Variations in the number of vertebrae among Iranian patients with adolescent idiopathic scoliosis

Abstract

Introduction: Correct-level surgery is one of the most important concerns in the treatment of patients with adolescent idiopathic scoliosis (AIS). Variations in vertebral number can potentially result in wrong-level surgery. It is possible that the incidence and type of these variations be affected by different factors such as ethnicity. In the current retrospective study, the prevalence of these variations in Iranian AIS patients was investigated.

Methods: Between 2012 to 2017, spinal fusion was performed for the treatment of AIS in 125 patients. The thoracic and lumbar vertebrae were enumerated on posteroanterior radiographs. The first thoracic vertebra was the one attached to the first pair of ribs. Enumeration was continued in a caudal direction. The lumbar level initiated just below the last vertebra with a pair of associated ribs.

Results: Abnormal vertebral enumeration was found in 18 patients (14.4%). The prevalence of abnormal lumbar enumeration was higher than thoracic vertebrae (10.4% versus 4%). Eleven thoracic vertebrae were found in 5 patients (4%). Four lumbar vertebrae were found in eleven patients (8.8%). There were two patients with six lumbar vertebrae (1.6%). There was no patient with abnormal enumeration of both thoracic and lumbar vertebrae.

Conclusion: The current study showed a relatively high rate of atypical number of thoracic and lumbar vertebrae in Iranian AIS patients. It is necessary to enumerate the vertebrae on the basis of an organized protocol preoperatively to prevent wrong-level surgery in AIS patients.

Keywords: Scoliosis, Vertebra , Adolescent, Spinal Fusion

Received: 3 months before printing; Accepted: 1 month before printing

Hassan Ghandhari[1], MD; Marziyeh Rashidi[2], MD; Saeed Sabbaghan[3], MD; Seyed Mani Mahdavi[4], MD; Elham Mirzamohammadi[5], MD; Abouzar Azizi[6], MD; Farshad Safdari[7], MSc

1,3,6. Orthopedic spine surgeon, Bone and Joint Reconstruction Research Center, Shafa Orthopedic Hospital, Iran University of Medical Sciences, Tehran, IR Iran.
2. General practitioner, Iran University of Medical Sciences, Tehran, IR Iran.
4. Orthopedic Spine Surgery Department, Rasoul-e-Akram Hospital, Iran University of Medical Sciences, Tehran, IR Iran
5. Occupational medicine, Iran University of Medical Sciences, Tehran, IR Iran.
7. PhD student of Orthotics &Prosthetics, Orthopedic researcher, University of Social Welfare and RehabilitationSciences, Tehran, IR Iran
Corresponding author: Seyed Mani Mahdavi
E-mail: dr.mahdavi.spine@gmail.com

Introduction

Adolescent idiopathic scoliosis (AIS) is one of the most common spinal deformities with unknown etiology[(1)]. In some patients, considerable curve magnitude with progression of the deformity necessitates the surgical fusion[(2)]. The goal of surgery is to correct the deformity and stabilize the spinal column. To this aim, performing surgery at the correct site is of considerable importance.

Wrong-site surgery is known to be one of the five “never events” in surgery[(3)] with its prevalence to be nine times more in spinal surgeries compared to hand surgeries[(4)]. Wrong-level vertebral surgery is reported to be the most common form of wrong-site surgery[(5)]. In a survey performed in 2008, half of the spine surgeons mentioned that they had experienced at least one wrong level vertebral surgery during their clinical practice[(4,6)].

Unusual patient anatomy and failure to verify the right operative site on the radiographic images could be regarded as one of the most frequent causes of the wrong-level vertebral surgery[(7-9)]. Although the number of cervical vertebrae is 7 but there could be variations in the number of thoracic and lumbar vertebrae[(10-14)].

Further, it may be possible that ethnicity affect the incidence and type of the numerical variations of vertebral column which has been investigated in the limited studies on AIS patients[(12-14)].

In the current study, the prevalence and the type of numerical variations of the thoracic and lumbar vertebrae were evaluated in Iranian AIS patients. To our knowledge, there has been no similar study performed on Iranian population which indicates the importance of conducting of the current study.

Method

This retrospective study included 158 patients who underwent spinal fusion for the treatment of AIS from 2012 to 2017.The institutional review board approved the proposal before the study. Clinical and demographic characteristics of the patients were obtained from the patients' medical files. Inclusion criteria consisted of the diagnosis of AIS, treatment with spinal fusion, and the availability of preoperative full-length spinal radiographs (posteroanterior (PA) and lateral views). Patients with other types of scoliosis were excluded from the study.

The radiographic images were reviewed by three observers including two spine surgeons and one general practitioner to determine the number of ribs and thoracic and lumbar vertebrae based on the guidelines represented by spinal deformity study group[15]. On the PA radiographic view, the first thoracic vertebra was the one attached to the first pair of ribs. Enumeration was continued in a caudal direction. All vertebrae with the rib attachments were considered as thoracic vertebrae. The lumbar level initiated just below the last vertebra with a pair of associated ribs. In case of any uncertainty about the presence of the 12th pair of the ribs, if there were 6 vertebrae below the T11, the vertebra just below the T11 was considered as T12. Lumbosacral junction was evaluated to detect the presence of lumbarization or sacralization.

Results

The study was completed with 125 patients because the x-rays of the rest of the patients were unavailable or incomplete. Among them, there were 116 (92.8%) females and 9 (7.2%) males aged 15.68±2.81 years (range: 11-26 years). Abnormal vertebral enumeration was found in 18 patients (14.4%). (Table 1)

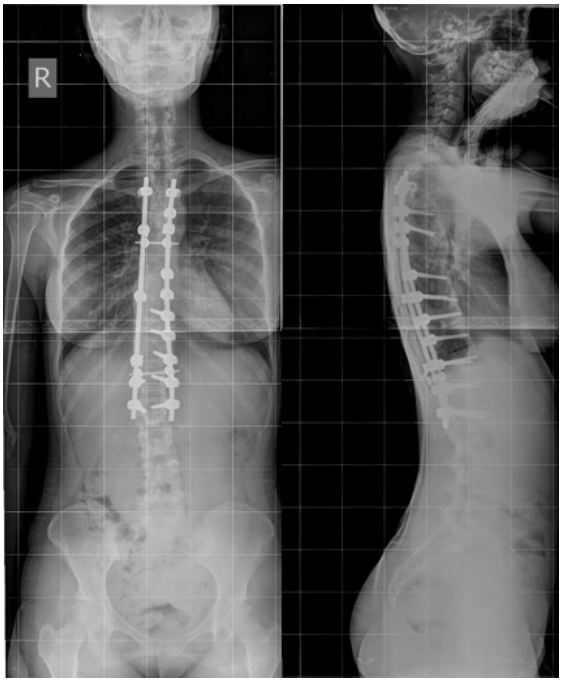

Fig. 1. Postoperative anteroposterior and lateral x-rays of an AIS patient with eleven thoracic vertebrae.

Fig. 2. Preoperative anteroposterior x-rays of an AIS patient with one less lumbar vertebrae.

Table 1. The types of abnormal vertebral enumerations and other deficiencies in AIS patients.

Patient ID	Lumbar vertebral count	Thoracic vertebral count	Other abnormalities
1	5	11	-
2	5	11	Cervical rib
3	4	12	-
4	4	12	-
5	4	12	-
6	4	12	-
7	5	11	Cervical rib
8	4	12	Sacralized vertebra
9	6	12	-
10	4	12	Single-sided sacralized vertebra
11	4	12	-
12	6	12	-
13	4	12	-
14	4	12	-
15	5	11	The ribs of one side were absent.
16	4	12	-
17	4	12	-
18	5	11	-

One less lumbar or thoracic vertebra was the most frequent abnormal enumeration observed in the current study (16 patients). Five patients had one less thoracic vertebra (4%) (fig. 1) and 11 had one less lumbar vertebra (8.8%) (fig. 2). Two patients had one more lumbar vertebra (1.6%). Atypical number of both thoracic and lumbar vertebrae was not found. Cervical rib and sacralized L5 were each detected in two patients (each in 1.6%). Interestingly, there was no wrong-level surgery occurrence in the current study.

The frequency of the abnormal vertebral number was higher in lumbar level compared to the thoracic level (10.4% vs. 4%, respectively). Furthermore, the incidence of loss of a vertebra and gain of a vertebra was 12.8% and 1.6%, respectively.

Discussion

Unfortunately, wrong-site surgery still occurs most commonly in orthopedic surgeries in spite of all the guidelines introduced to prevent it. Wrong level surgery is one of the most challenging events that can lead to serious complications for the patients and also suing spine surgeons.

Since self-assessed surveys are the only provided information about the incidence of wrong-level surgery, it is difficult to determine its true frequency[9, 16]. However previous studies show that 12%-68% of spine surgeons have experienced wrong-level surgery during their practice [4,8]. For example, in a self-reporting study by Jhawar et al the true incidence of wrong level lumbar surgery was about 4.5 cases in every 10,000 surgeries[8].

Wrong level surgery in spinal disorders including AIS may result in several legal, social and mental consequences and, also, medical complications such as inadequate correction of the deformity, postural imbalance and decompensation and be associated with increased financial burden on the patient and health care system[17-21].

Some authors have reported several factors that may increase the risk of wrong level spinal surgery. After evaluating 65 legal files regarding wrong disc space level surgery, Laska and Goodkin concluded that misinterpretation of preoperative radiographic images was likely to be the main risk factor[22]. It has been demonstrated that factors including emergent surgeries, surgeon's tiredness, shortage of time, performing several procedures in one surgery, inadequate positioning of the patient, inappropriate preparation of the surgical site, not benefiting from site markers, unusual patient anatomy for example severe obesity or anatomic deformities or anomalies may potentially increase the risk of wrong-level surgery [8,23,24]. Correct enumeration of the number of vertebrae is crucial for determining the appropriate surgical site and to prevent

errors [25,26] but in the case of possible variations this could be somehow challenging [14,25]. Some previous studies declared that anatomic variations of the spine such as the presence of transitional vertebrae (LSTV or TLTV) or change of the total number of the vertebrae can interfere with correct enumeration and thus increase the risk of wrong-level surgery[4,6,8-10,27].In the spinal surgery, the first or the last vertebrae with rib attachments are considered as landmarks of vertebral enumeration, thus disruption in proper vertebral segmentation can result in inaccurate enumeration[7].

Previously, it has been shown that the incidence of numerical variations in vertebrae is variable in different geographic areas and races[12], hence it appears to be essential to determine the amount of these variations in different regions and populations. To our knowledge there is no similar study in Iranian population. In the current study the prevalence of the vertebral variations in the lumbar and thoracic vertebrae was evaluated in AIS patients that underwent surgical treatment. Such data can play an important role in raising the awareness of surgeons about the wrong-level surgery as a result of numeral variation.

It has been found that an atypical enumeration of the thoracic/lumbar vertebrae was present in 14.4% of Iranian AIS patients, who underwent surgical treatment for the correction of deformity. In USA, Ibrahim et al. reviewed the standing full-length AP and lateral radiographs of 364 consecutive AIS patients undergoing operative treatment to assess the enumeration of thoracic and lumbar vertebrae. They found that 10% of the AIS patients (38 patients) had an atypical number of vertebrae in the thoracic and/or lumbar spine. Of note, 7 patients (1.6%) had multilevel anomalies[13]. In another study in USA, Spencer et al found that abnormal rib count or abnormal lumbar vertebrae count was found in 18% of American AIS patients [14]. As is shown, in latter, the incidence of abnormal vertebral enumeration in American AIS population was considerably higher than that reported by Ibrahim et al [13]. Hu et al, in China, investigated the variations in vertebral number in 657 AIS patients and compared the results to 248 normal adolescents. The incidence of numeral variation was found in 10.6% of AIS patients compared to 10.9% of normal subjects [12]. As shown, the incidence of variations in the number of lumbar and thoracic vertebrae in the current study (Iranian population) was higher than the previous studies [12-14].

Of importance, in the current study, abnormal enumeration was more frequent in the lumbar vertebrae than thoracic vertebra (10.4% vs. 4%, respectively). However, in two studies by Ibrahim et al (5.8% versus 6.6%, respectively) and Hu et al (5.6% versus 7.3%, respectively), the incidence of abnormal thoracic and lumbar vertebrae count was not different considerably [12,13].

In the current study, loss of a vertebrate was more frequent than gain of a vertebrate in total (12.8% vs. 1.6%, respectively) and in distinct thoracic and lumbar levels. In contrast, other authors found that decreased number of vertebrae was predominant in thoracic level while increased number of vertebrae was predominant in lumbar levels. For example, in the study of Ibrahim et al, 11 and 13 thoracic vertebrae were found in 3.8% and 1.9%, respectively. Furthermore, 4 (1.1%) and 20 (5.5%) patients had 4 and 6 lumbar vertebrae, respectively[13]. Furthermore, Hu et al reported the incidence of 11 and 13 thoracic vertebrae as 5% and 0.6%, respectively. They found that 2.1% and 5.2% of the patients had 4 and 6 lumbar vertebrae [12].

Fortunately, like the study of Spencer et al and Hu et al, there was no case of wrong-level surgery in the current study. It may be as Hu et al declared due to the utilizing preoperative whole spine radiography [12]. Furthermore, since during AIS surgery, the fusion levels are determined by the curve characteristics such as magnitude, stiffness and sagittal profile, the

variations in the number of vertebrae may not change the fusion levels [14]. However, Ammerman et al in two studies highlighted the necessity of intraoperative radiography to correctly determine the fusion level[28,29].
Like other studies, there were some limitations in the current study. The current study was limited by the small sample size. It is obvious that larger studies can result in more reliable outcomes. Furthermore, the small number of the male patients made it impossible for the authors to compare the incidence of numeral variations between two genders. In the current study, the incidence of numeral variations was not investigated in the normal population. Thus, it was not possible to compare the incidence of anomalies between scoliotic patients and normal population. The patients studied were selected from one hospital only while it is necessary to perform such studies on whole Iranian population.

Conclusion

It seems that the incidence of abnormal vertebral enumeration is to some extent higher in the group of Iranian AIS patients compared to some other regions. Furthermore, in the current study, the incidence of decreased number of vertebrae was higher than the incidence of increased number of vertebrae, both in total and in thoracic and lumbar regions. Also, the abnormal enumeration was more frequent in thoracic spine compared to the lumbar spine. The current study highlighted the importance of the enumeration of vertebrae in order to perform surgery on the correct site in AIS patients and adopting a system for enumeration of thoracic and lumbar vertebrae as part of our preoperative planning.

References

1. Fadzan M, Bettany-Saltikov J. (2017) Etiological Theories of Adolescent Idiopathic Scoliosis: Past and Present. Open Orthop J 11:1466-1489.
2. Trobisch PD, Ducoffe AR, Lonner BS, Errico TJ (2013)Choosing fusion levels in adolescent idiopathic scoliosis. J Am Acad Orthop Surg 21(9):519-28.
3. Michaels RK, Makary MA, Dahab Y, Frassica FJ, Heitmiller E, Rowen LC, et al (2007) Achieving the National Quality Forum's "Never Events": prevention of wrong site, wrong procedure, and wrong patient operations. Ann Surg245:526-532.
4. Mody MG, Nourbakhsh A, Stahl DL, Gibbs M, Alfawareh M, Garges KJ (2008) The prevalence of wrong level surgery among spine surgeons. Spine33:194-198.
5. James MA, Seiler JG 3rd, Harrast JJ, Emery SE, Hurwitz S (2012) The occurrence of wrong-site surgery self-reported by candidates for certification by the American Board of Orthopaedic Surgery. J Bone Joint Surg Am94(1):e2(1–12).
6. Groff MW, Heller JE, Potts EA, Mummaneni PV, Shaffrey CI, Smith JS (2013) A survey-based study of wrong-level lumbar spine surgery: the scope of the problem and current practices in place to help avoid these errors. World Neurosurg79(3–4):585–592.
7. Lindley EM, Botolin S, Burger EL, Patel VV (2011)Unusual spine anatomy contributing to wrong level spine surgery: a case report and recommendations for decreasing the risk of preventable 'never events'. Patient Saf Surg5:33.
8. Jhawar BS, Mitsis D, Duggal N (2007) Wrong-sided and wrong-level neurosurgery: a national survey. J Neurosurg Spine7:467-472.
9. Mayer JE, Dang RP, Duarte Prieto GF, Cho SK, Qureshi SA, Hecht AC (2014)Analysis of the techniques for thoracic- and lumbar-level localization during posterior spinesurgery and the occurrence of wrong-level surgery: results from a national survey. Spine J 14(5):741-8.
10. Hanson EH, Mishra RK, Chang DS, Perkins TG, Bonifield DR, Tandy RD, et al (2010) Sagittal whole-spine magnetic resonance imaging in 750 consecutive outpatients: accurate determination of the number of lumbar vertebral bodies. J Neurosurg Spine12:47-55.
11. Thawait GK, Chhabra A, Carrino JA (2012) Spine segmentation and enumeration and normal variants. Radiol Clin North Am50:587-598.
12. Hu Z, Zhang Z, Zhao Z, Zhu Z, Liu Z, Qiu Y (2016)A neglected point in surgical treatment of adolescent idiopathic scoliosis: Variations in the number of vertebrae. Medicine (Baltimore)95(34):e4682.

13. Ibrahim DA, Myung KS, Skaggs DL (2013)Ten percent of patients with adolescent idiopathic scoliosis have variations in the number of thoracic or lumbar vertebrae.J Bone Joint Surg Am 95(9):828-33.
14. Spencer HT, Gold ME, Hresko MT (2014) Cbnormal rib count in scoliosis surgery: impact ont he reporting of spinal fusion levels.J Child Orthop 8(6):497-503.
15. O'Brien MF, Kuklo TR, Blanke KM, Lenke LG, Spinal Deformity Study Group (2008) Radiographic Measurement Manual. Medtronic Sofamor Danek, USA.
16. Javid M, Shahcheraghi G, Lahiji F, Ahmadi A. Remember your Last "Wrong- Site Surgery"? Are You Prepared to Share Your Wrong Doing? Iranian Journal of Orthopaedic Surgery 2014;12(1):1-5.
17. Palumbo MA, Bianco AJ, Esmende S, Daniels AH (2013) Wrong-site Spine Surgery.J Am Acad Orthop Surg 21(5):312-20.
18. Potter BK, Rosner MK, Lehman Jr. RA Polly Jr. DW, Schroeder TM, Kuklo TR (2005) Reliability of end, neutral, and stable vertebrae identification in adolescent idiopathic scoliosis. Spine30(14):1658–1663.
19. Margulies JY, Floman Y, Robin GC, Neuwirth MG, Kuflik P, Weidenbaum M (1998) An algorithm for selection of instrumentation levels in scoliosis. Eur Spine J7:88–94.
20. Takahashi J, Newton PO, Ugrinow VL, Bastrom TP (2011) Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis Factors Influencing the Selection of the Optimal Lowest Instrumented Vertebra. Spine36(14):1131–1141.
21. Levy D (1998) No defense for wrong-site surgery. AAOS Bull46:18.
22. Goodkin R, Laska LL (2004) Wrong disc space level surgery: medicolegal implications. Surg Neurol61(4):323-42.
23. Devine J, Chutkan N, Norvell DC, Dettori JR (2010) Avoiding wrong site surgery: a systematic review. Spine (Phila Pa 1976)35:28–36.
24. JCAHO (2003) Universal protocol for preventing wrong site, wrong procedure, wrong person surgery.Available via:http://www.jointcommission.org/ PatientSafety/UniversalProtocol/.
25. Yun S, Park S, Park JG, Huh JD, Shin YG, Yun JH (2018) Spinal Enumeration by Morphologic Analysis of Spinal Variants: Comparison to Counting in a Cranial-To-Caudal Manner. Korean J Radiol19(6):1140-1146
26. Longo UG, Loppini M, Romeo G, Maffulli N, Denaro V (2012) Errors of level in spinal surgery: an evidence-based systematic review. J Bone Joint Surg Br94-B:1546–50.
27. Hsu W, Kretzer RM, Dorsi MJ, Gokaslan ZL (2011) Strategies to avoid wrong-site surgery during spinal procedures. Neurosurg Focus31(4):E5.
28. Ammerman JM, Ammerman MD (2008) Wrong-sided surgery. J Neurosurg Spine9:105-106.
29. Ammerman JM, Ammerman MD, Dambrosia J, Ammerman BJ (2006) A prospective evaluation of the role for intraoperative x-ray in lumbar discectomy. Predictors of incorrect level exposure. Surg Neurol66:470-474.