Relevance of the cranioaxial angle in the occipitocervical stabilization using an original construct: a retrospective study on 50 patients

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Abstract We present a retrospective study on a series composed of 50 patients, treated between 1992 and 2006, affected by pathologies of the craniocervical junction. All the patients were treated using an innovative procedure based on a cranial claw made up of low profile hooks, conceived by one of the authors. Advantages of this technique are, to our point of view, a higher resistance to cranial hooks dislodgment, when compared with screw fixation instrumentation, especially in pathological conditions, such as rheumatoid arthritis that leads to a qualitative deterioration of the bone stock and to the reduction of the occipital wall thickness. Occipitoaxial alignment was assessed radiographically using the McGregor line. We observed an improvement in the subjective evaluation of pain in all treated patients with a 46% improvement from the initial values. Moreover, patient stabilized with an occipitoaxial angle included in the physiological range showed better results either for the survival of the instrumentation or the onset of junctional pathology. Patients have been followed up afterwards and evaluated by the visual analogue scale for the assessment of pain and by the Nurick scale for the cases associated with myelopathy. We believe that cranial anchorage with a hook claw allows for an instrumentation provided with high stability, particularly useful in revision surgery and major instabilities. The study of the occipitoaxial angles showed that the better results and the long-lasting stability of the implant are correlated to a fusion angle included in the physiological range.

Keywords Occipitoaxial angle · Cranial hook claw · Craniocervical fixation · Occipitocervical instability

Introduction

Numerous pathologies can determine occipitocervical instability. The most common mechanisms can be identified into traumatic lesions, inflammatory diseases, such as rheumatoid arthritis or infectious diseases, neoplasm and congenital deformities. The therapeutical algorithm in these cases follows these steps: identification of the pathological process, correction of the misalignment, decompression and stabilization. The surgical treatment of the craniocervical instability in the last years had a great development. Since Förster [3] first described occipitocervical fusion without instrumentation, surgery of the craniocervical junction made enormous progresses. Numerous instrumentations were proposed in literature, which initially used steel wires to stabilize the metal constructs such as the Luque [2] technique or the derived Ransford loop. These systems required the integrity of the posterior elements, but this condition is not always applicable in case of cord compression. Afterwards, rigid osteosynthesis based on the plates and screws were proposed. Amongst the first, if not the first, Roy-Camille [1] introduced the screw fixation to the facet joints of the cervical spine, opening the way to the extension of the instrumentation to the Occiput. Grob et al. [4] described an upside down Y plate anchored to the midline of the occipital wall, where the bone is thicker and offers the best conditions for fixation.

Every stabilization system in this unique transitional area (occipitocervical junction) must be able to resist loads in the different axis of motion (flexion, extension, lateral

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flexion, rotation, distraction and axial loading), until an arthrodesis is obtained. Moreover, the implant must be structurally gentle enough to integrate itself and in adapting to the fine anatomy of the region. Based on the above original system of fixation was developed, which peculiarity consists in a cranial claw made only of hooks. The stiffness of the implant cannot alone guarantee success and the resolution of the symptoms over a long period. A correct occipitocervical alignment and the restoration, when possible, of the physiological cervical lordosis is, in fact, of great importance. This is one of the crucial steps of the surgical technique, being the craniocervical fusion angle related to the clinical outcome, as in the case of our study.

Materials and methods

We realised a retrospective study on a series of 50 patients, treated in the Spine Surgery Division of the Orthopaedic Clinic of the Catholic University of Rome, between 1992 and 2006, with the use of the craniocervical instrumentation with cranial anchorage by means of hooks, and cervical fixation with screws in the articular masses or sub-laminar hooks. The series consisted of 33 women and 17 men with a mean age of 52 years (21–79 years).

Most common pathology was rheumatoid arthritis (27 cases), following traumas (9), tumours (8), congenital malformations (6). At clinical presentation, the patient exhibited, in the majority of cases, cervical pain, associated or not with myelopathy. Levels fused were C0–C3 in 27 cases, C0–C4 in 6, C0–C5 in 8, C0–C6 in 4, C0–C7 in 5.

Mean follow-up was 3 years, with a maximum of 9 years and a minimum of 1 year. Patients underwent, prior to the operation, standard and flexion–extension radiograms to evaluate craniocervical alignment. Nurick [11] scale was used for assessing myelopathy, while visual analogue scale (VAS) was used to evaluate patient's pain.

In the immediate postoperative, and then again at the predetermined follow-up: at 1 month, 6 months, 1 year, patients underwent plain radiograms. Afterwards, the patients were controlled annually.

Positioning of the patient for surgery was obtained in a standard way: Halo external fixation or Mayfield clamp. To obtain a correct craniocervical angle while instrumenting, the position of the cervical spine was controlled continuously under fluoroscopy. The fixation was realised using the craniocervical metal construct described by Logroscino et al. [6, 7] which offers a stable cranial grip by means of hooks. Cervical anchorage was realised using screws inserted in the articular masses or sub-laminar hooks. For a correct assembly of the implant, cranial hooks must be placed between the dura and the occipital wall. The claw is

then completed by placing the opposite paired hooks directly into the foramen magnum. Proximal hooks should be placed 1.5 cm below the occipital notch and about 2 cm laterally with respect to the median line. Such hooks, having a low profile design, are ideal to be placed in regions with thin-tissue layers, allowing in reducing the risk for pressure sores due to the implant.

Positioning the hooks in the cranial wall is the most delicate step and requires great accuracy to avoid dural leaks or nervous lesions. Distal hooks are inserted directly in the foramen magnum by blunt dissection. The study here proposed is based on the relationship between the clinical outcome and the occipitocervical fusion angle. Occipitocervical angle in healthy adults, measured using the McGregor line, is about 15° in lordosis [9, 14], varying from 5° to 30° depending on the sex and age. Philips et al. [13] evaluated the normal occipitocervical angle in healthy individuals using the McRae and Barnum [10] line, therefore, obtain 44° in lordosis. This method seemed to us less reliable due to the difficulty to identify bony landmarks on the radiograms. For such reason, we used the McGregor line intersected with the tangent line to the C2 end-plate, and then compared the preoperative and postoperative values. The angle so identified between the two lines was defined, according to the literature, positive, with the occiput in retroversion or negative, with the occipital bone in anteversion. The values were acquired by performing three different measurements made by two different physicians and then obtaining the mathematical average of such values.

Results

Of the 50 operated patients; three reported failure of the instrumentation, two of these belonged to the rheumatoid arthritis group, one was affected by post-traumatic instability. We observed the dislodgment of the cranial hooks in two patients, all affected by rheumatoid arthritis. Mobilisations occurred in the first 2 years of follow-up, in no case in the immediate postoperative, and were treated by a limited surgical review. All patients, who underwent the surgical procedure reported in the postoperative pain improvement. Twenty-seven patients with associated myelopathy reported clinical and functional improvement (Table 1) corresponding in the majority of cases to an increase on the Nurick scale of 1 point. We did not observe any worsening of the neurological function following surgery.

The radiographical assessment of the occipitocervical fusion angle was obtained by dividing patients in four groups based on the etiopathology: rheumatoid arthritis, traumas, tumours and craniocervical junction's malformations (Table 1). The 27 patients affected by rheumatoid arthritis

Table 1 Distribution of the pathology, occipitoaxial values, Nurick scale values for the clinical and functional assessment of the myelopathy and visual analogue scale values

Case	Sex	Level	Age	Mobilisation	McGregor		Subaxial subluxation	Steinbrocker	Nurick		VAS	
					Pre	Post			Pre	Post	Pre	Post
Group 1 rheumatoid												
Subgroup a												
1	F	C0–C3	54	N	29+	27+	N	I	1	1	7	3
2	F	C0–C6	72	N	28°+	19°+	N	I	1	1	7	2
3	F	C0–C6	58	N	19.20°+	18.50+	N	I	1	1	5	2
4	F	C0–C7	56	N	22.3+	19.2+	N	I	1	1	6	3
5	M	C0–c4	61	N	28.5+	23.6+	N	I	1	1	7	2
6	F	C0–C6	56	N	20.15+	24.4+	N	II	1	1	6	4
7	F	C0–C3	69	N	15+	8+	S	II	1	1	6	3
8	F	C0–C3	31	N	12.5+	16.7+	N	II	1	1	8	5
9	F	C0–C3	49	N	22.5+	21.7+	N	II	1	1	5	2
10	F	C0–C3	51	N	14.5+	22.4+	N	II	1	1	5	2
11	M	C0–C3	76	N	20.18°+	8.54°+	N	II	2	2	8	5
12	F	C0–C3	72	N	28.3+	20.4+	N	II	2	2	8	2
13	F	C0–C3	69	N	13.5+	16.6+	N	II	1	1	9	4
14	F	C0–C3	66	N	26.5+	12.4+	N	II	2	2	5	2
15	M	C0–C3	79	N	13.5+	14.5+	N	II	1	1	5	2
16	F	C0–C5	56	N	3.4–	4.4–	N	II	1	1	5	3
17	M	C0–C5	45	N	8.21°+	3.25°+	N	II	2	2	8	4
18	M	C0–C3	60	N	20.53°+	6.20°+	N	II	4	3	6	4
19	F	C0–C3	53	N	12.4–	15.5–	S	II	4	3	8	5
20	M	C0–C3	64	N	24.5+	22.6+	N	II	2	2	8	4
21	M	C0–C3	62	N	18.6+	12.6+	N	II	3	3	7	4
Subgroup b												
22	F	C0–C5	66	N	12.6–	5.5–	S	III	3	3	6	3
23	F	C0–C3	49	N	8.7+	7.4–	S	III	4	3	7	3
24	F	C0–C5	53	S	6.7–	13.5–	S	III	2	2	6	4
25	F	C0–C6	52	N	24°+	20.56°+	S	III	4	3	7	3
26	F	C0–C4	69	S	5.5°–	12.5°–	S	IV	3	3	7	4
27	M	C0–C5	59	N	15.5–	7.7–	S	IV	3	3	7	3
Group 2: post-traumatic instability												
1	M	C0–C4	35	N	16.3+	24.4+	N		2	1	3	1
2	F	C0–C3	24	N	12.3+	12.6+	N		1	1	4	2
3	F	C0–C3	50	N	13.5–	11.5+	N		1	1	5	3
4	F	C0–C7	23	N	5.65°+	17.36°+	N		5	5	6	3
5	M	C0–C3	23	N	20.20°+	5.5°+	N		1	1	4	4
6	F	C0–C3	21	S	4.4+	18.4+	N		1	1	7	3
7	F	C0–C5	28	N	17.1+	16.2+	N		4	3	3	3
8	F	C0–C3	71	N	18.5+	19.7+	N		1	1	5	3
9	M	C0–C7	32	N	7.7–	12.1+	N		3	2	4	4
Group 3: tumoral instability												
1	F	C0–C3	61	N	12.6+	7.5+	N		1	1	6	2
2	M	C0–C4	58	N	18.4+	11.9+	N		1	1	7	3
3	F	C0–C3	55	N	18.57°+	7.62°+	N		2	1	4	4
4	F	C0–C4	63	N	25.69°+	10.93°+	N		5	4	6	2
5	F	C0–C3	45	N	8.64°+	5.40°+	N		1	1	7	2

Table 1 continued

Case	Sex	Level	Age	Mobilisation	McGregor		Subaxial subluxation	Steinbrocker	Nurick		VAS	
					Pre	Post			Pre	Post	Pre	Post
6	F	C0–C3	47	N	32.70°+	14.90°+	N		5	4	7	3
7	M	C0–C4	55	N	38+	27.4+	N		1	1	5	3
8	M	C0–C5	72	N	10.4+	32+	N		3	1	5	3
Group 4: congenital deformity instability												
1	F	C0–C7	41	N	42.2+	38.4+	N		1	1	3	2
2	M	C0–C7	21	N	30.5+	27.4+	N		2	2	3	2
3	F	C0–C3	39	N	12.5–	9.6+	N		2	2	8	7
4	M	C0–C3	48	N	34.4+	29.3+	N		3	3	8	5
5	F	C0–C3	39	N	6.6–	12–	N		5	4	9	8
6	M	C0–C5	57	N	16.2+	12.3+	N		4	4	5	3

showed an occipitocervical angle that was normal in 21 cases and negative in 6 cases. Patients were fused in the most physiological position trying to restore a normal occipito-axial alignment. In these cases, we can distinguish two subgroups based on the progression of the disease. In patients corresponding to stages I–II of rheumatoid arthritis (Steinbrocker classification [15]), we observed an important and long-lasting symptoms remission, together with a low percentage of subaxial subluxation (2 cases) in those patients who were fused in the physiological range (Table 1). Six patients who were in the stages III–IV of the disease developed a subaxial subluxation, which required surgical revision and distal lengthening of the construct. Of these six patients, five were stabilized in occipital anteversion and one case in retroversion. The two cases of mobilisation observed in the rheumatoid group belonged to this subgroup. Pain improvement in this group was good with a 52% decrease of the Vas value (preoperatively Vas average 6.6 points, reduced to 3.2 points postoperatively). Patients affected by post-traumatic deformities were surgically treated because of the severe instability at C0–C1–C2 levels (Fig. 1). Two of these patients also had signs of post-

traumatic myelopathy caused by subaxial cervical fractures. Patients in this group were fused in the physiological range, and they had pain improvement after surgery in the totality of the cases. In no case was observed junctional pathology under the treated levels. In this group, the Vas value improved to 37%, decreasing from an average of 4.6 points in the preoperative, to an average of 2.9 points in the postoperative. Patients with tumours required the most complex surgical treatment. In six cases, a double surgical approach was necessary, being the anterior decompressive resection of the tumoral mass associated with the posterior stabilization. Two of these cases required trans-oral decompression for tumoral localisation into the axis, while other two patients underwent trans-mandibulo-lingual approach to a wider tumoral lesion [6]. All the treated patients in this group reported an improvement in pain with a change in the Vas value of 53% from a preoperative average of 5.9 points that decreased to 2.7 in the postoperative. The group affected by congenital deformities of the occipitoaxial junction showed a more limited improvement of 25% in the Vas value, being the average Vas value 6 in the preoperative and 4.5 in the postoperative.

Fig. 1 Patient affected by severe post-traumatic deformity and instability with coronal disalignment. Patient came to our attention a year after trauma with severe pain, neurologically intact. She was fused in a correct occipitoaxial alignment (+27°) and showed 3 years after, at follow-up, good clinical and radiographic outcome

Discussion

In this paper, we present the results obtained with the craniocervical fixation performed using as cranial anchorage a couple of opposite paired hooks. This method, to our point of view, has intrinsic advantages consisting of a greater resistance to pull-out when compared with screw fixation, occurrence described mostly in those cases fixed in anteversion of the occiput. This metal implant allowed us to obtain a good percentage of fusion evaluated as radiographically significant fusion or as survival of the instrumentation. Three patients, 6% of the sample, reported mobilisation of the implant. Dislodgment of the cranial hooks was observed in two patients affected by rheumatoid arthritis. In one of these, the mobilisation of the cervical instrumentation was also observed. Such result is certainly attributable to the poor bone quality, but to our point of view, the wrong segmental biomechanics due to a fixation of the occiput in anteversion, is a significant factor for a potential failure of the instrumentation. In one case, we observed the isolated mobilisation of the facet joint's screws in a patient belonging to the group of the post-traumatic instabilities, secondary to a new cervical trauma in flexion.

The study of the occipitoaxial angle was carried out using plain radiograph in the lateral view, before and after surgery as well as in the follow-up. We have chosen to use the McGregor line for its sensitivity and interobserver reproducibility [14]. In literature, there are many reports evaluating the occipitoaxial angle and its relation to the clinical outcome, but many of this papers are not comparable because of the different methods of investigation used [10, 13]. Regarding the objective evaluation of the patient, the Nurick scale was used, while for the subjective evaluation of pain, and its modification after surgery, the visual analogue scale was used. In our series, the average pain improvement was 46% and, even if such result is based on a non-homogeneous series, as far as etiology concerns, it shows the good success of the stabilization and the optimal tolerance of the instrumentation from the patients. The incidence of subaxial subluxation was low, corresponding to the 17% of the treated patients. If we consider, however, that such occurrence was reported just in the group of patients affected by rheumatoid arthritis, this value raises to 30% and it is in concordance with the literature [5, 8]. The absence of this complication in tumoral pathology is probably related to the limited survival period of these patients which generally does not allow for a long follow-up. Regarding the patients with compressive myelopathy, it is possible that a lower functional demand, due to neurological deterioration, would be sufficient to avoid the involvement of the subaxial segments. As reported in the literature, one of the most common late complication of rheumatoid arthritis is the subaxial subluxation. Oda et al.

[12] believe that the subluxation of segments adjacent the instrumentation is probably related to the progression on the inflammatory disease. Matsunaga et al. [9] believes, instead, that such complication is more likely to be present in those patients stabilized with an angle out of the physiological range and, therefore, exposed to excessive shear forces; thus, the expression of a great biomechanical disorder. Several reports exist about the significance of rheumatoid arthritis in the pathogenesis of atloaxial and subaxial instability. Matsunaga et al. [8] reported an incidence of subluxation of 34% on a series of patients affected by rheumatoid arthritis in advanced disease. Kraus et al. [5] reported an incidence of 36% in a similar series.

It is interesting to note that, in our series, patients fused with angular values included in the normality range or with a slight gain of the occipitoaxial angle, reported the best clinical results and the lower percentage of complication over the long period. We agree, in fact, with Matsunaga about the importance of the occipitocervical angle in relation to the biomechanics of the cervical spine, which lack of balance, or its not correct restoration, might lead to secondary disalignment or to junctional complications adjacent to the instrumentation.

Conclusions

Occipitocervical fixation represents an extremely effective treatment for the neurological stabilization and for the symptomatic recovery of those patients affected by pathologies of the craniocervical junction. We believe that the use of a cranial claw made of hooks gives a better stability to the implant and it is, particularly, indicated in cases of major instabilities such as neoplastic instabilities or in those patients affected by pathologies such as rheumatoid arthritis, which considerably alter the bone quality. This condition can easily lead, when instrumented by screw fixation, to pull-out complications and secondary loss of stability and onset of deformities.

We also believe that the long distance result, regarding the stability of the implant and the absence of secondary deformities, is closely related to the correct alignment of the instrumentation, especially to an occipitoaxial angle as close as possible to the physiological values.

Conflict of interest statement None of the authors has any potential conflict of interest.

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