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ARTICLE

Reliability and safety of a new upper cervical spine injury treatment algorithm

Avaliação de reprodutibilidade e segurança de um novo algoritmo de tratamento das lesões cervicais altas

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ABSTRACT

In the present study, we evaluated the reliability and safety of a new upper cervical spine injury treatment algorithm to help in the selection of the best treatment modality for these injuries. **Methods:** Thirty cases, previously treated according to the new algorithm, were presented to four spine surgeons who were questioned about their personal suggestion for treatment, and the treatment suggested according to the application of the algorithm. After four weeks, the same questions were asked again to evaluate reliability (intra- and inter-observer) using the Kappa index. **Results:** The reliability of the treatment suggested by applying the algorithm was superior to the reliability of the surgeons' personal suggestion for treatment. When applying the upper cervical spine injury treatment algorithm, an agreement with the treatment actually performed was obtained in more than 89% of the cases. **Conclusion:** The system is safe and reliable for treating traumatic upper cervical spine injuries. The algorithm can be used to help surgeons in the decision between conservative versus surgical treatment of these injuries.

Keywords: spinal injuries; spinal cord injuries; therapeutics; classification.

RESUMO

Avaliamos a reprodutibilidade e segurança do algoritmo Upper Cervical Spine Injuries Treatment Algorithm (UCITA) recém proposto para a escolha do tratamento das lesões traumáticas da junção crânio-cervical. **Métodos:** Trinta casos previamente tratados de acordo com o algoritmo foram apresentados a quatro cirurgiões de coluna, sendo questionada a conduta pessoal dos mesmos e a conduta segundo a aplicação do algoritmo. Após 4 semanas, foram refeitas as mesmas perguntas para avaliar a reprodutibilidade (intra e interobservador) do algoritmo, através do índice estatístico "Kappa". **Resultados:** A reprodutibilidade da conduta com o uso do algoritmo foi superior a reprodutibilidade da conduta pessoal dos cirurgiões. Com o uso do UCITA, a concordância do tratamento realmente efetivado foi encontrada em mais de 89% dos casos. **Conclusão:** O uso do UCITA foi seguro e reprodutível, podendo ser usado como ferramenta auxiliar na tomada de decisão entre tratamento cirúrgico versus conservador dos traumatismos da junção craniocervical.

Palavras-chave: traumatismos da coluna vertebral; traumatismos da medula espinal; terapêutica; classificação.

Upper cervical spine injuries are the most severe traumatic lesions that affect the spine, and are potentially associated with tetraplegia, respiratory dysfunction and even sudden death[1,2,3,4]. These include injuries that may affect the occipital condyles, the atlas and the axis, as well as their adjacent ligamentous and facet joints. The stability of most of this region relies on powerful and complex ligamentous support, which allows the majority of cervical rotation (especially in the atlanto-axial joints) and flexion-extension (especially between the occipital condyles and the lateral masses of the atlas)[5,6].

Treatment goals are relatively well established and include: 1) maintenance or restoration of spinal stability, 2) protection and/or decompression of the spinal cord, 3) correction or avoidance of progressive spinal deformities. In the last few years, many new surgical techniques and spinal instrumentation systems have been developed, providing immediate stability with selective fusion of the involved levels[3,7,8].

However, due to the complexity of its anatomy and a multitude of possible injury patterns that affects this region, many classification schemes have been proposed for upper cervical spine injuries in the past decades, precluding an objective and standardized treatment. This context may result in heterogeneous treatment and complex classifications, sometimes not easily applied in the decision-making process of

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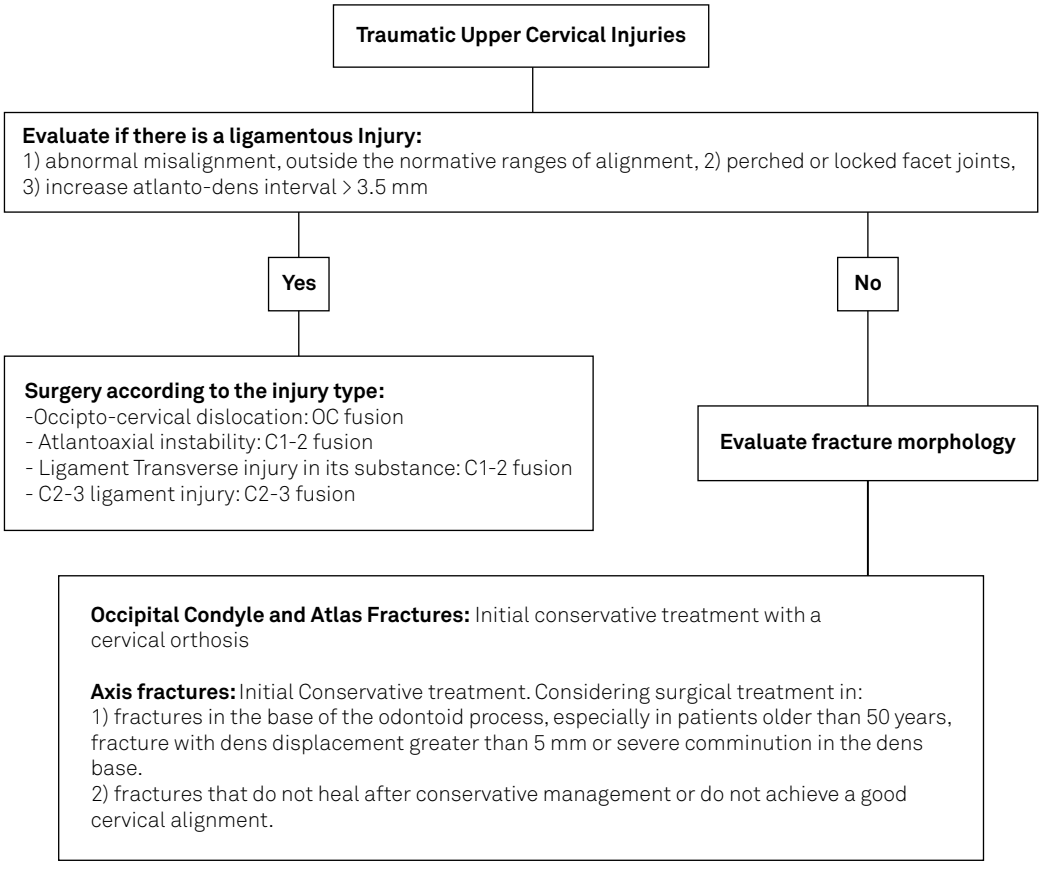
conservative versus surgical treatment[9]. Among numerous schemes some deserve attention, such as the Anderson and D'Alonzo classification, published in 1974, for odontoid fractures, the Effendi et al.[2] and the Levine and Edwards classification for injuries of the posterior elements of the axis, the Anderson and Montesano classification for occipital condyle fractures, among many others[1,4,10]. Most of them are complex, which may result in different classifications for the same specific injury pattern, as well as different treatment modalities. Also important is that the majority of these systems were proposed in the era of plain radiographs, without the details of recent 3D CT reconstructions that may display these injuries with higher sensitivity and specificity. In some cases, where soft tissue injuries cannot clearly be identified using CT imaging, an MRI provides additional information about the spinal cord and nerve roots, even though this information is not included in the vast majority of the classical classification systems[3,9].

In this scenario, a unified and simplified classification system for upper cervical spine injuries became necessary. In 2014, Joaquim et al.[9] proposed a new upper cervical spine injury treatment algorithm for choosing between conservative and surgical treatment for upper cervical spine injuries, based on a literature review of the accepted surgical indications for traumatic injuries of the upper cervical spine and craniovertebral junction. The idea of this new system is to classify injuries according to: 1) integrity of their ligamentous injuries – disrupted ligaments (with or without fractures) may preferentially be treated with surgical fixation due to their high risk of instability and neurological deterioration; and 2) isolated fractures, which should be managed conservatively, with surgery reserved for those who have had a high rate of non-healing or failure of conservative treatment (with deformity, misalignment or neurological risk). An adapted version of the algorithm is presented in the Figure.

However, although promising, this proposed algorithm requires further validation. The main goals of this study were to evaluate the reproducibility and the safety of this new algorithm in supporting surgeons to choose between conservative versus surgical treatment of upper cervical spine injuries.

METHODS

Thirty cases, previously treated according to the new algorithm, were presented to four spine surgeons. Of the 30 cases included in our study, 19 were treated conservatively, achieving good bone healing and also maintaining normal cervical alignment, whereas 11 were referred for surgical fixation according to the upper cervical spine injury treatment



OCD: Occipto-cervical dislocation; OC: Occipto-cervical; AA: Atlanto-axial Instabilit; LT: Transverse Ligament.
Figure. Adapted algorithm from Joaquim et al.[9], for treatment of upper cervical spine injuries.

algorithm applied by one of the authors. There were 23 men (76.7%) and seven women (23.3%) in this series. Ages ranged from 16 to 77 years (mean 38.4, median 37, SD ± 14.41 years). The mean follow up was 13.5 months (ranging from three to 36 months, with a median of 10.5, SD ± 11.2 months). The mean follow up was 21 months in the surgical group compared with 9.1 months in the group managed conservatively.

After institutional review board approval (CAAE: 53542416.2.0000.0065), the algorithm description was presented by one of the authors to four spine surgeons with expertise in the management of spinal cord injuries. All four evaluators were board-certified neurosurgeons. After that, 30 consecutive cases (> 16 years old) of upper cervical spine injuries, treated by one of the authors, were presented digitally with high resolution images, with age and neurological status (assessed on the *American Spine Injury Association Impairment Scale – AIS*), to the four surgeons (RSB, VMPG, LHS, MAT). These patients had been treated according to the algorithm and the treatment was blinded to the four evaluators. All the patients were followed up after hospital discharge by the same surgeon (AFJ) with routine radiological and clinical follow up (two weeks, one month, three months and then every six months after hospital discharge, with dynamic plain radiographs and CT scans when necessary). A successful conservative treatment was considered when there was evident bone healing and a good cervical alignment on post-injury images at least three months after the trauma, without incapacitating local pain.

The evaluators were questioned about: 1) the specific diagnosis of the upper cervical spine injury (injury classification according to the evaluator's preference), 2) their personal treatment proposal (conservative versus surgical), based on their own clinical experience, and 3) management option according to the application of the algorithm, with a total of three answers for each patient. After four weeks, the same questions were presented again. Both intra- and inter-observer agreements were assessed using the kappa coefficient (Table 1), calculated with the STATA software for Windows®, version 13.

In order to evaluate safety, we compared the actual treatment for the 30 patients with the treatment proposed by the each of the evaluators.

RESULTS

General results

The mechanisms of the injuries were as a result of 24 patients (80%) being involved in motor vehicle accidents, five (16.7%) falling from a height and one diving into shallow water (3.3%). One patient, with an odontoid fracture in the dens base, without risk factors for nonunion, was initially conservatively managed, but then required late surgery for nonhealing (three months) and mild persistent cervical pain and was, therefore, included in the surgical group. In 19 patients treated conservatively, all were AIS E at the index level (except for one patient with a concomitant thoracic fracture and AIS A at T3). Of the 11 patients who underwent surgical treatment, seven were AIS E and four were AIS C by the time surgical treatment was indicated. Posterior atlanto-axial fusion was performed in seven patients, two patients had an occipito-C2-3 fusion, one had an anterior C2-3 fixation and fusion and one had a C1-2-3 instrumented fusion. The clinical data of all patients included in this study are summarized in Table 2 (conservative treatment) and Table 3 (surgical treatment). No patient had additional surgery for local pain or severe disability during the follow up.

Classification systems used for the evaluators to guide treatment of upper cervical spine injuries

To describe injury characteristics in the first and in the second evaluation, the evaluators used a total of ten classifications systems/eponyms for upper cervical spine injuries, as shown in Table 4.

Evaluation of reliability

Intra-observer analysis

Table 5 shows the results of intra-observer reliability assessed for treatment proposal in each round, and suggested treatment according to the algorithm.

Table 6 shows the results of intra-observer reliability assessed for treatment according to the application of the algorithm, and the treatment actually performed.

Inter-observer analysis

Table 7 shows the inter-observer reliability, assessed for personal treatment option and for the treatment proposed by the application of the algorithm.

Validity

Table 8 shows the agreement rates according to three variables: 1) treatment proposal by the evaluator and the application of the algorithm, 2) application of the algorithm and treatment actually performed and 3) treatment proposal by the evaluator and the treatment actually performed.

Of the 34 answers where there was disagreement between the treatment suggestion by the evaluator and the application of the algorithm, 20 (58.8%) occurred in odontoid fractures, attesting to the controversies in the management of these injuries.

Table 1. Kappa values according the Landis and Koch grading system[15].

K value	Agreement
< 0.20	Slight
0.21–0.40	Fair
0.41–0.60	Moderate
0.61–0.80	Substantial
0.81–1.00	Excellent

Table 2. Summary of 19 patients treated conservatively.

Case	Age	Injury description	Etiology	AIS - Observations
1	21	Linear fracture of C2 body	Dive in shallow water	AIS E
2	58	Fracture of the anterior arch of C1 and also a linear fracture of C2 body	MVA	AIS E
3	28	Linear fracture of the posterior elements of C2 without displacement	MVA	AIS E
4	33	Linear fracture of the posterior elements of C2	MVA	AIS E AIS A - thoracic level (T3 fracture)
5	38	Fracture of the dens base without displacement	MVA	AIS E
6	60	Fracture of the body of C2	Fall from a height	AIS E
7	38	Fracture of the body of C2	MVA	AIS E
8	38	Fracture of the dens base	MVA	AIS E
9	26	Linear right side condyle fracture	MVA	AIS E
10	37	Fracture of both anterior and posterior arches of C1	MVA	AIS E
11	44	Linear fracture of the posterior elements of C2	MVA	AIS E
12	17	Fracture of the body of C2	MVA	AIS E
13	35	Fracture of the anterior arch of C1	Fall from the height	AIS E
14	43	Linear fracture of the body of C2	MVA	AIS E
15	36	Fracture of the posterior elements of C2 and mild increase of the angulation of C2 over C3	MVA	AIS E
16	43	Fracture of the body of C2 involving the left C12 joint but without any displacement	MVA	AIS E
17	48	Linear left side occipital condyle fracture without displacement of the facet joints	MVA	AIS E
18	59	Linear fracture of the posterior arch of C1 without displacement	MVA	AIS E
19	45	Linear fracture of the posterior elements of C2 without displacement	MVA	AIS E

AIS: American Spine Injury Association Impairment Scale, MVA: motor vehicle accidents.

Table 3. Summary of 11 patients operated on.

Case	Age	Injury Description	Etiology	AIS - Observations
1	35	Fracture of the dens base	MVA	AIS E Posterior C12 fixation Heavy smoker Failure of conservative treatment due to pseudoarthrosis
2	60	Fracture of the dens base	MVA	AIS E Posterior C12 fixation
3	45	Fracture of the posterior elements of C2 with unilateral subluxation C23	Fall from the roof	AIS E Anterior C23 fixation
4	16	Fracture of the odontoid and C12 luxation	MVA	AIS C Posterior C12 fixation
5	31	Fracture of the base of the dens with dens luxation anteriorly	MVA	AIS E Posterior C12 fixation Wound infection requiring antibiotics
6	37	Fracture of C1 and C2 and C12 subluxation C2 fracture in the dens base	MVA	AIS E Posterior C123 fixation AIS E
7	37	Fracture of C1 lateral mass and unilateral subluxation of C12 and condyle-C1	MVA	AIS E Occipito-C23 Fixation
8	16	C12 luxation and fracture of the dens base	MVA	AIS C Last follow up AIS E Posterior C12 fixation
9	77	Fracture of the dens with its displacement posteriorly	Fall from a height	AIS E Posterior C12 fixation
10	20	Occipital C1-2 distraction	MVA	AIS C Last follow up AIS D Posterior occipital C23 fixation
11	31	C12 luxation	Fall from a height	AIS C Last follow up AIS D Posterior C12 fixation

AIS: American Spine Injury Association Impairment Scale, MVA: motor vehicle accidents.

Table 4. Most-used systems for treatment of upper cervical spine injuries (note: some injuries were classified more than once).

Classification	N (first evaluation)	N (second evaluation)	Total
Anderson and D'Alonzo[1] (for fractures of the axis)	45	41	86
Primary injury description	27	36	63
Levine and Edwards[11] (for posterior elements of the axis fractures)	16	17	33
Benzel et al.[16] (for axis body fractures)	8	8	16
Grauer et al.[14] (for odontoid fractures)	7	9	16
Fujimura et al.[17] (for axis body fractures)	6	8	14
Anderson and Montesano[10] (for occipital condyle injuries)	5	1	6
"Jefferson" fracture[12,13] (for atlas injuries)	4	4	8
Fielding and Hawkings classification[18] (for atlanto-axial instability)	4	4	8
Tuli et al.[19] (for occipital condyles)	4	3	7
"Hangman's fractures"[11] (for posterior elements of C2)	3	0	3

Table 5. Intra-observer reliability assessment of each evaluator according to personal treatment proposal and the treatment suggested by the algorithm.

Evaluator	Kappa – first evaluation	Kappa – second evaluation
1st	0.4828 (Moderate)	0.6667 (Substantial)
2nd	0.7964 (Substantial)	0.6637 (Substantial)
3rd	0.9333 (Excellent)	0.7183 (Substantial)
4th	0.7945 (Substantial)	0.6666 (Substantial)

Table 6. Intra-observer reliability assessment of each evaluator according to treatment proposed by the application of the algorithm and the treatment actually performed

Evaluator	Kappa – first evaluation	Kappa – second evaluation
1st	0.6193 (Substantial)	0.6479 (Substantial)
2nd	0.8565 (Excellent)	0.7235 (Substantial)
3rd	0.7964 (Substantial)	0.8507 (Excellent)
4th	0.9296 (Excellent)	0.7333 (Substantial)

Table 7. Reliability assessment of treatment proposal by the evaluator and the treatment proposed by the application of the algorithm.

Evaluation	Kappa – personal treatment proposal	Kappa – treatment proposed by the algorithm
1st	0.5996 (Moderate)	0.6326 (Substantial)
2nd	0.4661 (Moderate)	0.5378 (Moderate)
1st and 2nd rounds together	0.5662 (Moderate)	0.6292 (Substantial)

Table 8. Evaluation of the agreement rates according to three variables: 1) treatment proposal by the evaluator and the application of the algorithm, 2) application of the algorithm and treatment actually performed and 3) treatment proposal by the evaluator and the treatment actually performed.

Evaluator	Agreement of treatment proposal by the evaluator and the application of the algorithm	Application of the algorithm and treatment performed	Treatment proposal by the evaluator and treatment performed
1st Round			
1st	22/30 (73.33%)	26/30 (86.67%)	23/30 (76.67%)
2nd	27/30 (90%)	27/30 (90%)	27/30 (90%)
3rd	27/30 (90%)	29/30 (96.67%)	28/30 (93.33%)
4th	29/30 (96.67%)	27/30 (90%)	26/30 (86.67%)
2nd Round			
1st	25/30 (83.33%)	25/30 (83.33%)	24/30 (80%)
2nd	25/30 (83.33%)	26/30 (86.67%)	25/30 (83.33%)
3rd	25/30 (83.33%)	26/30 (86.67%)	26/30 (86.67%)
4th	26/30 (86.67%)	28/30 (93.33%)	24/30 (80%)
TOTAL	206/240 (85.83%)	214/240 (89.16%)	203/240 (84.5%)

DISCUSSION

In 2014, the upper cervical spine injury treatment algorithm used in our study based on a literature review and expert opinion was published. The algorithm, divided upper cervical spine injuries into ligamentous injuries (with or without concomitant fractures) and isolated fractures, in an attempt to guide toward the best treatment option[9]. In 2015, preliminary results of a cohort of patients with upper cervical spine injuries, treated according to this rational treatment guide, was published, with 23 patients treated conservatively and 15 surgically managed. During the follow up, the authors reported that there was no neurological worsening and patients with incomplete deficits had some improvement[3]. However, evaluation of the reliability and validity of this system has not been performed since its publication.

In the present series, the majority of the patients were men (76.7%), mostly with injuries secondary to motor vehicle accidents (80%). All patients treated conservatively were neurologically intact (19/19 – 100%). However, four in the surgical group (4/11 – 36.36%) had incomplete deficits. Although neurological deficits are not criteria for instability, they may be associated with more severe injuries that potentially would require surgical treatment.

As noted, a wide range of different classification systems were used by the four spine surgeons, even for similar injury patterns, such as axis fractures. Additionally, we observed that the injury description by itself, or classic eponyms (such as "Jefferson's" or "Hangman's" fractures), were used to describe upper cervical spine injuries, suggesting a heterogeneous classification and potentially difficult comparison of treatment modalities[2,11,12,13].

The evaluators' treatment options had substantial agreement with the treatment suggested by the application of the algorithm in the majority of the cases (with a substantial kappa value obtained in six of eight comparisons, and moderate and excellent in one comparison each, as shown in Table 5). However, when intra-observer reliability was assessed for the treatment suggested by the application of the algorithm and the actual treatment performed, we obtained an even higher kappa value (a substantial kappa value was obtained in five of eight comparisons and an excellent kappa value in three of eight comparisons, as shown in Table 6). Therefore, the use of a global and more uniform system improves classification reproducibility.

Finally, the inter-observer reliability for the application of the algorithm was substantial (0.63) compared with moderate (0.57) reliability for the evaluators' personal treatment option. Based on this, we infer that the system is more reliable than the surgeon's own opinion about the treatment proposed.

When evaluating safety, we obtained a higher rate of agreement between the application of the algorithm and the treatment actually performed, ranging from 83.3% to 93.3%, as shown in Table 8. This suggested that the use of this new system was reliable and safe. Of note, in the 240 evaluations, 20 (58.8%) of the 34 answers where there was disagreement between the personal treatment option and the algorithm refer to odontoid fracture management. Management of odontoid fractures is controversial, especially for fractures in the dens base, classified according to Anderson and D'Alonzo as type 2[7,14]. These injuries had a higher rate of pseudoarthrosis, especially when risk factors for nonunion are present[7]. However, even in the absence of these risk factors, surgical treatment is acceptable. As a consequence, we proposed in our final version of the algorithm that odontoid fractures in the dens base may be treated surgically or conservatively, despite the risk factors for nonunion, based on the surgeon's preference and patient's characteristics (preference, comorbidities, age, etc.), until further evidence for the best treatment option of these injuries is available.

Limitations of the study

The retrospective application of the algorithm, with limited information, may result in potential bias for a treatment decision. Additionally, it is a guide to treatment, not a descriptive injury system, which may still result in an imprecise description of upper cervical spine injuries. Finally, disability and pain were not specifically addressed, which may alter potential surgical indications. Nonetheless, the patients required no further surgery or intervention for pain management. Due to its practical nature, the algorithm may guide surgical indication, helping to identify the most important factors that lead to conservative or surgical management of these complex injuries.

In conclusion, an acceptable intra- and inter-reliability application of the upper cervical spine injury treatment algorithm is reported in the current study. Additionally, the algorithm was safe to guide treatment of upper cervical spine injuries with respect to neurological morbidity. The management of odontoid fractures in the dens base is still controversial. Further studies evaluating the results of treatment of upper cervical spine injuries are necessary.

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