RETROSPECTIVE ANALYSIS OF SCREW MALPOSITIONS FOLLOWING INSTRUMENTED CORRECTION OF THORACIC AND LUMBAR SPINE DEFORMITIES*

A.V. Gubin, S.O. Ryabykh, A.V. Burtsev
Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics, Kurgan, Russia

Objective. The study objective was to analyze screw malposition cases following instrumented correction of thoracic and lumbar spine deformities.

Material and Methods. We performed a retrospective analysis of 73 patients aged 3 to 58 years with thoracic and lumbar spine deformities. Deformity magnitude (Cobb angle) ranged 20° to 134° (mean 61° ± 4°). A total of 1,065 screws were implanted using a free-hand technique to correct spine deformities. Postoperative CT was used to detect screw malpositions. Screw malpositions were graded according to the following scale: A — no malposition, B — malposition of less than 2 mm, C — malposition between 2 and 4 mm, and D — malposition of more than 4 mm.

Results. Implantation of 628 (59.0 %) transpedicular screws was performed correctly, while trajectories of 437 (41.0 %) screws were displaced. Malposition of less than 2 mm was observed for 263 screws (24.7 %); for 112 screws (10.5 %), malposition reached 4 mm and was considered as the safe zone threshold; for 62 screws (5.8 %), it exceeded 4 mm and was regarded as potentially dangerous in terms of primary or delayed injury to neural structures and vessels.

Conclusion. Transpedicular fixation is the method of choice for surgical correction of spine deformities. Its application is associated with a risk of neurovascular complications. Free-hand screw implantation is the most common, affordable, and fairly safe technique, but requires appropriate surgical skills.

Key Words: transpedicular fixation, screw malposition, spine deformity.

At present, surgical corrections of most spinal deformities is carried out through the dorsal approach using extended fixation systems. Transpedicular constructions requiring accurate placement of screws into the vertebral bodies through the arch roots are the most secure systems. Transpedicular fixation enables three-plane correction of deformities with fixation of the three spine columns, with the maximum number of spinal-motion segments being spared [1, 6, 7, 11, 14, 15, 25, 30]. Despite the obvious advantages of transpedicular fixation, its wide application is limited due to the risk of neurological and vascular complications due to screw malposition [7, 14, 36, 40, 43, 46].

The objective of this study was to analyze screw malposition cases following instrumented correction of thoracic and lumbar spine deformities.

Material and Methods

We performed a retrospective analysis of 73 patients aged 3 to 58 years with thoracic and lumbar spine deformities. Of these, 46 (63.0 %) patients were diagnosed with idiopathic scoliosis; 13 (17.8 %) patients had congenital scoliosis; 6 (8.2 %) patients had systemic deformities; 5 (6.9 %) patients had neuromuscular scoliosis; 3 (4.1 %) patients had Scheuermann's disease. Deformity magnitude (Cobb angle) ranged 20° to 134° (mean 61° ± 4°). The patients were allocated into three groups, depending on deformity magnitude:

1) deformity of 20 to 40° – 25 (34 %) patients;

2) deformity of 41° to 90° – 40 (55 %) patients;

3) deformity of 90° – 8° (11 %) patients.

This allocation was based on the following reasons: 40° is the biomechanical compensation threshold after which deformity develops progressively [47]; 90° is the magnitude of the transition from severe deformity to extremely severe deformity associated with a greatly increased risk of intraoperative (including malpositions) and postoperative complications [18].

A total of 1,065 transpedicular screws were placed in 73 patients to correct spinal deformities. A free-hand technique by Lenke [7, 27] was used in all patients to implant transpedicular screws. Postoperatively, all patients, regardless of complaints, underwent MSCT control of

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screw positions to detect malpositions. Malpositions were evaluated according to the following scale: A – no malposition, B – malposition of less than 2 mm, C – malposition of 2–4 mm, D – malposition of more than 4 mm [14, 29].

Results and Discussion

Implantation of 628 (59.0 %) transpedicular screws was performed correctly, while trajectories of 437 (41.0 %) screws were displaced. It should be noted that malposition of less than 2 mm was observed for 263 (24.7 %) screws; malposition reached 4 mm for 112 (10.5 %) screws and was defined as the Amiot and Vaccaro safe zone threshold [3, 7]. Malposition of 62 (5.8 %) screws was higher than 4 mm and was regarded as potentially dangerous in terms of primary or delayed injury to neural and vascular structures [2, 7, 14, 46] (Table). The largest number of malpositions was observed in the thoracic spine – 334 (76.4 %) screws and lumbar spine – 103 (23.6 %) screws.

An analysis of the dependence of the malposition number on deformity magnitude revealed that the distribution of correctly placed screws (type A) was not significantly different in the three study groups (from 20° to 40°; from 41° to 90°; more than 90°). In this case, the rate of minor malpositions (type B) was 25.5 % in group 1, 25.3 % in group 2, and 19.9 % in group 3, indicating a reduction in the number of malpositions in patients with severe deformities. At the same time, the rate of significant (type C) and excessive (type D) malpositions increased as the deformity angle increased (from 8.6 to 13.2 % for type C and from 4.7 to 6.6 % for type D) (Figure; Table).

No statistically proven correlation among age features, etiology of deformities, surgeon's experience, and malposition magnitude was found. There were no neurological complications due to screw malposition.

According to numerous literature data, the rate of screw malpositions in the thoracic and lumbar spine upon correction of spinal deformities ranges from 1 to 58 % for the free-hand technique [2–10, 12, 15–17, 20, 21, 24, 25, 29, 30, 33, 35, 39, 41, 42, 44]. In this case, the rate of correctly implanted screws in children under 10 years of age is less than 1 % [16]. According to Kuklo et al. [22], 96.3 % of screws were placed correctly when the free-hand technique was used for correction of scoliotic deformities of more than 90°. According to other data [29], the rate of malpositions reaches 31.6 % in the thoracic spine and 10.6 % in the lumbar spine. Up to 48.0 % of malpositions in the thoracic spine occur at the T1 T6 level, which is due to a smaller diameter of the vertebral arch pedicles [6]. About 56 % of incorrectly placed screws are located on the concave side of deformity [2], which may be attributed to structural arch dysplasia and apical torsion. In this case, malposition is less than 2 mm in 81–86 % of screws [3, 29] and less than 4 mm in 68 % of screws [44].

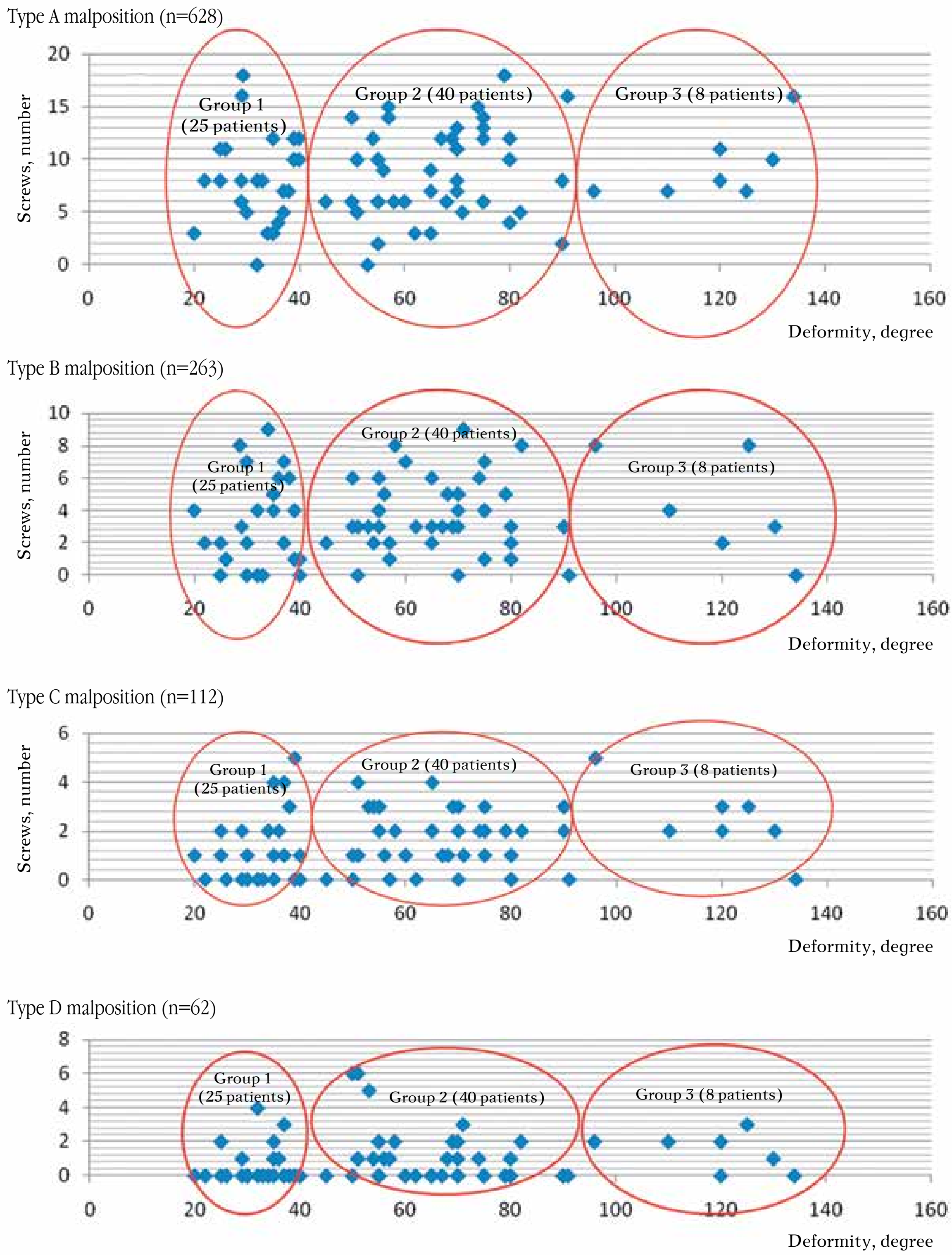
According to the literature data, medial malposition of up to 4 mm does not lead to neurological injuries because it is within the so-called safe zone. This rule applies mostly to the thoracic spine where 2 mm occurs in the epidural space, and 2 mm occurs in the subarachnoid space. Therefore, there is no direct compression of the spinal cord [2, 7]. There are data that intracanal malposition in the thoracic spine, occluding up to 50% of the canal, is not associated with neurological injuries in some cases. However, this screw position is regarded unacceptable and requires replacement [2, 26]. In this case, neurological complications develop in less than 7 % of cases [2, 10]. The reoperation rate due to an incorrect screw position amounts to 7 % for the free-hand technique [3]. Placement of screws in revision surgery is associated with a higher risk of malposition. The use of EMG to control screw placement is believed to be unreliable because it has low sensitivity, especially at the T_2–T_9 level [8, 31]. However, the use of detailed imaging of the posterior structures and implantation sites in combination with the free-hand technique under EMG control improves the accuracy of screw placement to 98 % [19]. A "PediGuard" electrical conductivity device (ECD) is a sufficiently secure mean to form a correct transpedicular canal. Its principle of action is based on impedancemetry, which significantly reduces the risk of dangerous malpositions [28].

The experience and skills of the surgeon are the most important parameters affecting the number of malpositions [7]. For example, the rate of malpositions in correction of deformities may reach 50 % for a young surgeon and no more than 29 % for an experienced surgeon. In this case, the rate of dangerous malpositions is significantly higher for a young surgeon than for a surgeon with 5 years or more experience [12, 30]. To reduce the malposition rate,

Table

The relationship between the screw malposition type and deformity magnitude (according to Cobb), n (%)

Malposition type	Deformity of 20—40 25 patients	Deformity of 40—90° 40 patients	Deformity >90° 8 patients	A total of screws
A	199 (61,2)	347 (57,5)	82 (60,3)	628 (59,0)
B	83 (25,5)	153 (25,3)	27 (19,9)	263 (24,7)
C	28 (8,6)	66 (10,9)	18 (13,2)	112 (10,5)
D	15 (4,7)	38 (6,3)	9 (6,6)	62 (5,8)
A total of screws	325	604	136	1065



Type A malposition (n=628)

Type B malposition (n=263)

Type C malposition (n=112)

Type D malposition (n=62)

Fig.
The relationship between the number of screw malpositions and deformity magnitude

experience in placement of at least 60 screws is required, provided that a young surgeon is skilled in a technique of screw implantation into the vertebrae with normal anatomy [30]. According to other data, placement of 80 transpedicular screws is required to substantially minimize the risk of malpositions [13]. Some authors recommend training of young surgeons for placement of screws in cadavers, noting that the malposition rate after four sessions is reduced to that typical of experienced surgeons [5]. Placement of screws in the thoracic spine should be performed with the greatest caution. In difficult cases, laminectomy should be used to improve visualization of vertebral pedicles, or screws should be implanted through the transverse process [9].

The most vulnerable area for injury by screws in the thoracic spine is the concave side of deformity [7]. Having analyzed the anatomy of the vertebral pedicles in the thoracic spine in 53 patients with scoliosis, the authors divided pedicles into four types, depending on the pedicle bony canal. The type A pedicle (61 %) has a large spongy canal; the type B pedicle (29 %) has a small spongy canal; the type C pedicle (7 %) has a cortical canal; the type D pedicle (3 %) has no canal. Types A and B were found on the convex side of deformity in 98.2 % of cases and on the concave side of deformity in 81.5 % of cases [45].

The accuracy of screw placement is increased when MSCT with 3D reconstruction is used for preoperative planning, which enables more accurate planning of screw implantation sites. Its use in thoracolumbar deformities of 42 78° increases the accuracy of screw placement up to 94.1 % versus 84.5 % in the absence of MSCT with 3D reconstruction [34]. A navigation system makes it possible to avoid malpositions even when the degree of axial rotation amounts to 20° [38]. The use of navigation systems reduces the malposition rate compared to that of conventional techniques. In this case, the use of CT navigation is more preferable than fluoro-navigation [37]; the rate of type B and C malpositions is not more than 5 %, with no need for reoperation [3]. The use of CT navigation improves the accuracy of screw placement up to 96.4 % in children and up to 98.2 % in adults [23]. A study [20] revealed that 95.2 % of screws (out of 37,337 implanted) were placed correctly if navigation was used, while this parameter was 90.3 % without navigation. According to other data, the rate of correctly placed screws is 74.0 % for navigation systems and only 42.0 % for the free-hand technique. The rate of severe malpositions is 3.0% for navigation-assisted surgery and 9.0 % without navigation assistance. The risk of potentially dangerous malpositions is 3.8 times higher in the case of the free-hand technique and 7.6 times higher for medial malpositions [39]. According to other data based on an analysis of 5,992 screws, the use of navigation did not have a statistically significant benefit in terms of prevention of neurovascular complications. The rate of incorrectly placed screws in the case of navigation assistance amounts to 39.8 % [42]. The intraoperative use of the O-arm system increases the accuracy of screw placement up to 97.5 %; however, the rate of malposition was 2.5 %, and repeated surgery was required in 1.8 % of cases [41]. In addition, the technique has a high coefficient of intrarater and interrater agreement [32].

Conclusion

Transpedicular fixation is the method of choice for rapid correction of deformities. However, its use is associated with the risk of neurovascular complications. The most affordable and common technique of screw implantation, free-hand, is fairly safe, but requires the surgeon to be skilled. The introduction of navigation equipment has not reduced substantially the number of malpositions, most of which are minor. The intraoperative use of the O-arm system cannot guarantee 100 % confidence in the accuracy of screw placement. We adhere to the opinion on the efficacy and safety of the free-hand technique for placement of screws in the thoracic and lumbar spine in the case of various multiplanar deformities. However, promotion of this technique is not a specific objective of this publication. At the same time, we believe that transpedicular correction and stabilization are the method of choice in the treatment of spinal deformities because they facilitate successful multiplanar correction.

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Address correspondence to:
Aleksandr Gubin,
Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics,
M. Ul'yanova str., 6, Kurgan, 640014, Russia,
Alexander@gubin.spb.ru

Aleksandr V. Gubin, MD, DMSc; Sergey O. Ryabykh, MD, DMSc; Aleksandr V. Burtsev, MD, PhD, Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics, Kurgan, Russia.