ANALYSIS OF C1, C2 SCREW FIXATION FOR ATLANTOAXIAL INSTABILITY IN PATIENTS OF DIFFERENT AGE GROUPS

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Objective. To analyze feasibility and safety of C1, C2 fixation for craniocervical stabilization in patients of different age groups.

Material and Methods. Study design is a retrospective multicenter cohort analysis. Level of evidence — II. The study was based on the diagnosis and treatment data of 43 patients aged 5—74 years who underwent C1, C2 screw fixation.

Results. In most cases, atlantoaxial instability was due to traumatic injuries. Screws were implanted in C1 in 81 cases, and in C2 in 80. Postoperative MSCT data were evaluated in 41 patients. The position of the screws in C1 was defined as ideal in 63,0 % of cases, in the remaining cases there were malpositions, with 6 screws having double malpositions. Out of 80 screws inserted in C2, 64 were implanted transpedicularly. In 59.5 % of cases, a good position was revealed; in other cases different malpositions were noted. In none of the cases neurovascular damage or clinical manifestation occurred.

Conclusion. Analysis of screw fixation of C1, C2 showed that this technique is feasible in patients of different age groups. Duration of surgery and blood loss did not go beyond the conventional values. Postoperative malpositions are not accompanied by neurological disorders, which allows to consider this fixation quite safe.

Key Words: atlantoaxial instability, screw fixation, C1, C2.

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Craniocervical instability caused by traumatic injury, congenital developmental malformations, tumor, or autoimmune disease is an indication for instrumented stabilization. Unique anatomical structure of the upper neck (C1—C2) increases the potential risks of injury to vascular and nervous structures, especially the vertebral artery, which is often a significant limiting factor in the choice of fixation method [17]. Until recently, various methods of sublaminar fixation were widely used. However, high risk of pseudoarthrosis, up to 86 % of cases, is indicative of its low reliability. The technique of C1—C2 screw fixation developed in the 1990s by Goel et al. [6] and popularized in the early 2000s by Harms [8, 17] significantly improved the effectiveness of stabilization. Nevertheless, widespread use of this technique is limited due to the potential risk of neurovascular injury, especially when inserting screws into C1.

The study was aimed at analyzing the feasibility and safety of C1, C2 craniocervical fixation in different age groups of patients.

Study design: a retrospective multicenter cohort analysis. Level of evidence — II.

Material and Methods

The study was based on the data of the diagnosis and treatment of 43 patients aged 5—74 years, who were operated on at the Russian Scientific Center of Restorative Traumatology and Orthopedics n.a. acad. G.A. Ilizarov (Kurgan), Federal Neurosurgical Center (Novosibirsk), and Ural Clinical and Rehabilitation Center (Nizhny Tagil) and underwent screw fixation of C1, C2.

Inclusion criteria: diagnosed atlantoaxial instability, the presence of a complete radiographic archive.

There were 29 (67.4 %) male and 14 (32.6 %) female patients, whose average age was 41 ± 16 years.

All patients underwent preoperative CT followed by 3D-modeling for preoperative planning. The operation was performed through the posterior medial approach using the free hand technique with intraoperative fluoroscopic control. Screws were inserted into the lateral masses of C1 vertebra through the posterior arch, partly through the posterior arch, or under the arch, depending on the size of the latter. In C2 vertebra, the screws were inserted transpedicularly, into the pars articularis, or translaminarly. In the case of transpedicular placement, the insertion site was located in the upper medial quadrant of the vertebral isthmus. The trajectory was individually selected in each particular case with direct visualization of the inner edge of the vertebral pedicle from the side of the vertebral canal. In our opinion, the method of implantation into the pars articu-

laris is more simple and safe. Insertion site and the trajectory corresponded to the Magerl transarticular insertion method and were located 2–3 mm above the edge of the lower articular process of C2 and to the outside of the boundary of the arch and articular portion of C2 vertebra, 20–30° in the cranial direction and 10° inward. Translaminar screw insertion is the most technically simple and safe one. Insertion site is located on the boundary of the spinous process and the arch. The insertion trajectory was selected in parallel to the opposite side of the arch. When using this implantation method, special attention is paid to determining the presence of the internal wall of the screw channel, which disables intracanal penetration of the screw (Fig. 1). Biplane radiography and CT were performed in the postoperative period to assess screw positions in C1 and C2 according to the previously proposed criteria (Fig. 2, Table). Duration of the operation and blood loss were recorded.

Results

In most cases, atlantoaxial instability was caused by traumatic injuries: at the level of C2 — in 33 (76.7 %) patients, at the level of C1 — in 3 (7.0 %), of os odontoideum — in 3 (7.0 %); caused by atlantoaxial rotatory fixation — in 3 (7.0 %), and by rheumatoid artritis — in 1 (2.3 %).

Duration of the operation varied from 75 to 300 min (on the average, 163 ± 44 min), blood loss was 50–600 ml (on the average, 201 ± 120 ml).

A total of 161 screws were implanted: 81 in C1 and 80 in C2. Post-operative CT images were evaluated in 41 patients. Screw positions in C1 was rated as ideal in 63.0 % of cases (51 screws); in other cases, various malpositions were observed (Fig. 3, 4), including 6 screws with double malpositions. Displacements were attributed to one or another type based on the highest risk level (up and down malpositions are considered as safe from the viewpoint of neurovascular injuries, while in and out malpositions are danger).

In C2 vertebra, 80 screws were evaluated: transpedicular implantation — 64 (80.0 %) screws, insertion into the pars articularis — 10 (12.5 %), and translaminar implantation — 6 (7.5 %). The screws implanted into the pars articularis and inserted translaminarly were located completely within the bone tissue in all cases. Good position was observed in 59.5 % of transpedicular screws implanted in C2 (38 screws); in other cases, various misplacements were observed (Fig. 5, 6).

There were no cases of neurovascular injury or clinical manifestations.

Fig. 1
Variants of screw insertion into C1 and C2 vertebra as shown by X-ray images and CT scans

Discussion

Recent publications show that posterior fixation using screw structures is an effective and indispensable method to treat atlantoaxial instability [12, 18]. Biomechanical studies show high efficacy, especially in controlling rotational movements [7, 13], while high variability in terms of age limits makes this technique quite universal for almost all groups of patients. In this study, the minimum age of patients was 5 years, while, according to the literature [11], insertion of screws into C1 is possible only in 5 % of children under 6 years, and 2 % of children older than 7 years. It should be noted that traumatic injuries are the most common pathologies, accounting for up to 44.1 % of cases [2], whereas this value exceeded 83 % in the current study, which is extremely important in view of increase in injury rate over time.

The data on traumatism and duration of the operation indicate that the values obtained in our study are acceptable as compared to those reported in the literature. Duration of the operation was 75–300 min vs 192–416 min [1], and blood loss was 50–600 ml vs 100–462 ml [1, 24]. However, these data may vary depending on the pathology and anatomical features of C1–C2 vertebrae.

Retrospective analysis of screw fixation of C1–C2 by Harms showed that it is sufficiently safe [5, 21] and results in bone block formation in 100 % of cases [12, 20]. However, the technique is still difficult to reproduce, especially when bone structures are hypoplastic [20]. The position of the vertebral arteries should be carefully assessed [12], since deep position in C2 can be observed in 10–25 % of cases [16], which can significantly increase the risk of its damage, provided that preoperative CT angiography is not a conventional routine examination for planned fixation. Detected

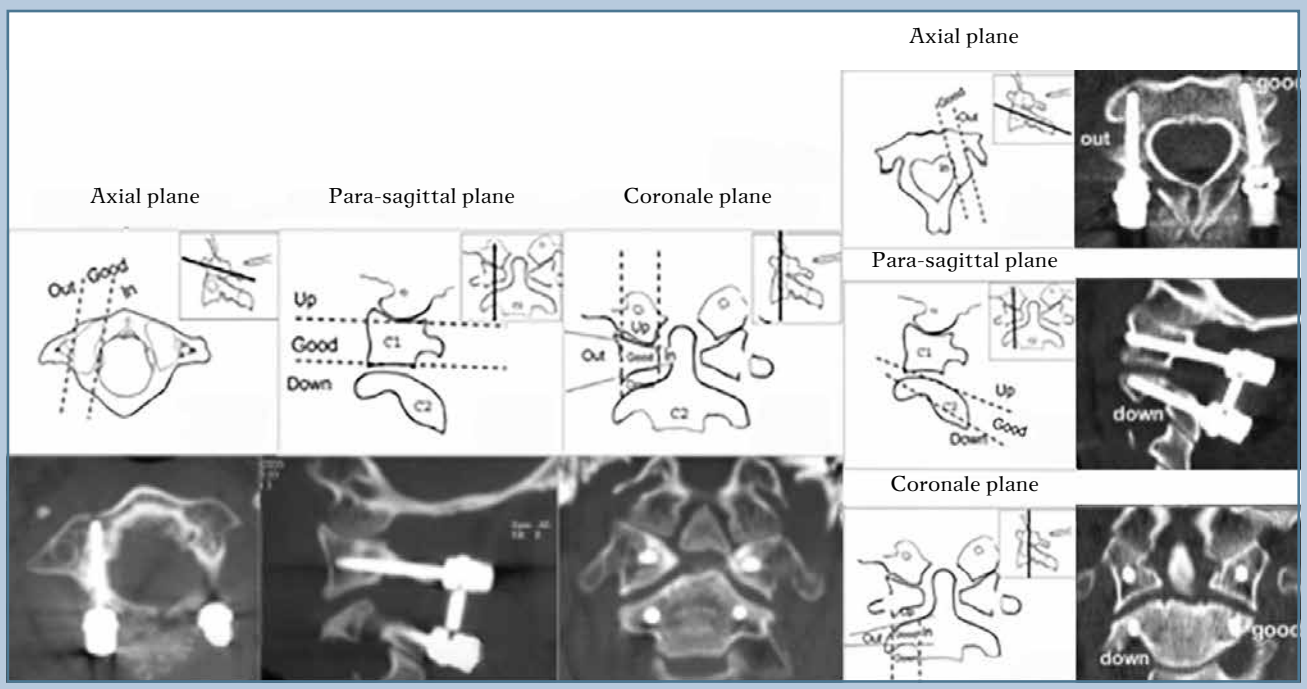

Fig. 2
Criteria for assessing the position of screws inserted into lateral masses of C1; and transpedicularly inserted into C2 [22]

postoperatively screw malpositions to the transverse foramen are not accompanied by neurological disorders, which suggests that this fixation is quite safe [9, 10, 19, 22]. According to meta-analysis, the risk of injury to the vertebral artery during transpedicular screw insertion into C2 is 0.3 % [3, 4]. In the case of high risks, translaminar fixation of C2 can be an acceptable alternative [14, 15, 23]. In this situation, even in the presence of developmental anomaly, the thickness of C2 vertebral pedicle is sufficient for transpedicular fixation in 60 % of cases [21].

In our study, ideal screw position in C1 was found in less than 70 % of cases, in C2 — in less than 60 %. According to the literature data, including significantly higher sampling (196—319 patients), optimal position in C1 was detected in 85.5—95.5 % of cases [9, 22], in C2 — in 92.8 % of cases [22], which is most likely, among other factors, due to surgeons' experience and the number of performed fixations.

Table
Criteria for assessment of screw positions in C1 [9]

Type	Criteria
I (ideal position)	The screw is located completely within the bone without protrusion beyond the cortical layer
II (acceptable position)	No more than 50 % of the diameter is located beyond the cortical layer, protrusion of no more than 1 mm beyond the anterior cortical
III (unacceptable position)	Malposition into the spinal canal or transverse foramen regardless of clinical manifestations

It should be noted that, along with assessment of the effectiveness and safety of this technique, technical aspects are the subject of frequent discussions, especially in the case of C1.

Thus, the following three ways of screw insertion into C1 were suggested: completely through the arch, partly through the arch, or under the arch [22]. Other publications describe various technical tricks to avoid injury to the venous plexus of C1—C2 [20]. These facts indicate that screw fixation according to Harms cannot be regarded as routine stabilization, and careful preoperative evaluation is required in each particular case, when selecting trajectories and methods of screw insertion. At the same time, this technique allows for certain placement errors in implantation.

Conclusion

Analysis of the screw fixation of C1, C2 vertebrae showed that this technique is feasible in various age groups of patients. Duration of the operation and blood loss

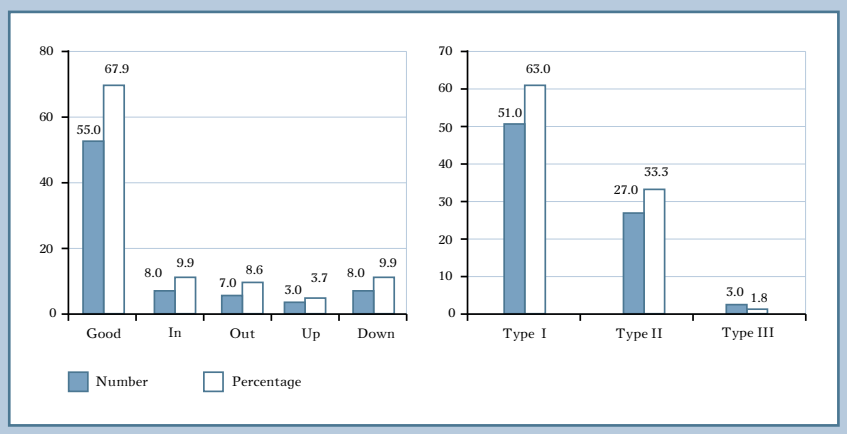

Fig. 3
Screw position in C1 (n = 81)

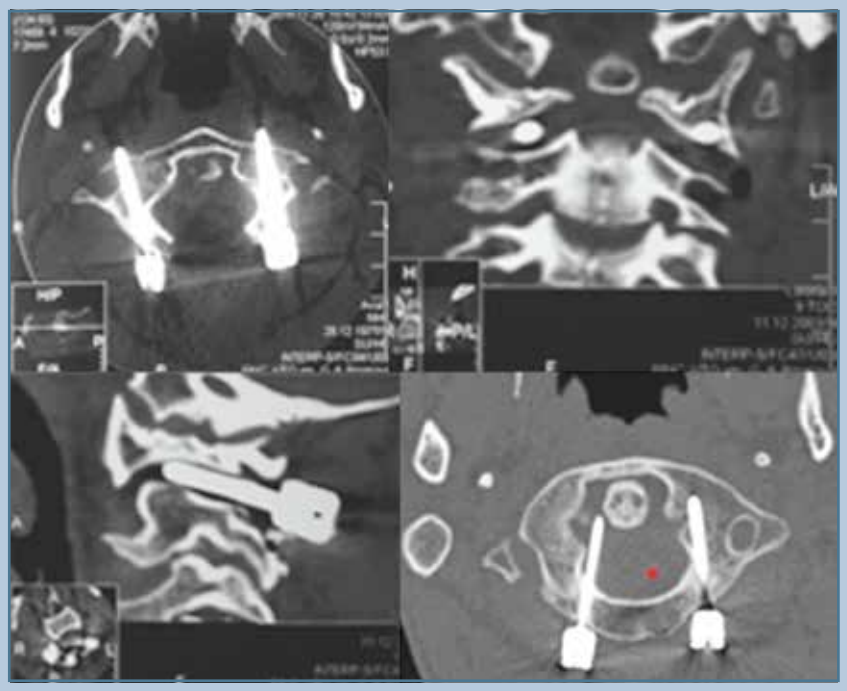

Рис. 4
Variants of screw malpositions in C1 as shown by CT

do not go beyond the conventional values. Relatively high malposition rate and the absence of neurologic symptoms is indicative of safety of this fixation.

The study was not sponsored. The authors declare no conflict of interest.

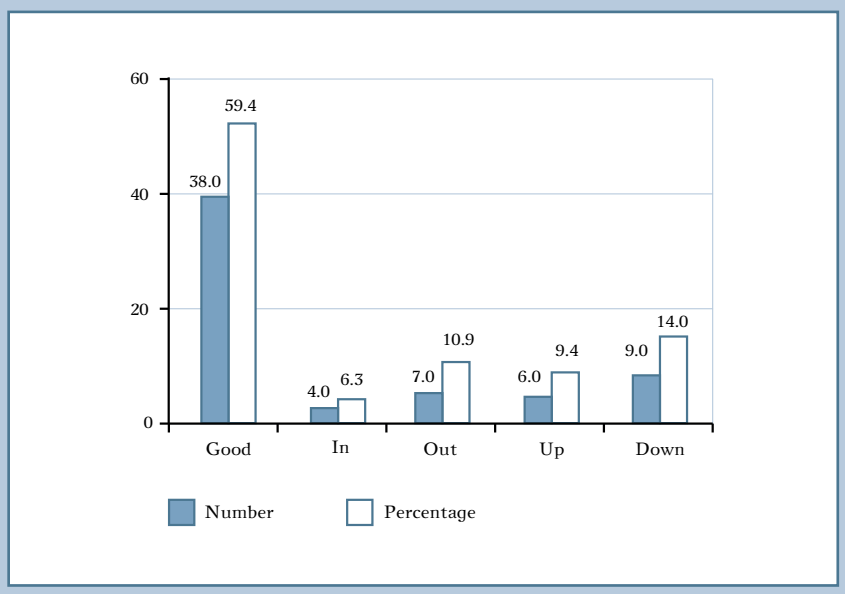

Fig. 5
Transpedicular screw positions in C2 (n = 65)

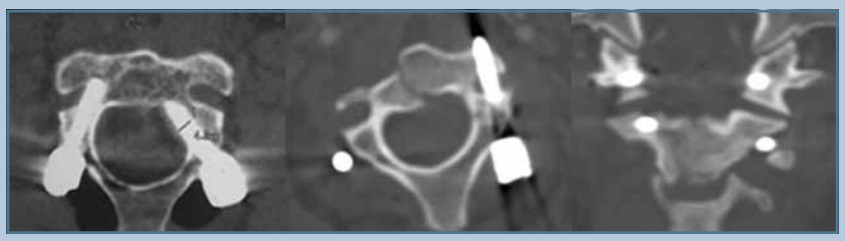

Fig. 6
Variants of screw malpositions in C2 as shown by CT

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