chemical or mechanical prophylaxis. Rev Esp Cir Ortop Traumatol 60:133–140. doi:10.1016/j.recot.2015.10.002
55. Fabricant PD, Admoni S, Green DW, Ipp LS, Widmann RF (2012) Return to athletic activity after posterior spinal fusion for adolescent idiopathic scoliosis: analysis of independent predictors. J Pediatr Orthop 32:259–265. doi:10.1097/BPO.0b013e31824b285f
56. Tarrant RC, O'Loughlin PF, Lynch S, Queally JM, Sheeran P, Moore DP, Kiely PJ (2014) Timing and predictors of return to short-term functional activity in adolescent idiopathic scoliosis after posterior spinal fusion: a prospective study. Spine (Phila Pa 1976) 39:1471–1478. doi:10.1097/BRS.0000000000000452
57. Green BN, Johnson C, Moreau W (2009) Is physical activity contraindicated for individuals with scoliosis? A systematic literature review. J Chiropr Med 8:25–37. doi:10.1016/j.jcm.2008.11.001
58. Acaroglu E, Yavuz AC, Guler UO, Yuksel S, Yavuz Y, Domingo-Sabat M, Pellise F, Alanay A, Perez Grueso FS, Kleinstück F, Obeid I (2016) A decision analysis to identify the ideal treatment for adult spinal deformity: is surgery better than non-surgical treatment in improving health-related quality of life and decreasing the disease burden? European Spine Study Group. Eur Spine J 25(8):2390–2400
59. Acaroglu E, Guler UO, Cetinyurek-Yavuz A, Yuksel S, Yavuz Y, Ayhan S, Domingo-Sabat M, Pellise F, Alanay A, Perez Grueso FS, Kleinstück F, Obeid I, European Spine Study Group (2017) Decision analysis to identify the ideal treatment for adult spinal deformity: What is the impact of complications on treatment outcomes? Acta Orthop Traumatol Turc 51(3):181–190