



# Fluoroscopy for Transpedicular Screw Placement in Scoliosis: To What Extent Can Radiation Exposure Be Reduced by the Freehand Technique?

## *Skolyozda Transpediküler Vida Yerleştirilmesi için Floroskopi Kullanımı: Serbest El Tekniği ile Hangi Ölçüde Radyasyon Maruziyeti Düşürülebilir?*

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### ABSTRACT

**AIM:** In spinal surgery, high doses of radiation are delivered during surgical procedures that require fluoroscopic control. The aim of this study was to determine the amount of radiation delivered from the fluoroscopic unit and also the factors to reduce the amount of radiation during the surgery of adolescent idiopathic scoliosis patients.

**MATERIAL and METHODS:** In this retrospective study 21 patients with adolescent idiopathic scoliosis treated by transpedicular screws between 2009 and 2012 were enrolled the study. Dose Area Product (DAP) values, number of views obtained during screw placement and other data were retrieved from the medical records of the patients.

**RESULTS:** The mean number of transpedicular screws used was 18. An average of 10,1 vertebrae were instrumented. The mean number of images obtained was 7.76. Mean fluoroscopy time was 7.95 seconds. The total mean DAP was 64.6 cGy.cm<sup>2</sup>.

**CONCLUSION:** The amount of ionizing radiation transmitted to the patient and the surgical team can be reduced by freehand insertion, confirmation of screw position by AP and lateral fluoroscopic views including more than one segment, the use of K-wires as a guide in spinal segments with abnormal pedicular anatomy and neuromonitorization of the patient during the surgical correction of adolescent idiopathic scoliosis.

**KEYWORDS:** Scoliosis, Fluoroscopy, Radiation dosage, Instrumentation

### ÖZ

**AMAÇ:** Spinal cerrahide özellikle floroskopik kontrol gereken cerrahi girişimlerde yüksek doz radyasyon yayılır. Bu çalışmanın amacı, adolesan idiopatik skolyozlu hastaların cerrahisinde floroskopi ünitesinden yayılan radyasyonunu miktarını belirleme ve anormal yapılanmış pediküllerde klavuz k tellerinin kullanılması, serbest el tekniği ile transpediküler vidaların yerleştirilmesi, intraoperatif nöromoniterizasyonun kullanılması ve çok seviye transpediküler vidanın tek floroskopik görüntüde görüntülenmesinin radyasyon dozunun düşürülmesini sağladığını göstermektir.

**YÖNTEM ve GEREÇLER:** Bu retrospektif çalışmaya, 2009 ile 2012 yılları arasında transpediküler vida ile tedavi edilen 21 hasta dahil edilmiştir. Doz Alan Ürün (DAÜ) değerleri, vida yerleştirilmesi esnasındaki görüntülenme sayıları, toplam floroskopi zamanı ve diğer bilgiler tıbbi kayıtlarından bulundu.

**BULGULAR:** Kullanılan transpediküler vida sayısının ortalaması 18 idi. Ortalama 10.1 vertebra enstrümente edildi. Elde edilen görüntüleme sayısı ortalama 7.76 idi. Ortalama floroskopi zamanı 7.95 saniye idi. Floroskopi ünitesi tarafından verilen ortalama DAÜ değeri 64.6 cGy.cm<sup>2</sup> idi.

**SONUÇ:** Adolusan idiopatik skolyozlu hastaların cerrahi düzeltmesinde transpediküler vidaların serbest el tekniği ile yerleştirilmesi, AP ve lateral floroskopik görüntüler ile vida pozisyonunun teyidi sırasında birden fazla segmentin görüntülenmesi, anormal pediküler anatominin olduğu segmentlerde K tellerinin klavuz olarak kullanılması ve hastanın nöromoniterizasyonu hastaya ve cerrahi takıma iletilen iyonize radyasyon miktarını azaltabilir.

**ANAHTAR SÖZCÜKLER:** Skolyoz, Floroskopi, Radyasyon dozu, Enstrümantasyon

## INTRODUCTION

In spinal surgery, high doses of ionizing radiation are delivered during surgical procedures that require fluoroscopic control, such as correction of spinal deformities with third generation transpedicular screws or kyphoplasty (12,17). Therefore, radiation safety has become a major concern for spinal surgeons in recent years. Although cytostatic effects of low dose ionizing radiation have been reported (2,5,6,10), there is no consensus about the definition of a low dose and the safety limit for a cumulative dose. In BEIR VII (Biologic Effects of Ionizing Radiation) study, low dose radiation (<100 msv) was found not to increase the malignancy risk, but doses over 100 msv increase the overall cancer risk by 1% per 100 msv(14). Thus radiation safety should be provided for both the patient and the surgical team. As in all medical procedures, the basic principle of radiation safety "As Low As Reasonably Achievable" (ALARA) should be followed; radiological imaging should be used only if absolutely necessary.

The amount of radiation exposure during transpedicular screw insertion is closely associated with the experience of the surgeon and the technique. As the experience of the surgeon increases, fluoroscopy time and the radiation exposure of the patient and the surgical team decreases. Also, intraoperative use of neuromonitorization, freehand transpedicular screw insertion technique and using guide K-wires in pedicles with a different structure are other factors that may help to decrease the need for fluoroscopy.

Many studies that measure the radiation exposure of the patient and surgical team during transpedicular screw placement have focused on the fluoroscopy usage for each screw placed, which eventually increases the fluoroscopy time and the amount of radiation. Post or intra-operative use of computed tomography (CT) to confirm the position of the screws, also exposes patients and the surgical team to high doses of ionizing radiation compared to plain radiographs (1).

The aim of this study was to determine the amount of radiation delivered from the fluoroscopic unit and to assess the amount of dose reduction that can be achieved when the transpedicular screws are inserted with freehand technique, using guide K-wires in abnormally structured pedicles, using intra-operative neuromonitorization and imaging the multi-level transpedicular screws in one fluoroscopic image during the surgery of adolescent idiopathic scoliosis (AIS) patients and comparing the measured doses with those reported in literature.

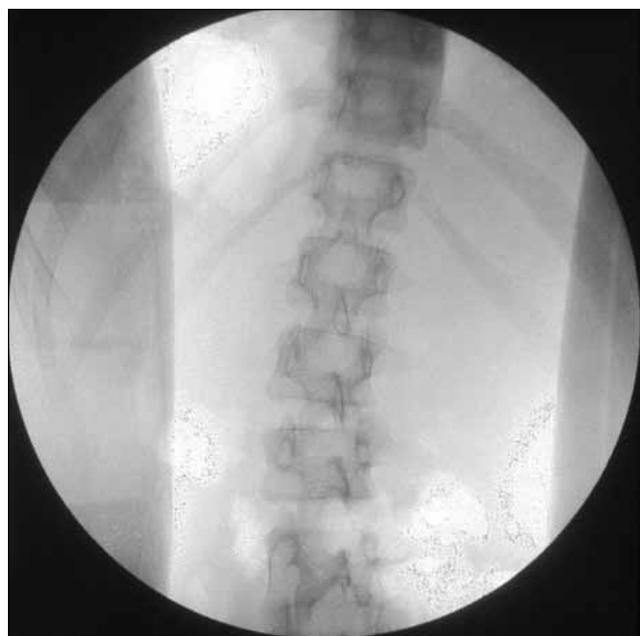
## MATERIAL and METHODS

In this study, 21 patients with (AIS) treated with posterior instrumentation and fusion using transpedicular screws in our clinic between 2009 and 2012 were retrospectively evaluated. Patients that underwent revision surgery were excluded from the study. All transpedicular screws were placed by two spinal surgeons who had at least 10 years of experience in spinal surgery. Imaging was performed by a Philips Pulsara fluoroscopy unit (Philips Medical Systems Nederland B.V.)

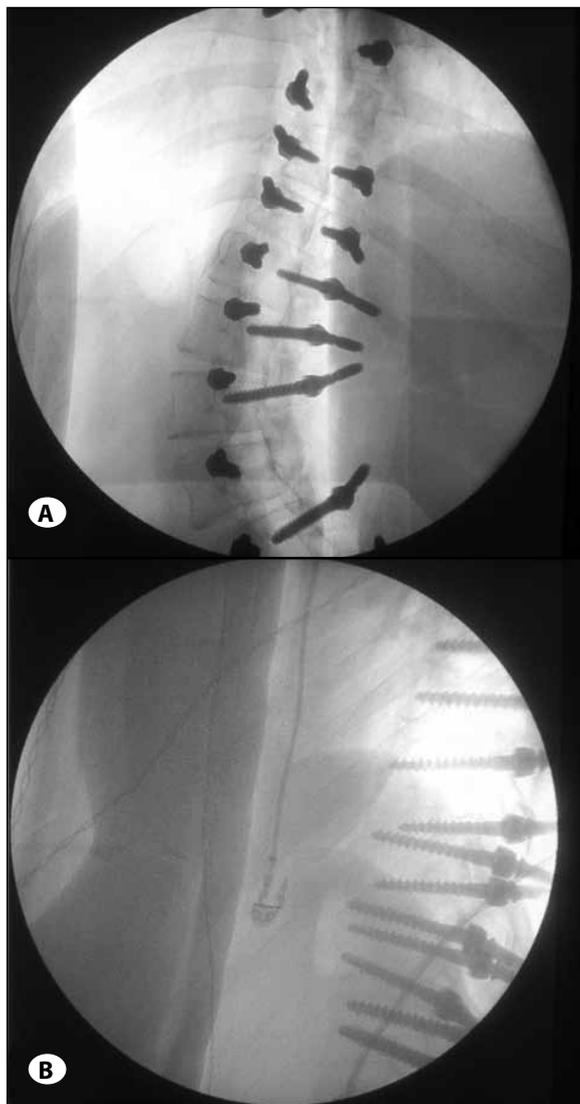
with automatic dose adjustment. The unit had an integrated Dose Area Product meter (DAP meter) which shows the total delivered radiation dose. The total dose was registered in the hard disc of the device as "cGy.cm<sup>2</sup>" thus the DAP value of each patient could be individually obtained. The total number of views obtained during screw placement including preoperative traction radiography, total fluoroscopy time, separate tube current and voltage values for anteroposterior (AP) and lateral views were retrieved from the unit's hard disc drive; weight and body mass indexes of the patients, total number of instrumented vertebrae, total time of surgery, total amount of blood loss, postoperative complications were retrieved from the medical records of the patients. CT was not used for evaluation of the transpedicular screw positions in the postoperative period.

### Surgical Procedure

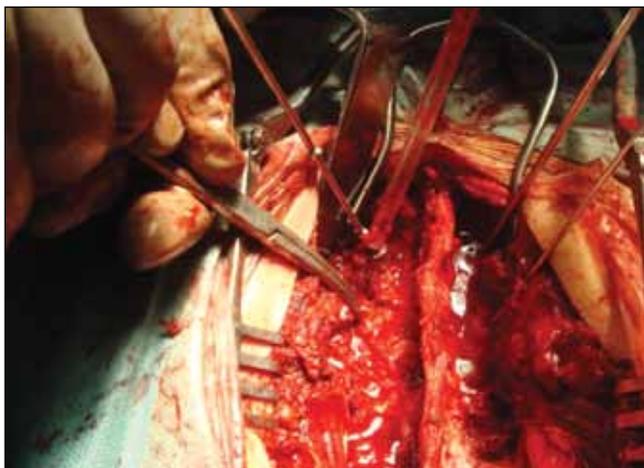
Traction views were taken by fluoroscopic unit under general anesthesia before the surgery (Figure 1). Somatosensory evoked potentials (SSEP) were used for neuromonitorization of all patients. In cases of suspicion, the wake-up test was performed (Five patients). Following a median incision and blunt dissection of paraspinal muscles, facet joints were exposed. Facet joints were excised and the four walls of the pedicles were palpated by a ball-pointed probe. After then the transpedicular screws were inserted. To minimize scattered radiation, the fluoroscopy unit was placed with the under couch tube and the over couch image intensifier. The image intensifier was placed as close as possible to the patient to include the maximum possible number of pedicle screws within one image. AP and lateral views of the maximum number of spinal segments that the image intensifier allowed were taken (Figure 2A, B). The surgical team was kept away from the field behind the lead apron during fluoroscopy. A



**Figure 1:** Traction radiograph taken under fluoroscopic control.



**Figure 2:** **A)** Intra-operative fluoroscopic images of multi-level transpedicular screws. AP view **B)** Intra-operative fluoroscopic images of multi-level transpedicular screws. Lateral view.



**Figure 3:** Intra-operative view of the positions of the guide K wires.

guide K-wire was inserted into the pedicle in case any problem was encountered during the placement of transpedicular screws (Figure 3). Fluoroscopic AP and lateral views of the related spinal segments were obtained, and screws were reinserted taking the position of the guide K-wire into consideration (Figure 4). Following placement of the rods and correction of the deformity, the final status of the spine and shoulder symmetry was confirmed by fluoroscopy (Figure 5). Conventional plain radiography was not used during the surgery.

**RESULTS**

All patients had roto-scoliotic deformities at the thoracolumbar region. Fifteen patients were female, and six were male. Mean age was 13.4 years (range 11-15 years), the average weight of the patients was 58.3 kg (range 47-61 kg) with an average body mass index (BMI) of 22.7 (21.2-24). The mean number of transpedicular screws used was 18 (range 12-24 screws). An average of 10,1 (8-14) vertebrae were instrumented. The mean number of images obtained was 7.76 (range 5-16 images), and mean fluoroscopy time was 7.95 seconds (range 5-17 seconds). In 12 patients, additional views were taken for suspicious spinal levels with K-wires in place. In the fluoroscopic parameters, while the mean tube current (mA) was 2.4 (2.1-2.7) for lateral views and 2.0 (1.9-2.3) for AP views, the mean tube voltage (kVp) was 71 (68-77) for AP views and 75 (71-80) for lateral views. The total mean DAP value given by the fluoroscopy unit was 64.6 (15-122) cGy.cm<sup>2</sup>. The mean DAP value of traction views was found to be 3.3 (2.8-3.9) cGy.cm<sup>2</sup>. The average time of instrumentation was 2.2 hours with an average blood loss of 1870 ml. Summary of patient data is summarized in Table I. One patient suffered from pneumothorax due to malpositioning of a transpedicular

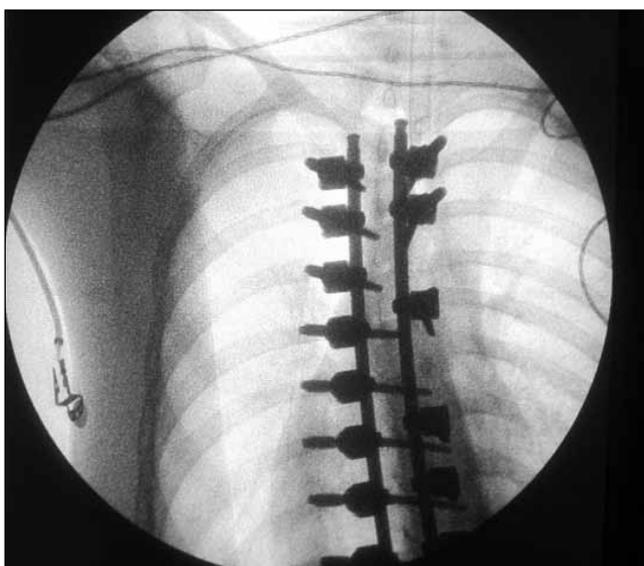


**Figure 4:** A guide K-wire was inserted into the pedicle if any problem was encountered during placement of the transpedicular screws.

screw at T8 vertebrae level. This patient did well following revision and insertion of a chest tube.

### DISCUSSION

All-pedicle screw insertion in the treatment of AIS has become more widespread in recent years.(9,18). Transpedicular screw insertion in scoliotic deformities is technically more difficult compared to other indications of transpedicular screw applications due to the abnormal pedicle structure and anatomy. Thus, fluoroscopy is commonly employed in these surgeries depending on the experience of the surgeon and the technique. Although fluoroscopy is essential for safe screw placement, the patient and surgical team are exposed to high doses of radiation with increased fluoroscopy time, which is closely associated with the learning curve (8,11,13,16,17). Haque et al (17) placed an average of 23 screws per patient for correction of idiopathic scoliosis, with a fluoroscopy time



**Figure 5:** Final status of the spine and shoulder asymmetry evaluated with AP and lateral fluoroscopic images.

of 7.36 seconds per screw, making a total of 167.74 seconds during the operation and the surgical team was exposed to 13.49 msv of radiation annually. Jones et al (8) reported 0.33 minutes of fluoroscopy use for each screw and Perisinakis et al (13) utilized fluoroscopy for 1.2 minutes for AP and 2.1 minutes for lateral imaging for an average of 4.8 screws in the lumbar region. Moreover, reported fluoroscopy times are significantly high with percutaneous transpedicular screw applications. Thus, Mroz et al (11) used fluoroscopy for 4 minutes 56 seconds for an average 10 percutaneous transpedicular screws. In the current study, the freehand transpedicular screw insertion technique under continuous neuromonitorization was used. More than one transpedicular screw was imaged in one AP / lateral fluoroscopic image and guide K-wires were used which were imaged with the other transpedicular screws in the same fluoroscopic image in cases of suspicion. Finally, a total 7.95 seconds of fluoroscopy usage for an average 18 transpedicular screws was achieved, which is significantly lower compared to reports in literature.

In addition to fluoroscopy time, DAP is an important parameter to determine the radiation dose delivered to the patient (4). Today DAP meters integrated into fluoroscopic units show the total dose in units as  $\mu\text{Gy}\cdot\text{m}^2$  or  $\text{cGy}\cdot\text{cm}^2$ . DAP values are related to fluoroscopy time, fluoroscopy output and filtration, diameter of image intensifier and kVp-mA values. Measured values may be compared to reference values reported for certain procedures (7). In adolescent idiopathic scoliosis, Schaefer et al (15) reported mean DAP values of 94.9  $\text{cGy}\cdot\text{cm}^2$  for conventional AP full spine radiographs and 7.8  $\text{cGy}\cdot\text{cm}^2$  for the fluoroscopic scanning method. Peristinakis et al (13) reported DAP values for an average of 4.8 lumbar transpedicular screws as 232  $\text{cGy}\cdot\text{cm}^2$  for AP views and 568  $\text{cGy}\cdot\text{cm}^2$  for lateral views. In the current study, the total mean DAP value was 64.6 (15-122)  $\text{cGy}\cdot\text{cm}^2$  and significantly lower compared to those reported in literature. Moreover, preoperative conventional traction or bending radiographies were not used to minimize the radiation dose delivered to the patient. The surgical team was kept away from the surgical field during fluoroscopic imaging to minimize the hazardous effect of scattered radiation.

**Table I:** Summary of Patient Data

Number of patients	21	
Age *	13.4 years (11-15years)	
Body weight*	58.3kg (47-61 kg)	
BMI (Body mass index)*	22.7 (21.2-24)	
Number of transpedicular screw *	18 screws (12-24)	
Number of instrumented vertebrae *	10,1 vertebrae (8-14)	
Number of fluoroscopic images (including traction radiograph)*	7.76 images (5-16)	
Mean fluoroscopy time *	7.95 seconds (5-17 seconds)	
Tube voltage (kVp)*	AP: 71 kVp(68-77)	Lateral: 75 (71-80)
Tube current (mA)*	AP: 2.0 (1.9-2.3)	Lateral: 2.4 mA (2.1-2.7)
Total DAP value*	64.6 $\text{cGy}\cdot\text{cm}^2$ (15-122)	
DAP value for traction radiographs*	3.3 $\text{cGy}\cdot\text{cm}^2$ (2.8-3.9)	

\*:mean value.

To reduce the need of intra-operative imaging procedures, new transpedicular screw insertion techniques have been reported. Chang et al (3) placed 992 screws in 39 patients using the Tai-Chi method with no imaging during surgery. However, they confirmed the position of the screws by postoperative AP and lateral radiographs and CT scan, thus patients were exposed to relatively higher doses of radiation than in the current study. The main advantages of the method used in the current study were found to be decreased radiation exposure for the surgical team and the patient during surgery, and also decreased patient radiation exposure as traction radiographs were obtained under general anesthesia by the fluoroscopic unit rather than conventional radiographs being taken (15). Additionally, it is thought that freehand insertion of transpedicular screws, utilization of K-wires in difficult vertebral anatomy, imaging of multi-level segments in a one fluoroscopic image and neuromonitorization during surgery will help to decrease the need for fluoroscopy use, and reduce surgery time and the amount of blood loss with increased safety of screw insertion.

There are some limitations to this study. Thermoluminescent dosimeters were not used, and separate DAP values for AP and lateral views, or for thoracic and lumbar regions could not be measured separately. However, the effective dose to which the patient was exposed would be as low as 0.27 msv even in the worst possible case scenario (when the maximum DAP to Effective dose conversion coefficient with AP view in L1 vertebrae level was used ) (12).

### CONCLUSION

The amount of ionizing radiation transmitted to the patient and the surgeon was significantly reduced by freehand insertion of transpedicular screws in idiopathic scoliosis. Confirmation of screw position by AP and lateral fluoroscopic views including more than one segment, the use of K-wires as a guide in spinal segments with abnormal pedicular anatomy, obtaining traction radiographs by fluoroscopy under general anesthesia and neuromonitorization of the patient during screw placement were seen to be effective. Fluoroscopy time and DAP values are important and useful parameters for monitoring the amount of radiation during fluoroscopy assisted spinal surgery.

### REFERENCES

1. Biswas D, Bible JE, Bohan M, Simpson AK, Whang PG, Grauer JN: Radiation exposure from musculoskeletal computerized tomographic scans. *J Bone Joint Surg Am* 91(8):1882-1889, 2009
2. Boei JJ, Vermeulen S, Skubakova MM, Meijers M, Loenen WA, Wolterbeek R, Mullenders LH, Vrieling H, Giphart-Gassler M: No threshold for the induction of chromosomal damage at clinically relevant low doses of x rays. *Radiat Res* 177(5):602-613, 2012
3. Chang KW, Wang YF, Zhang GZ, Cheng CW, Chen HY, Leng X, Chen YY: Tai Chi Pedicle Screw Placement for Severe Scoliosis. *J Spinal Disord Tech* 25(3):E67-73, 2012
4. Chida K, Saito H, Otani H, Kohzuki M, Takahashi S, Yamada S, Shirato K, Zuguchi M: Relationship between fluoroscopic time, dose-area product, body weight, and maximum radiation skin dose in cardiac interventional procedures. *AJR Am J Roentgenol* 186(3):774-778, 2006
5. Chou LB, Chandran S, Harris AH, Tung J, Butler LM: Characterization of breast cancer risk among female orthopedic surgeons in the United States. *Journal of Women's Health*, 2002
6. Einstein AJ: Effects of radiation exposure from cardiac imaging: How good are the data? *J Am Coll Cardiol* 59(6): 553-565, 2012
7. Hart D, Hillier MC, Wall F: National reference doses for common radiographic, fluoroscopic and dental X-ray examinations in the UK. *British Journal of Radiology* 82:1-12, 2009
8. Jones DP, Robertson PA, Lunt B, Jackson SA: Radiation exposure during fluoroscopically assisted pedicle screw insertion in the lumbar spine. *Spine* 25(12):1538-1541, 2000
9. Luhmann SJ, Lenke LG, Erickson M, Bridwell KH, Richards BS: Correction of Moderate (<70 Degrees) Lenke 1A and 2A curve patterns: Comparison of hybrid and all-pedicle screw systems at 2-year follow-up. *J Pediatr Orthop* 32(3):253-258, 2012
10. Menzel HG, Harrison J: Dosimetric quantities in radiological protection and risk assessment. *J 2012 J Radiol Prot* 32(1):N41-46, 2012
11. Mroz TE, Abdullah KG, Steinmetz MP, Klineberg EO, Lieberman IH: Radiation exposure to the surgeon during percutaneous pedicle screw placement. *J Spinal Disord Tech* 4(4):264-267, 2011
12. Perisinakis K, Damilakis J, Theocharopoulos N, Papadokostakis G, Hadjipavlou A, Gourtsoyiannis N: Patient exposure and associated radiation risks from fluoroscopically guided vertebroplasty or kyphoplasty. *Radiology* 232(3):701, 2004
13. Perisinakis K, Theocharopoulos N, Damilakis J, Katonis P, Papadokostakis G, Hadjipavlou A, Gourtsoyiannis N: Estimation of patient dose and associated radiogenic risks from fluoroscopically guided pedicle screw insertion. *Spine* 29(14):1555-1560, 2004
14. Puskin JS: Perspective on the use of LNT for radiation protection and risk assessment by the U.S. Environmental Protection Agency. *Dose Response* 7(4):284-291, 2009
15. Schaefer J, Kluba T, Niemeyer T, Hahnfeldt T, Vonthein R, Kottke R, Kamm KF, Claussen C: Comparison of conventional full spine radiographs and fluoroscopic scanning method in young patients with idiopathic scoliosis. *Rofo* 177(8):1110-1115, 2005
16. Slomczykowski M, Roberto M, Schneeberger P, Ozdoba C, Vock P: Radiation dose for pedicle screw insertion. Fluoroscopic method versus computer-assisted surgery. *Spine* 24(10):975-982; discussion 983, 1999
17. Ul Haque M, Shufflebarger HL, O'Brien M, Macagno A: Radiation exposure during pedicle screw placement in adolescent idiopathic scoliosis: is fluoroscopy safe? *Spine* 31(21):2516-2520, 2006
18. Zheng CK, Kan WS, Li P, Zhao ZG, Li K: Treatment for Severe Idiopathic Upper Thoracic Scoliosis in Adolescence. *J Spinal Disord Tech* 26(2):107-111, 2013