Atlantoaxial fixation using the polyaxial screw–rod system

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Abstract The aim of this study is to evaluate the first results of the atlantoaxial fixation using polyaxial screw–rod system. Twenty-eight patients followed-up 12–29 months (average 17.1 months) were included in this study. The average age was 59.5 years (range 23–89 years). The atlantoaxial fusion was employed in 20 patients for an acute injury to the upper cervical spine, in 1 patient with rheumatoid arthritis for atlantoaxial vertical instability, in 1 patient for C1–C2 osteoarthritis, in 2 patients for malunion of the fractured dens. Temporary fixation was applied in two patients for type III displaced fractures of the dens and in two patients for the atlantoaxial rotatory dislocation. Retrospectively, we evaluated operative time, intraoperative bleeding and the interval of X-ray exposure. The resulting condition was subjectively evaluated by patients. We evaluated also the placement, direction and length of the screws. Fusion or stability in the temporary fixation was evaluated on radiographs taken at 3, 6, 12 weeks and 6 and 12 months after the surgery. As concerns complications, intraoperatively we monitored injury of the nerve structures and the vertebral artery. Monitoring of postoperative complications was focused on delayed healing of the wound, breaking or loosening of screws and development of malunion. Operative time ranged from 35 to 155 min, (average 83 min). Intraoperative blood loss ranged from 50 to 1,500 ml (average 540 ml). The image intensifier was

used for a period of 24 s to 2 min 36 s (average 1 min 6 s). Within the postoperative evaluation, four patients complained of paresthesia in the region innervated by the greater occipital nerve. A total of 56 screws were inserted into C1, their length ranged from 26 to 34 mm (average, 30.8 mm). All screws were positioned correctly in the C1 lateral mass. Another 56 screws were inserted into C2. Their length ranged from 28 to 36 mm (average 31.4 mm). Three screws were malpositioned: one screw perforated the spinal canal and two screws protruded into the vertebral artery canal. C1–C2 stability was achieved in all patients 12 weeks after the surgery. No clinically manifested injury of the vertebral artery or nerve structures was observed in any of these cases. As for postoperative complications, we recorded wound dehiscence in one patient. The Harms C1–C2 fixation is a very effective method of stabilizing the atlantoaxial complex. The possibility of a temporary fixation without damage to the atlantoaxial joints and of reduction after the screws and rods had been inserted is quite unique.

Keywords Atlantoaxial fixation · Spine surgery · Atlantoaxial instability

Introduction

The Harms technique of stabilizing C1–C2 by fixation with polyaxial screws is another option for the atlantoaxial fixation from the posterior approach. This technique was published by Harms and Melcher [15] in 2001. The first of the authors performed this operation for the first time in August 1997. Indications for this operation are identical to the Magerl C1–C2 fixation

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[13, 15–17, 21, 28–30, 32], i.e. acute or chronic atlantoaxial instability and painful arthritis of the atlantoaxial joints. This method is contraindicated only in case of a massive destruction of the lateral masses of the atlas, destruction of epistropheus and a fixed severe anterior dislocation of the atlas. The aim of this study is to evaluate the first results and try to assign the Harms C1–C2 fixation an appropriate standing in the broad range of options for stabilization of the atlantoaxial complex.

Materials and methods

Materials

Between December 2002 and May 2006 we applied at our department the Harms C1–C2 fixation in 43 patients. Six patients were excluded due to the follow-up shorter than 12 months; 28 patients—18 males and 10 females between 23 and 89 years of age (average 59.5 years)—were included in this study and were followed-up longer than 12 months. In 24 patients, we used the Harms technique as a permanent fixation of C1–C2 in order to achieve the atlantoaxial fusion; in 4 cases, we applied it only temporarily for a period of 4–6 months without the use of bone grafts or their substitutions. Permanent fixation was employed in three patients for the acute atlas fracture of type III after Geweihler [9] (unstable Jefferson fracture [18], twice a two-part fracture, once a four-part fracture), in seven patients for the acute IIA type fracture of the dens after Greene et al. [12], in three patients for the acute fracture of C2 categorized as “other” (fracture of the C2 body), in one patient with rheumatoid arthritis for atlantoaxial vertical instability, in one patient for a painful osteoarthritis of C1–C2, in two patients for malunion of the fractured dens, in seven patients for an acute complex trauma to C1–C2 (in all cases fracture of the dens and fracture of the anterior or posterior arch of the atlas). The temporary fixation was used for type III displaced fractures of the dens in two cases [1] and the fixed atlantoaxial rotatory dislocations also in two cases. Only one patient showed signs of Frankel C neurological deficit on admission [6], the rest were without neurological findings.

Methods

All patients underwent radiograph examination in the lateral and transoral projections and CT scan including the sagittal and frontal reconstructions. MRI examination was indicated in 12 patients for suspicion of

soft-tissue injury, particularly of the ligaments of the atlantodental articulation, in case of diagnosis of a potentially unstable lesion. Chronic and some acute instabilities were verified using lateral functional radiographs. Preoperative angiography was performed in one patient. Based on these examinations, patients with an acute or chronic instability or painful atlantoaxial osteoarthritis were indicated for the surgery. Contraindications were mentioned in the introduction. All screws were inserted under an image intensifier always in the lateral projection. First we retracted the greater occipital nerve in a caudal direction towards C2 with a fine raspatory and, using an awl, marked the entry point in the C1 lateral mass. Subsequently, a pilot hole, reaching through the anterior cortical bone, was made with a 2.5 mm drill. In the lateral radiograph projection, the drill was directed to the plane of the anterior arch of the atlas, and in the transversal plane it followed a straight sagittal or slightly convergent trajectory. Individual anatomical variations in the atlantoaxial complex of every patient were respected. As the next step, the hole was tapped through the entire vertebral body, with the exception of osteoporous bone in which only the posterior cortical bone was treated with a screw tap. At this stage, profuse bleeding usually arose from dissection around the epidural venous plexus. This was effectively controlled by a quick insertion of a screw and compression of the venous plexus with the screw head. To control bleeding by bipolar coagulation is difficult and is always associated with a risk of nerve injury. Screws 3.5 mm thick, with polyaxial heads, were inserted into the lateral mass of C1 in such a way to reach through the anterior cortical bone of the atlas. Subsequently, the C2–C3 facet joint was localized and its medial border in the spinal canal was palpated subperiostally using a fine raspatory for a better orientation. The entry point was marked with an awl at the point of intersection at a distance of 2 mm from the medial border and 5 mm from the caudal border of the C2 inferior articular process. Under an image intensifier in the lateral projection, a hole was drilled approximately parallel to the screws inserted in C1, i.e. at an angle of 20°–30° cranially, again up to and through the anterior cortical bone. In the transversal plane, the screws were situated in a convergent direction at an angle of 20°–25°. After all screws had been inserted, we reduced the atlantoaxial complex in the correct anatomical position by manipulating the patient's head or by directly adjusting the screws according to the nature of the dislocation. Connecting 3.0 mm rods were then applied and fastened by cap nuts or inner nuts (according to the instrumentation

Fig. 1 A complex atlantoaxial fracture in a 79-year-old patient: **a** fracture of the dens and of the anterior arch of the atlas with C1 dislocation posteriorly on the lateral preoperative radiograph; **b** the transversal CT section on the level of C1 proves fracture of the anterior arch; **c** condition after reduction and atlantoaxial fixation after Harms on the postoperative lateral radiograph; **d** postoperative transoral projection; **e** screws inserted into the lateral mass of the atlas and pedicles of epistropheus on the CT frontal reconstruction; **f** screws inserted through the pedicles into the C2 body on the transversal C2 section

used) (Fig. 1d). Where the aim of the operation was to achieve a fusion of the atlantoaxial complex, we harvested cancellous bone autografts from the iliac crest and placed them on the posterior arches of C1–C2 in 19 patients. In five cases we replaced the cancellous bone by chronOS (Synthes) synthetic cancellous bone graft substitute. In case the internal fixation was planned as a temporary one, this step was skipped and the hardware was removed 4 or 6 months after the primary surgery. In contrast to Harms and Melcher [15], we did not resect the atlantoaxial joint. In the first 28 patients operated on at our department, we used in 23 cases the Peak Summit (DePuy Acromed), in one case the Spine System Cervical (Aesculap) and in four cases the Vertex (Medtronic) fixation systems. If permitted by their general condition, patients were

allowed to leave the bed as early as on the first day after the surgery, with the cervical spine fixed in the soft Schanz collar for 6–12 weeks. Follow-up in the outpatients department took place at 3, 6, 12 weeks, 6 and 12 months and then once a year. The lateral and transoral radiographs were indicated during hospitalization, 3 weeks after the surgery and then within regular follow-up. Functional radiographs of the cervical spine were taken after 12 weeks.

Evaluation

The whole group of patients was finally checked at the interval of 12–29 months postoperatively with average of 17.1 months. Patients with the interval less than 12 months after the surgery were not included in the

group. Retrospectively we evaluated operative time, intraoperative bleeding and the interval of the use of image intensifier. The final outcome was evaluated both subjectively by patients and objectively. The subjective evaluation was focussed on the pain in the upper cervical spine and the pain in the region of bone graft harvesting. During checks in out-patient department, patients were asked by the surgeon to specify the pain. They evaluated it as severe (permanent use of analgesics, marked limitation of daily routine activities), moderate (occasional use of analgesics, limitation of daily routine activities), mild (without using analgesics, without limitation of daily routine activities) or none. Objective evaluation by means of CT scan covered the placement of the inserted screws, their length and direction. Correctly inserted we considered the screws passing through the C2 pedicle to the anterior cortex of the vertebral body without perforation of the cortex of the pedicle, including the transverse foramen, and in case of C1, the screws inserted through the lateral mass into the anterior cortex of the atlas without perforation of the outer or inner cortex or the transverse foramen. In the fixations combined with bone grafts or their substitute, fusion in the C1–C2 segment was evaluated by means of lateral radiographs taken at 3, 6, 12 weeks and 6 and 12 months after the surgery. The same interval of evaluation was used for the segment stability in temporary fixations. Functional radiographs in flexion and extension were taken in all patients at 12–14 weeks after the surgery in order to evaluate the atlantodental distance and the distance between the C1 posterior arch and C2 spinous process in flexion and extension. Neurological findings we evaluated by the Frankel scale. As concerns complications, intraoperatively we monitored any injury of the nerve structures and the vertebral artery. Monitoring of early postoperative complications was focused on healing of the wound and late complications were monitored in terms of breaking or loosening of screws or development of malunion.

Results

Operative time ranged from 35 to 155 min, with an average of 83 min. Intraoperative blood loss ranged from 50 to 1,500 ml with the average of 540 ml. The image intensifier was used for a period of 24 s to 2 min 36 s, with an average of 1 min 6 s. Within the subjective evaluation, four patients complained of paresthesia in the region innervated by the greater occipital nerve. In three patients the condition significantly improved within 12 weeks, in one patient

paresthesia persisted even 9 months after the surgery. One of 19 patients in which bone grafts were harvested, complained of a mild pain in the region of bone graft harvesting. Pain in the upper cervical spine was reported by three patients, of which two evaluated it as mild and one as moderate. A total of 56 screws were inserted into the atlas, their length ranged from 26 to 34 mm (average 30.8 mm). All screws were positioned correctly in the C1 lateral mass, two screws did not reach up to the anterior cortical bone and one protruded over it (without clinical response). Another 56 screws were inserted into the axis. Their length ranged from 28 to 36 mm with the average of 31.4 mm. Forty-seven screws were applied correctly through the isthmus into the C2 anterior cortex, three screws were too short to reach it, five screws were placed too laterally, i.e. too close to the vertebral artery canal, two of them perforated the artery canal without any clinical consequences. One screw inserted too medially passed into the spinal canal, again without any clinical response. As a result, of the total number of 56 screws inserted into C2, 3 screws were malpositioned, i.e. 5.4%. Bony fusion at C1–C2 was the goal of this operation in 24 patients. Bone bridging noticeable on the lateral radiograph between the posterior arch of the atlas and the arch of the epistropheus was achieved at 6 weeks postoperatively in 4 patients, at 12 weeks in 21 patients and at 6 months in all 24 patients. The functional radiographs taken at 12 weeks after the surgery did not show in flexion and extension any change of the atlantodental interval or in the distance between the C1 posterior arch and C2 spinous process in any of the patients. The C1–C2 segment was stable at 12 weeks in all 28 treated patients. Four patients with a temporary fixation had after removal of the hardware a clinical restriction of motion in rotation by 10–25%, as compared to average values of the healthy population. The C1–C2 alignment achieved surgery was persistent. As concerns intraoperative complications, despite the above-mentioned three malpositioned screws and paresthesias in the region innervated by nervus occipitalis maior, we did not find any injury of the nerve structures or the vertebral artery. In six cases, we recorded profuse bleeding from the venous plexus around the greater occipital nerve, which we treated at first by bipolar coagulation, later by a quick insertion of a screw and tamponing. Early postoperative complications included one wound dehiscence, which we treated by resuture. As concerns late complications, we recorded neither any breakage nor loosening of screws, nor any deep infect.

Discussion

The atlantoaxial fixation can be performed either from the transoral [20], the anterior retropharyngeal [33], the lateral [27] or the posterior approaches [2, 7, 10, 15, 21]. The anterior and lateral approaches are used exceptionally, while the posterior approach dominates. In 1986, Magerl and Seeman [15] published the technique of C1–C2 transarticular fixation by screws the benefits of which as compared to the wiring techniques are frequently described and highlighted in the literature [3–5, 8, 13, 14, 16, 17, 24, 25, 28–30]. The success rate of bony fusion of the posterior wiring techniques ranges around 75–80% [28–30], while with the Magerl technique it is 90% [3, 13, 14, 16, 17, 28, 29]. In 1994, Goel and Laheri [10] published the study of a group of 30 patients who had atlantoaxial instability fixated with screws which were inserted into the lateral mass of the atlas and through the isthmus into the epistropheus connected with a plate. Contrary to the Magerl technique, the Goel method of fixation did not win much recognition. In 2001, Harms and Melcher [15] published the study of a group of 37 patients with the C1–C2 mobile segment stabilized by screws inserted similarly as in the Goel technique [10, 11] but in a much more sophisticated manner. In 2002, Goel et al. [11] published the results of a group of 160 patients operated on between 1988 and 2001 by their own original method. It is noteworthy that both Harms et al. and Goel et al. succeeded in achieving the C1–C2 bony fusion in 100% of cases. In 2002, Resnick and Benzel [26] published a case report of C1–C2 fixation using an internal fixator in an extremely obese patient. They stabilized the atlantoaxial complex by the Vertex fixator (Medtronic Sofamor Danek). Unlike Harms and Melcher [15] and Goel et al. [10, 11], they inserted only 20 mm-long screws which could never reach the anterior cortex, and combined the fixation with the modified Gallie technique using the sublaminar cable. They recommend this technique as an alternative to the Magerl C1–C2 fixation in the case of an anomalous location of the vertebral artery and unfavorable physical condition of the patient. All of the above-mentioned devices may be used as a temporary fixation, without the risk of damage to the atlantoaxial joints. Another advantage is the possibility of reduction after the screws and rods had been inserted. As concerns the greater occipital nerve with venous plexus, Goel et al. [11] recommend to make a sharp dissection of the nerve and control bleeding by means of bipolar coagulation. Harms and Melcher [15] recommend to leave the nerve intact, retract it caudally and control bleeding by means of bipolar coagulation in combination with tamponade.

Goel et al. [11] state that patients tolerate dissection of the nerve quite well. However, a different experience has been expressed by authors in the commentary on the article at the end of report (V. K. Sonntag, P. C. McCormick, M. G. Kaiser). In a biomechanical study on cadavers, Melcher et al. [23] compared the Magerl and Harms C1–C2 fixation techniques. Magerl fixation was combined with the Gallie wiring technique. They have found out that there is no significant difference in terms of stability between the two techniques. The essential issue in all types of C1–C2 fixation with screws is the possible injury of the vertebral artery and the nerve structures. Individual authors report damage of the vertebral artery when using the Magerl technique in 3.7–8.2% of cases [3, 13, 17, 22, 28, 29, 34]. With the insertion of screws after Harms [15] or Goel [10, 11], neither of the two authors has recorded any case of a damage of the vertebral artery or the spinal cord. They ascribe this fact to a better direct visual control of screws being inserted, as compared to the Magerl technique. Using the Harms and Melcher procedure [15] we saved the greater occipital nerve. According to our experiences patients find paresthesia in the innervation area of the greater suboccipital nerve quite annoying. In most patients of our group the complaints subsided spontaneously. In case of persisting paresthesia we extract the fixator after the healing and revise the nerve, if necessary. Of the total of 112 inserted screws, only 3 were assessed as malpositioned (2.7%), however, when related to the 56 screws inserted into C2, this was 5.4%, which indicates that insertion of screws in C2 was more difficult. A relatively high percentage of incorrectly inserted screws into C2 was caused by a complicated anatomical location and the initial lack of experience with the new operating technique. Limitation of the movement after removal of the hardware in four temporary fixation was similar to the direct internal fixation of the dens [31] and half as compared to the permanent C1–C2 fusion [16, 28, 29]. The only more frequent complication, i.e. bleeding from the venous plexus around the greater occipital nerve, we now treat by a prompt insertion of a polyaxial screw into the C1 lateral mass and by tamponade.

Conclusion

The Harms C1–C2 fixation is a very effective method of stabilizing the atlantoaxial complex. It provides the possibility of a temporary fixation without damage to the atlantoaxial joints and of reduction after the screws and rods had been inserted which is quite unique and compensates for the higher price of the implant.

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