STRATEGY FOR USE OF DIFFERENT DORSAL INSTRUMENTATIONS IN CHILDREN WITH ADOLESCENT IDIOPATHIC SCOLIOSIS

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INTRODUCTION

Although etiology of adolescent idiopathic scoliosis (AIS)remains unknown, it's well known that Heuter-Volkmann law contributes to progression of spinal deformity forcing vertebrae to turn into wedge-shaped and making vicious cycle onset[1, 2, 6]. Main treatment options include observation, conservative treatment and surgery [1]. Surgery is recommended in skeletally immature patients with Cobb angle exceeding 40° or rapid progression [1]. Surgical treatment options include anterior fixation, posterior fixation or its combination and no difference found between Cobb angle correction between anterior and posterior constructs [3, 4].There are a lot of dorsal instrumentations for AIS treatment in conditions of incomplete spinal growth, only few of them studied for influencing on subsequent spinal growth: growth friendly hook instrumentation with sliding rods (HISR) and transpedicular screw fixation (TSF) construct [5, 9].

AIM OF STUDY

The aim of this prospective longitudinal non-randomized study was to define indications for use of different dorsal instrumentations in children with AIS according both to their spinal growth modulation (spine remodeling) effect and effectiveness of spinal deformity correction.

MATERIALS AND METHODS

The study started in 2004 and now is on go. By the end of 2016 we collected data of 293 children. 35 were excluded mainly due to insufficient data. In summary 258 children, 32 boys (12,4%) and 226 girls (87,6%) were included in the research by the end of 2016. Patients were divided into 3 groups according to the type of instrumentation used for operative correction of spinal deformity. 1st group is represented by 198 children (74%) instrumented with hook instrumentation with sliding rods permitting consequent spinal growth. 2nd group is represented 22 (9%) children instrumented with hook instrumentation with locked rods (HILR). 3rd group is represented by 44 children (17%) instrumented with transpedicular screw fixation constructs (TSF). We also divided patients for 2 age groups based on age at the moment of surgical treatment for thorough assessment of correction effectiveness: 12 years old and younger; 13 y/o and older. Complex analysis of all scoliosis deformity parameters was carried out, major of them were Cobb angle and its correction rate (CR), apical vertebral rotation and its correction rate and its correction rate (AVRCR), Risser testvalues (R0–R5), stability index (SI), King type (I–V). Mean follow-up was 27±0,7 months with consequent follow-up periods: 5 days after surgery, 6 months, 12 months, 24 months and final follow-up. We used comprehensive morphometric assessment of spine evaluating plain AP radiographs of the spine in Radiant DICOM Viewer computer program (fig. 1).

The most important morphometric analysis data which represents the severity of vertebral bodies and intervertebral discs wedging areconcave-convex vertebral body height ratio (CCVB) concave-convex intervertebral discs height ratio (CCID). The values of these parameters should ideally be near 1. Other parameters include concave disc-body ratio (ConcaveDB) and convex disc-body ratio (ConvexDB). These parameters represent whether vertebral bodies or intervertebral spaces contribute more for spine remodeling after instrumentation. Complex statistical analysis was made in Statistica 10.0 program using Kruskal-Wallistest for independent variables, Friedman ANOVA for dependent, Spearman criteria for correlations and Pearson Chi-Square for qualitative variables.

RESULTS AND DISCUSSION

The highest correction rate (CR) early after operation were obtained in 1st group (76,6±0,9% versus 68,6±1,5% in 2nd group and 66,4±3% in 3rd group, p<0,001). Despite the results of CR at final follow-up, the highest increase of CR during follow-up period was obtained in 3rd group (+2,3±0,4% versus CR change +0,3±0,2% in 1st group and -1,7±1,3% in 2nd group; p<0,0001), showing better post-operative overcorrection comparing to other groups. No statistically significant differences of AVRCR value both at final follow-up and total increment were found between 1st group and 3rd group (total AVRCR increment in 1st and 2nd groups were -0,23±0,3% and -0,97±1,4% respectively; p=0,3) while loss of AVRCR obtained in 2nd group during follow-up period (-4,12±1,29%; p=0,0008). We built correlation matrices for the thorough analysis of correlations and found some significant (p<0,05) correlations between CR, AVRCR and a few of important parameters such as pre-operative Cobb angle (r=-0,46), Age (r=-0,3), Risser (r=-0,29) and SI (r=-0,2) which means that better correction can be achieved using active surgical strategy with early surgery in growing adolescents with AIS. representing better post-operative over correction if there is TSF construct applied. The highest rate of technical complications, such as rod failure or migration obtained in 1st group (16,6% versus4,5% in 2nd groupand 4,5% in 3rd group, p=0,0009; fig. 2) as well as rate of related reoperations (20,8% versus 4,5% in 2nd group and 4,5% in 3rd group). Very important feature is that

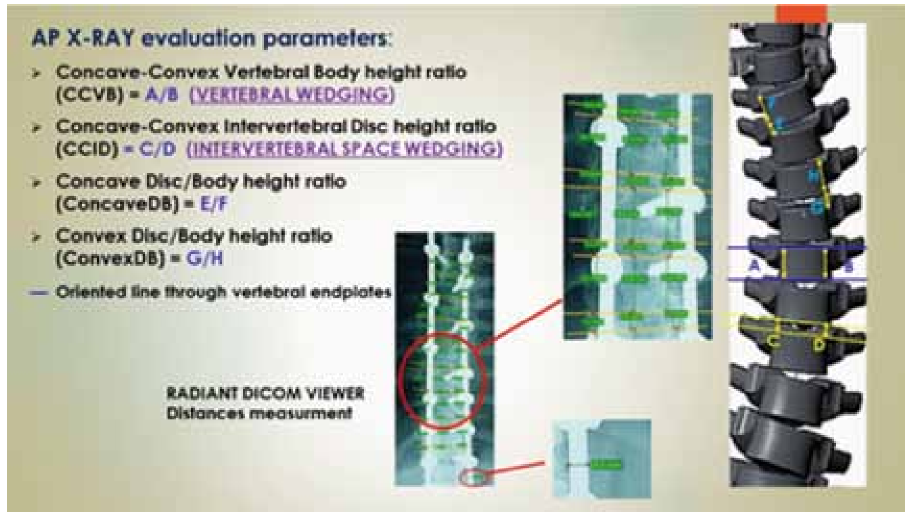

Fig. 1.

COMPLICATIONS

Pearson Chi-Square = 0,07

M-L Chi-Square = 0,01

	HISR	HILR	TSF	ALL
No complications	74,0%	86,4%	86,4%	78%
Rod fracture	4,2%	0,0%	0,0%	3%
Seroma	5,2%	4,5%	4,5%	5%
Rod migration	8,3%	0,0%	0,0%	6%
Suppuration	4,2%	4,5%	4,5%	4%
Seroma&Rod migration	0,0%	0,0%	4,5%	1%
Rod migration&Suppuration	2,1%	0,0%	0,0%	2%
Rod fracture&migration&suppuration	1,0%	4,5%	0,0%	1%
Rod fracture&migration&wound disrepancy	1,0%	0,0%	0,0%	1%

Fig. 2.

construct-associated mechanical complications in 1st group noticed mostly in children underwent surgery at the age after 13 years old (67% migrations and 50% breakages). It could happen with insufficient dorsal fusion forming at the end of spine growth due to loose hook-road connectives allowing rods to slide simultaneously with spine growth. However using stable (non-slide) rod constructs can lead to crankshaft phenomenon developing as the result of spinal fusion during spinal growth period [7].

Morphometric analysis shows highest rates of CCVB and CCID at final follow-up in 1st group; 0,99±0,002; p=0,001 and 0,87±0,029; p=0,001 respectively (fig. 3), while highest increment of CCVB obtained in 1st group (+0,04±0,001; p=0,004) and highest increment of CCID — in 3rd group: -0,04±0,02; p=0,05 (fig. 4).The worst results at the final follow-up and total increment of CCVB

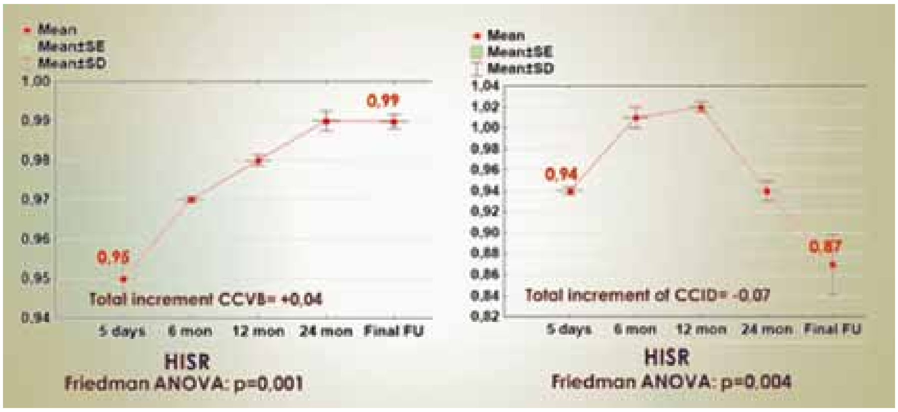

Fig. 3.

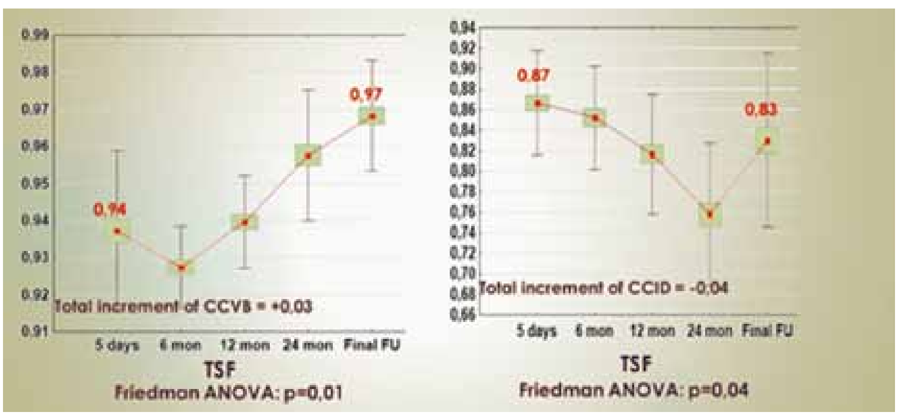

Fig. 4.

(0,87±0,04; -0,0±0,03; p=0,009) and CCID (0,75±0,06; -0,0±0,03; p=0,001)obtained in 2nd group comparing to other groups. These results represent vertebral bodies remodeling which means turning them from wedge-shaped to normal shape (it's supposed for vertebral body heights to be equal to each other on concave and convex sides of spinal deformity). Taking to account obtained results we can state that finally the best spine remodeling occurs while using HISR earlier in skeletally immature patients trying to avoid any delay.

Other important parameters include ConcaveDB and ConvexDB. These parameters are interesting for its results interpretation. One of last studies showed that there aren't any changes in intervertebral discs that can be related to growth in children after 10 years old [10]. The point is that aforementioned parameters doesn't have exact normal values especially in deformed spine, but it's obvious that ConcaveDB and ConvexDB ideally should be equal in normal spine to be symmetric. Furthermore, total increment of these parameters should be ideally equal to each other during growth to allow the spine having symmetric residual growth. If that condition achieved there is a physiological symmetric vertebral body growth allowed without any mechanical modulation which may cause concave side of vertebral body to overgrow that on convex side after deformity correction. We found that difference between values of ConcaveDB (0,17±0,012) and ConvexDB (0,20±0,013) at the final follow-up in 1st group (p=0,0001) are equal to the same difference in 3rd group (0,19±0,026 and 0,22±0,019 respectively; p=0,0001). Otherwise the most physiological and symmetric total increment of ConcaveDB (-0,02±0,019) and ConvexDB (-0,01±0,024) obtained in 3rd group (p=0,01) comparing to the same values 1stgroup (-0,07±0,012 and -0,05±0,013 respectively; p=0,01) — fig. 5. We also measured central intervertebral spaces within the curve before and after operation and found the highest increment to be in 3rd group (+4,4±0,7 versus 2,1±0,13 and 1,3±0,3 in 1st and 2nd groups respectively), which means better intraoperative spine distraction in 3rd group and lower pressure to growth plates resulting in better growth modulation. Thus post-operative changes are more physiological in TSF construct comparing to HISR.

Finally, we made a special ranking system using major parameters of our study which represents correction effectiveness (CR, AVRCR, complications rate) and post-operative spinal remodeling (CCVB; CCID; ConcaveDB and ConvexDB). We compared 2 major values for these parameters between different groups: value at the final follow-up and the value of total increment (fig. 6) and found out, that the best construct for final follow-up values is HISR and for total increment values — TSF construct in case of applying at the age of 13 y/o and older because of the absence of any advantages of HISR for correction effectiveness but significantly better post-operative remodeling obtaining by TSF construct applying. We suppose there is also a need of further research for use of TSF constructs in skeletally immature patients using these parameters due to a recent study where author showed absence of crankshaft phenomenon forming [8].

CONCLUSION

We believe that hook instrumentation with sliding rods is preferable for use in children with AIS before 12 y/oand Risser 0–1 with either subsequent construct replacement for TSF instrumentation or using strains for rods locking to achieve sufficient dorsal fusion. We believe that TSF construct is preferable for use in children after 13 years old and Risser 2–4 due to better post-operative spine remodeling, lower technical complications and reoperations rates. It's possible to use HILR only in children reached Risser 4 after age of 13 in case of contraindications presence for use of TSF construct.

REFERENCES

1. **John P. Horne, MD; Robert Flannery, MD; and Saif Usman, MD,** Adolescent Idiopathic Scoliosis: Diagnosis and Management; Am Fam Physician. 2014 Feb 1;89(3):193-198
2. **Stokes IAF, Spence H, Aronsson DD, Kilmer N.** Mechanical modulation of vertebral body growth: implications for scoliosis progression. Spine. 1996;21(10):1162–1167
3. **Hari T. Vigneswaran et al.,** Surgical treatment of adolescent idiopathic scoliosis in the United States from 1997 to 2012: an analysis of 20,346 patients. J Neurosurg Pediatr. 2015 Sep;16(3):322-8.
4. **Rushton PR, Grevitt MP, Sell PJ.,** Anterior or posterior surgery for right thoracic adolescent idiopathic scoliosis (AIS)? A prospective cohorts' comparison using radiologic and functional outcomes. J Spinal Disord Tech. 2015 Apr;28(3):80-8.
5. **Sampiev M.T., Laka A.A., Zagorodniy N.V.:** Scoliosis; 2008. ISBN. 978-5-9704-0893-3
6. **Roaf R.** Vertebral growth and its mechanical control. J Bone JointSurg Br. 1960;42-B:40–59
7. **Dubousset J1, Herring JA, Shufflebarger H,** The crankshaft phenomenon. J Pediatr Orthop. 1989 Sep-Oct;9(5):541-50.
8. **Fenghua Tao, MD et al.** The Effect of Differing Spinal Fusion Instrumentationon the Occurrence of Postoperative CrankshaftPhenomenon in Adolescent Idiopathic Scoliosis. J Spinal Disord Tech 2010;23:e75–e80
9. **Suk SI, Lee CK, Kim WJ, et al.** Segmental pedicle screw fixation in the treatment of idiopathic thoracic scoliosis.Spine 1995; 20: 1399–1405

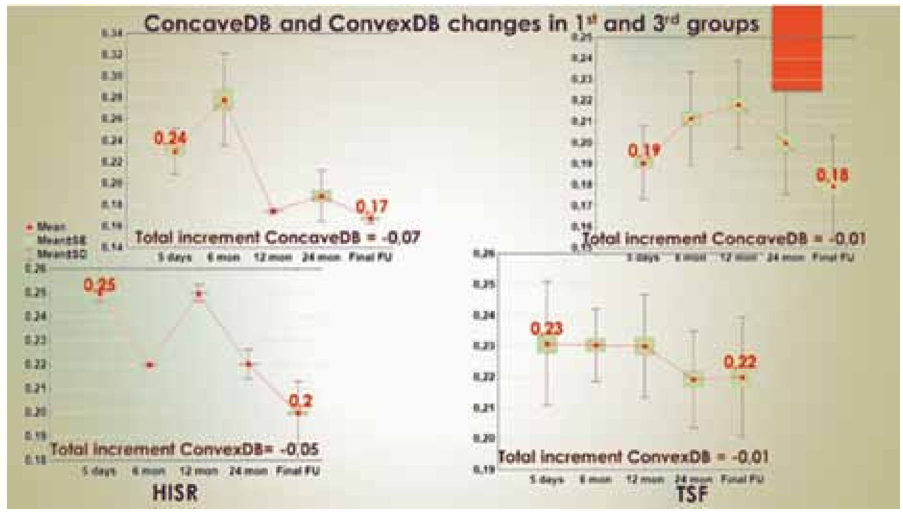

Fig. 5.

INCREMENT-BASED RANKING

	HISR	HILR	TSF
CR%	II	III	I
AVRCR%	I	III	II
CCVB	I	III	II
CCID	III	II	I
ConvexDB	II	III	I
ConcaveDB	II	III	I
Complications	II	I	I

TSF recommended

FINAL FU value - BASED RANKING

	HISR	HILR	TSF
CR%*	I	III	I
AVRCR%*	I(II*)	II	II(I*)
CCVB	I	III	II
CCID	I	III	II
ConvexDB	I	III	II
ConcaveDB	I	III	II
Complications	II	I	I

HISR recommended

*Statistical analysis for 13-15 y/o group

Fig. 6.

10. **Ian A.F. Stokes, PhD and Luke Windisch, BS,** Vertebral height growth predominates over intervertebral disc height growth in adolescents with scoliosis.Spine (Phila Pa 1976). 2006 Jun 15; 31(14): 1600–1604.