Approach to Surgical Management of Adolescent Idiopathic Scoliosis: 5 Years' Experience at HRDC

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Adolescent Idiopathic Scoliosis (AIS) is complex three dimensional deformity of spine which occurs in children after 10 years of age till skeletal maturity. It is the common cause of spinal deformity in children. Cosmesis is the main problem in case of AIS but untreated cases may lead to adverse psychosocial affects, cardiopulmonary problems, back pain and even death. Surgery is performed to correct the deformity or to prevent the progression. This is a retrospective study of such cases that were operated in Hospital and Rehabilitation Center for Disabled Children (HRDC). We reviewed medical records, operation notes and imaging. The approach to the patients for surgical management was same in all patients diagnosed as AIS. Total 99 spine surgeries were performed from January 2013 to December 2017. Twenty seven cases were of AIS. Twenty three cases underwent deformity correction and posterior instrumentation, two cases tethered cord release and two cases revision surgeries. Mean age of these patients was 13.84 years (range 11-18 years). Eighteen cases were girls and five were boys. The curve pattern was Lenke type I in 14 cases, type V in five cases, type III in three cases and type VI in one case. Nine cases had intra-spinal pathologies. Mean pre-operative cobb's angle of major curve was 59.76^0 (range 44^0-86^0) and post-operative was 30.76^0 (range 11^0-52^0) and mean correction achieved was 29^0 (range 3^0-71^0). Pedicle screw breakage occurred in one case and pedicle screw loosening due to infection in another case. This study discusses the approach to surgical management of AIS and concludes that detail evaluation of the patient and preoperative planning provides better surgical outcome.

Keywords: adolescent idiopathic scoliosis, deformity correction, Lenke classification.

Adolescent Idiopathic Scoliosis is a complex three dimensional deformity of spine which occurs between 10 years of age and skeletal maturity. Although different hypothesis has been postulated about the cause of AIS, the exact cause is still unknown. The prevalence of AIS is 2-3% in general population, with almost 10% requiring some form of treatment and 0.1% requiring surgery.[1] AIS is basically a cosmetic problem but if not treated may lead to progression of deformity, adverse psychosocial effects, compromised pulmonary function, back pain and even death.[2] Early identification and proper treatment are key factors for better outcome. There are 3 modalities of treatment of AIS: observation, bracing and surgery. The choice of treatment depends on the age and gender of the patient, severity and progression of the deformity, flexibility of curve and associated intra-spinal pathologies. If surgery is indicated, detail evaluation should be done to determine the flexibility of curve and to rule out any intra-spinal pathology or cardiopulmonary issues before embarking deformity correction surgery. Lenke Classification is a comprehensive classification which helps to define curve pattern and hence decide the instrumentation and fusion levels.[3]

The aim of this study is to share our experience regarding approach to surgical management of AIS and discuss outcome of surgery that were performed in Hospital and Rehabilitation Center for Disabled Children (HRDC).

Materials and Methods

This is a retrospective study of all the cases of Adolescent Idiopathic scoliosis (AIS) that were managed in Hospital and Rehabilitation Center for Disabled Children (HRDC) from January 2013 to December 2017. We reviewed the medical records, operation notes, X-rays, MRIs. We recorded demographic data, location of the curve, severity and flexibility of curve, intra-spinal pathologies, Lenke classification, surgical intervention done, correction achieved after surgery and post-operative complications. All the cases that were diagnosed as AIS were approached via same protocol for surgical management which is discussed below **(Figure1)**.

Approach to management of AIS

After detail history and physical examination, detail radiological evaluation was done which includes X-Rays of whole spine standing anteroposterior and lateral views and supine side bending views. In anteroposterior view, level of the apex of deformity was determined and severity of curve was measured. The severity of curve

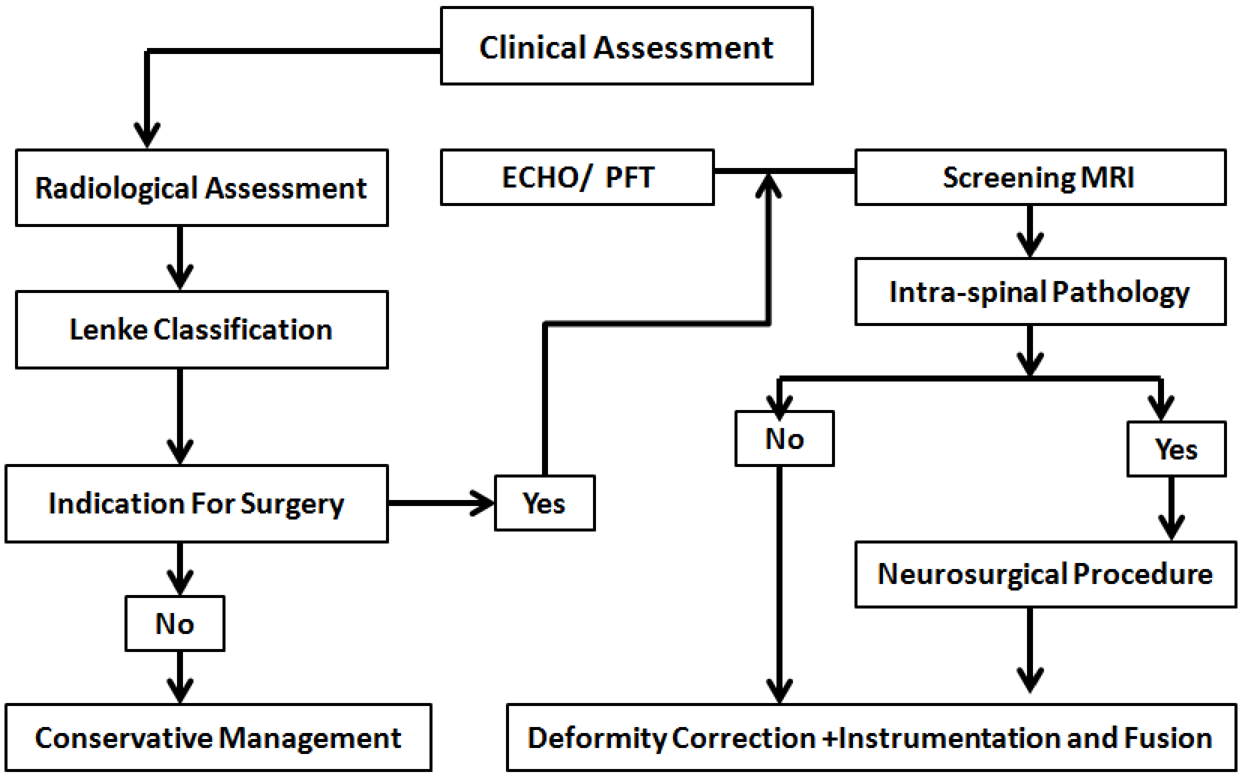

Figure 1: Algorithm showing approach to surgical management of AIS

was measured by Cobb's angle formed by superior end plate of upper end vertebra and inferior end plate of the lower end vertebra in standing anterio-posterior radiography. Similarly cobb's angle were measured in bending views from the same end vertebrae. If multiple curves were present, then they were measured in each curve. The severity of curve in bending views gave information about the flexibility of curve and whether the curve was structural or not. We also measured angle of kyphosis from T5 to T12 in lateral view. With this information, we classified the curve according to Lenke Classification which guides the instrumentation and fusion levels **(Figure 2)**. We performed screening MRI in all the cases who were planned for surgery to rule out any intra-spinal pathology. If any intra- spinal pathology was present, neurosurgical consultation was done for necessary intervention before deformity correction. Routine echocardiography and pulmonary function test were done to assess the status of the cardiopulmonary function. Instrumentation and fusion levels were decided according to Lenke Classification. We used stainless steel implants in majority of cases. The pedicle screws were inserted by free hand technique and deformity was corrected by rod rotation, compression and distraction, cantilever and in situ rod bending techniques. Intra-operative neuromonitoring was not used in our center but in selective cases we did wake up test. Patients were mobilized as soon as brace was available which was continued for 18 months.

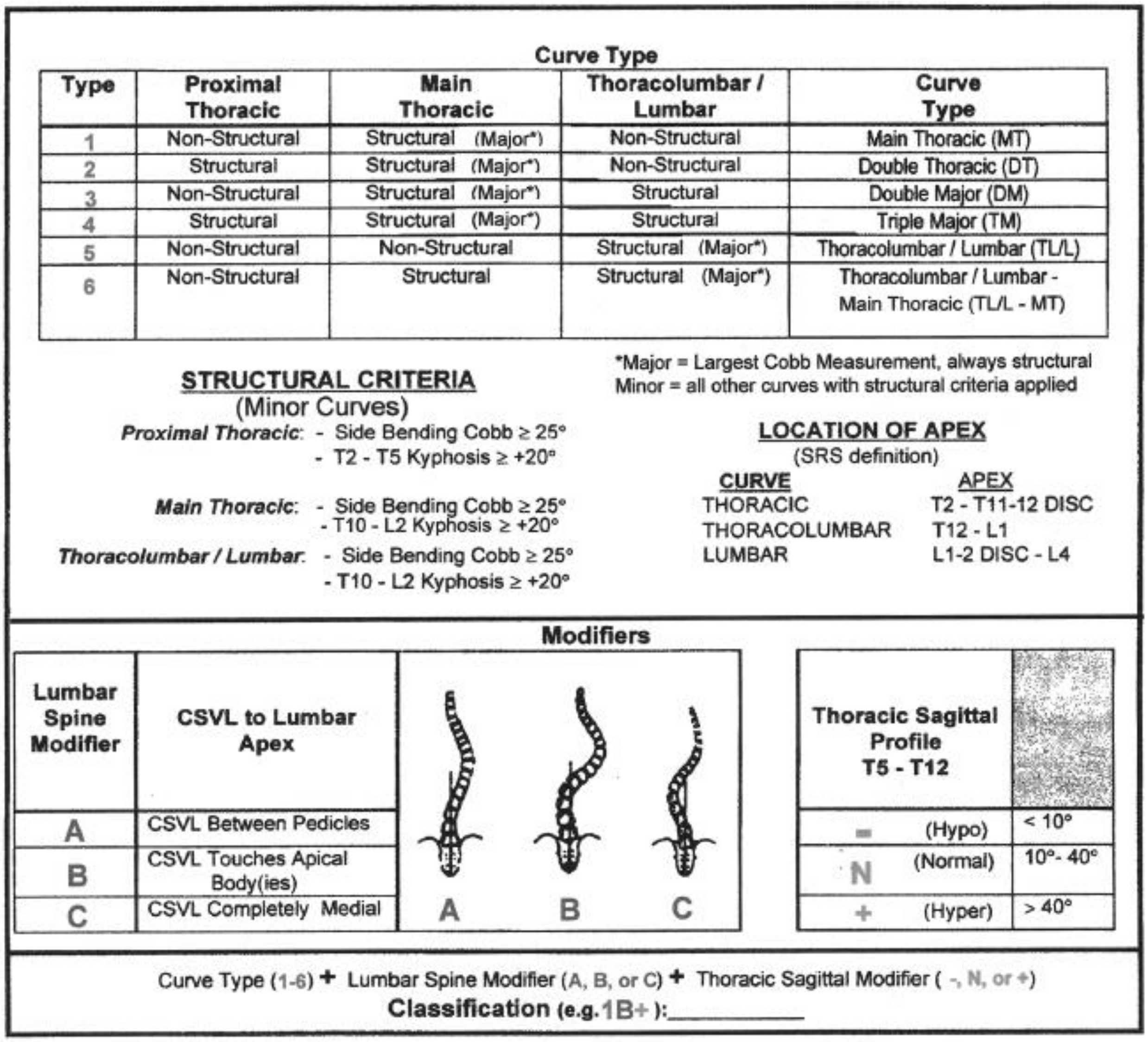

Figure 2: Lenke Classification for AIS

Results

In total 363 new spine cases were evaluated in outpatient department of HRDC in the specified duration of time. Ninety-nine cases underwent spine surgery, out of which 27 were cases of AIS. All the cases were approached according to the protocol described earlier. Out of these 27 cases, 23 underwent deformity correction and posterior instrumentation and fusion, two cases were operated by neurosurgeon for intra-spinal pathologies and two cases were operated for implant failure and loosening due to infection. So these 23 cases that underwent deformity correction and posterior instrumentation and fusion were included in the study to discuss the approach to surgical management and post-operative outcome.

The mean age of the patients was 13.84 years (range 11-18 years). The common age of

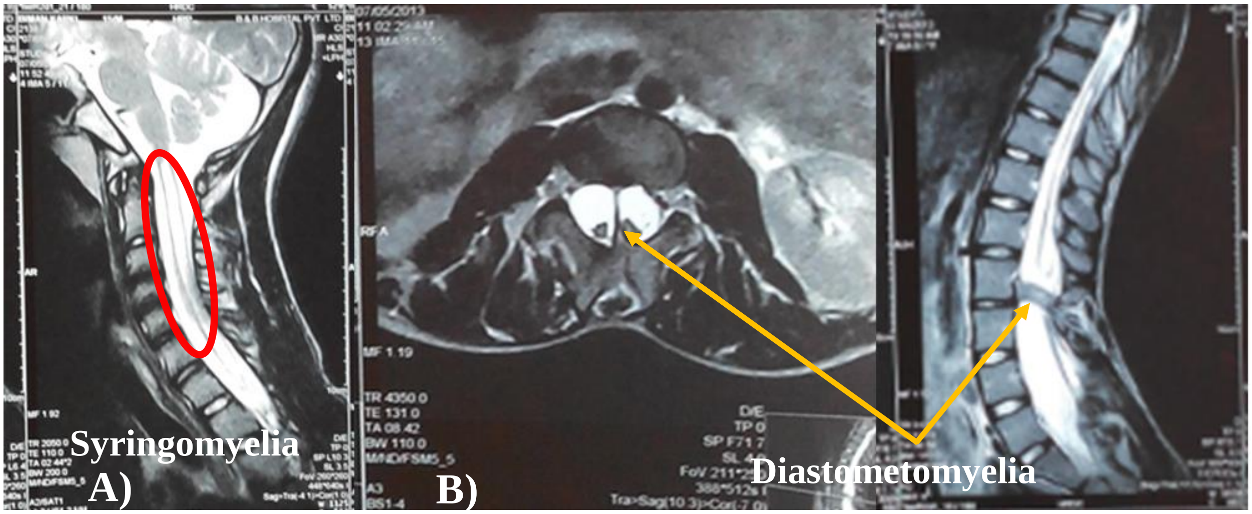

Figure 3: A) Syringomyelia B) Diastematomyelia

presentation in our center was 14 and 15 years. Eighteen cases were girls and five were boys. The curve pattern was Lenke type I in 14 cases, type V in five cases, type III in three cases and type VI in one case. In Lenke type I i.e. main thoracic curve, the common level of apex of deformity was D10, followed by Type V i.e. thoracolumbar/lumbar curve with common level of apex being L3. The mean pre-operative cobb's angle of major curve was 59.67^0 (range 44^0-86^0). The screening MRI whole spine showed intra-spinal pathologies in nine (31.03%) cases which include tethered cord, syringomyelia, diastometomyelia, Arnold Chiari Malformation **(Figure 3)**.

Out of these nine cases, two cases underwent surgery for intra-spinal pathology in this center and two cases in the other center by neurosurgeons.

All 23 cases that underwent deformity correction surgery were approached from posterior approach. We used stainless steel implants in majority of cases. The pedicle screws were inserted by free hand technique. The facetectomy and Pontes osteotomy were performed in selective cases to enhance flexibility and increase the rate of fusion in

Figure 4: Surgical outcome, before and after surgery A) x-ray of dorsal spine, B, C) picture showing back of the patient

thoracic scoliosis **(Figure 4)**. The deformity was corrected by rod rotation, distraction and compression, in situ bending and cantilever techniques. The common fusion level in Lenke type I curve was from D4 to L3, type V was from D5 to L4 and in type III was from D2 to L4. The mean post-operative cobb's angle was 30.76^0 (range 11^0-52^0) and mean correction achieved was 29^0 (range 3^0-71^0). In a case, the correction achieved was only 3 degree after surgery which was in situ fixation and fusion to prevent the progression of deformity. Thoracoplasty was performed in two cases to correct the rib hump deformity.

Intra-operative neuromonitoring was not used in any case but Stagnara wake up test was performed in selective cases. We did not encounter post-operative neurological deficit. Two cases developed complications which required revision surgery. In first case, distal most screw was broken and developed hardware prominence and pain which was managed by extension of instrumentation using domino connector. Second case developed late infection with implant loosening with persistent drainage which was managed with implant removal, meticulous debridement, intravenous antibiotics and bracing.

Discussion

Adolescent Idiopathic Scoliosis (AIS) is a complex three dimensional deformity of spine. It is one of the common causes of spinal deformity in children. Almost 2-3% of general population suffers from this deformity but only about 0.1% requires surgery.[1] The main concern in such deformity is cosmesis but if remain untreated, it may lead to several problems like progression of deformity, adverse psychosocial affects, cardiopulmonary decompensation, back pain and even death.[2] The surgical treatment can lead to improvement in self-confidence, self-image, cosmetic and life satisfaction and back pain.[4] The etiology of AIS is unknown. Various theories have been described based on biomechanical, neuromuscular, genetic, hormonal and environmental origin but understanding of scoliosis etiology is still limited.[5]

The treatment of AIS depends on age and gender of the patient, skeletal maturity, severity and progression of deformity, flexibility of curve and presence of intra-spinal pathology. There are three modalities of treatment for AIS: observation, bracing and surgery. The severity of the curve is measured by cobb's angle in standing anteroposterior radiograph of whole spine and progression of the curve is determined by increase in cobb's angle measured from the same bony landmarks in subsequent follow up. The flexibility of curve is measured by cobb's angle measured from the same bony landmarks in different radiographic views: supine anteroposterior bending views, traction anteroposterior views in dorsal decubitus position and fulcrum bending views in lateral decubitus position.[6] We used supine anterioposterior bending views as this is technically easy to perform and doesn't require assistant or any assistive devices.

In general, the patients with cobb's angle upto 25^0 can be managed with observation. Some deformity gets corrected by itself during skeletal growth. Patients with cobb's angle 25^0 to 40^0 should be managed with brace. Bracing may help to hault or slow the progression of deformity and prevent development of secondary curves. Different types of braces have been described but Milwaukee, Wilmington, Spine-Cor and Boston braces are superior to other types of braces.[7] If the curve is 40^0-50^0, the treatment is either bracing or surgery. The decision between bracing and surgery depends upon age and gender of the patient, skeletal maturity, menarche, Risser's stage, peak height velocity, progression of deformity and degree of cosmetic problem. Generally, all the patients with curve more than 50^0 are managed surgically because they have tendency to progress even after skeletal maturity.[7]

The main aim of surgery in AIS is to correct the deformity or to prevent the progression of deformity. Before we embark surgery, detail pre-operative evaluation should be done to rule out cardiopulmonary decompensation and intra-spinal pathology. Severe deformity of thoracic cage leads to restrictive lung function and hence increases risk of pulmonary decompensation and possible need of postoperative ventilator support. Mortality in patients with adult idiopathic scoliosis is related to thoracic curves more than 100 degrees, with resultant cor pulmonale.[8] Asymptomatic anomalies of brain stem and spinal cord are present in almost 9.7% of the cases and need of surgical intervention in such cases is quite common.[9] Subtle neurological deficits like absent abdominal reflexes are also correlated with presence of intra-spinal anomalies but Rajasekaran et al has demonstrated that 54.5% of patients had neural abnormality in MRI but no neural deficit.[10] Left sided thoracic curve, hyperkyphosis, scoliosis with back pain are some features of atypical AIS which are considered to be associated with intra-spinal pathologies. However, no specific indicator appears reliable or reproducible in its predictive value.[9] So screening MRI of the whole spine is recommended in all the cases of AIS to rule out intra-spinal pathologies. In our study, nine (33.33%) cases out of 27 cases had intra-spinal pathologies but surgery was necessary in only four cases. The rate of intra-spinal pathology is higher in our study because we have included only those cases that underwent surgical intervention. The common intra-spinal pathologies encountered are tethered cord, syringomyelia, diastometomyelia, Arnold Chiari malformation. These intra-spinal pathologies should be addressed before deformity correction because presence of such pathology increases risk of neurological deficit during deformity correction.

Lenke classification is two-dimensional

classification of AIS which helps to decide the level of spinal arthrodesis. This classification has got three components: curve type, thoracic sagittal modifier and lumbar spine modifier. There are six curve types depending on location of curve, three thoracic sagittal modifier depending on degree of kyphosis between T5 and T12 and three types of lumbar spine modifier depending on location of central sacral vertical line in relation to pedicle of apical vertebra of lumbar curve.[3] We used this classification and it definitely helped us to decide the surgical approach, need of osteotomy and levels of spinal fusion.

According to Lenke, all the curve types can be managed by posterior spinal fusion. The anterior approach is technically demanding and is associated with high morbidities. Type I, II and V can be managed with anterior spinal fusion or posterior spinal fusion.[3] After the introduction of transpedicular fixation by Roy-Camille, the pedicle screw fixation is choice of instrumentation in any spine pathologies approached via posterior approach. Pedicle screws offer the advantage of three-column purchase of the vertebrae with higher pull-out strength and better rotational control.[11] In mid 1990s, Suk presented his experience with use of thoracic pedicle screws for the correction of thoracic AIS and now it has become the implant of choice for all curves including thoracolumbar curves.[12] In 2016, Lui et al reported the perforation rate 32% when pedicle screws were inserted by free hand technique, however when lateral thoracic perforation was excluded perforation rate decreased to 12.1%.[13] We performed pedicle screw insertion by free hand technique in all cases of AIS and we did not encounter any symptomatic perforation of pedicle screws. Stainless steel is used by many surgeons for correction of AIS because it bends easily and can be used to obtain a physiological contour. We also used pedicle screws in majority of cases and there were no major complications except breakage of one screw in one case and infection on other case. Okada et al performed prospective study to compare stainless steel and titanium alloy instruments in posterior correction and fusion for AIS and they did not find any difference regarding clinical and radiological outcome between these two groups.[14]

Rod rotation, cantilever, compression and distraction, in situ bending and direct vertebral rotation are some techniques described for correction of deformity. [1] We used rod rotation, compression and distraction, cantilever and in situ bending as techniques of deformity correction. In our study, the mean preoperative cobb's angle was 59.76^0 (range 44^0-86^0) and postoperative cobb's angle was 30.76^0 (range 11^0-52^0) and mean correction achieved was 29^0 (range 3^0-71^0). The techniques which we used for the correction of deformity provided good results. Since facetectomy and osteotomies help to make rigid curves more flexible, in selective rigid deformities we performed facetectomy and Ponte's osteotomy in multiple levels. The techniques that we used basically helped to correct the coronal plane deformity. Since AIS is three dimensional rotational deformity of spine, the correction of rotation by these techniques is debatable. Lee et al originally described direct vertebral rotation as a new technique of three dimensional deformity correction with segmental pedicle screw fixation in AIS. [15] This technique provides better rotational and coronal correction than simple rod derotation technique.[15] The instrumentation system in this technique is expensive and requires separate instruments for derotation. We didn't use direct vertebral rotation technique to correct the deformity due to unavailability of instrumentation system. Correction of rib hump provides better cosmetic result during deformity correction. Thoracoplasty is recommended by several authors to correct the deformity. The main complication of thoracoplasty is reduction in postoperative pulmonary function.[16] Hwang et al reported a correction of the rib hump by up to 50% with direct vertebral rotation alone and recommended thoracoplasty only if the angle of rib inclination is $>15^0$ and following discussion with the patient and family.[17] We performed thoracoplasty in only two cases and achieved reasonable cosmetic correction of rib hump in remaining cases by the techniques we performed.

The surgical management of AIS is associated with many possible perioperative and postoperative complications. The reported rate of complications ranges between 0% and 15.4%.[18] The major perioperative complications are pulmonary complications, wound complications (e.g. superficial and deep infections, dehiscence), neurological complication (e.g. nerve root injury, spinal cord injury), complication related to instrumentation (e.g. malposition of screws, loss of fixation, broken rod, prominent hardware) and even death.[18] The delayed major complications are pseudoarthrosis, failure of instrumentation, neurological complications, wound infections, reoperation and even death.[18] We encountered complications in two cases. The first case had broken distal most pedicle screw with hardware prominence causing pain which was managed with extension of instrumentation using domino's connector. The second case developed delayed infection eight months after the surgery with loosening of implants and persistent discharge and this case was managed successfully with debridement, removal of implants, intravenous antibiotics and bracing. In both the cases stainless steel pedicle screws were used.

Since surgical management of AIS is a major intervention which is associated with different factors influencing the outcome, detail evaluation and preoperative planning is mandatory. A set protocol regarding approach to surgical management of AIS helps to standardize the treatment and provide better outcome.

Limitation of Study

This is a retrospective review of cases of Adolescent Idiopathic Scoliosis that were managed surgically. The sample size is small which may not reflect the exact scenario. Only those cases that underwent surgical intervention were included in this study so the incidence of intra-spinal pathologies according to our study may not correlate with findings in other literature

Conclusion

Adolescent Idiopathic Scoliosis is a complex three dimensional deformity of spine. There are different factors associated with this condition so a well defined set protocol regarding approach to surgical management should be followed for better decision making, avoiding possible complications and to achieve better post-operative outcome.

References

1. Tambe AD, Panikkar SJ, Millner PA, et al. Current Concepts in the surgical management of adolescent idiopathic scoliosis. Bone Joint J 2018;100:415-42.
2. Asher MA, Burton DC. Adolescent idiopathic scoliosis: natural history and long term treatment effects. Scoliosis 2006;1:2.
3. Lenke LG, Betz RR, Harms J, et al. Adolescent Idiopathic scoliosis: a new classification to determine extent of spinal arthrodesis. J Bone Joint Surg [Am] 2001;83:1169-81.
4. Zhang J, He D, Gao J, et al. Changes in life satisfaction and self-esteem in patients with adolescent idiopathic scoliosis with and without surgical intervention. Spine (Phila Pa 1976) 2011;36:741-5.
5. Fadzan M, Bettany-Satikov J. Etiological Theories of Adolescent Idiopathic Scoliosis: Past and Present. The Open Orthopedics Journal 2017;11:1466-89.
6. Gotfryd AO, Frazin FJ, Poletto PR, et al. Bending Radiographs as a predictive factor in surgical correction of Adolescent idiopathic scoliosis. Rev Brass Ortop 2011;46:572-6.
7. Yaman O, Dalbayrak S. Idiopathic Scoliosis. Turk Neurosurg 2014;24:646-57.
8. Canale ST, Beaty JH. Campbell's Operative Orthopedics 12th edition. Philadelphia,PA: Elsevier/Mosby; 2013.
9. Singhal R, Perry DC, Prasad S, et al. The use of routine preoperative magnetic resonance imaging in identifying intraspinal anomalies in patients with idiopathic scoliosis: a 10-year review. Eur Spine J 2013;22:355-9.
10. Rajasekaran S, Kamath V, Kiran R, Shetty AP. Intra-spinal anomalies in scoliosis: an MRI analysis of 177 consecutive scoliosis patients. Indian J Orthop 2010;44:57-63.
11. An HS, Singh K, Vaccaro AR, et al. Biomechanical evaluation of contemporary posterior spinal internal fixation configurations in an unstable burst fracturecalf spine model: special

references of hook configuration and pedicle screws. Spine (Phil Pa 1976) 2004;29:257-62.

12. Lonner BS, Ren Y, Yaszay B, et al. Evolution of Surgery for Adolescent Idiopathic Scoliosis Over 20 years: Have Outcomes Improved? Spine (Phil Pa 1976) 2018;43:402-10.
13. Chan CYW, Kwan MK. Safety of Pedicle Screws in Adolescent Idiopathic Scoliosis Surgery. Asian Spine J 2017;11:998-1007.
14. Okada E, watanabe K, Hosogane N, Yuta S, Yohei T, Yuji Nishiwaki, et al. Comparison of Stainless Steel and Titanium Alloy Instruments in Posterior Correction and Fusion Surgery for Adolescent Idiopathic Scoliosis-Prospective Cohort Study with Minimum 2-year Follow-Up. Journal of Medical and Biological Engineering 2012;33:325-30.
15. Lee SM, Suk SI, Chung ER. Direct Vertebral Rotation: A New Technique of Three-Dimensional Deformity Correction With Segmental Pedicle Screw Fixation in Adolescent Idiopathic Scoliosis. Spine (Phil Pa 1976) 2004;29:343-9.
16. Kim YJ, Lenke LG, Bridwell KH, Kin KL, Steger-May K. Pulmonary function in adolescent idiopathic scoliosis relative to the surgical procedure. J Bone Joint Surg[Am] 2005;87:1534-41.
17. Hwang SW, Samdani AF, Lonner B, et al. Impact of direct vertebral body derotation on rib prominence: are preoperative factors predictive of changes in rib prominence? Spine(Phil Pa 1976) 2012;37:E86-E89.
18. Bartley CE, Yaszay B, Bastrom TP, et al. Perioperative and Delayed Major complications Following Surgical Treatment of Adolescent Idiopathic Scoliosis. J Bone Joint Surg[Am] 2017;99:1206-12.