Original Article

Clinical relevance of occipital condyle fractures

ABSTRACT

Context: No consensus about classification, treatment, and clinical relevance of occipital condyle fractures (OCFs) exists.

Aims: The aim of the study was to determine radiological, clinical, and functional outcome of OCFs and thereby determine its clinical relevance.

Settings and Design: This was a retrospective analysis of a prospective follow-up study.

Materials and Methods: From May 2005 to May 2008, all OCFs were included from a Level-1 trauma center. Patient files were reviewed for patient and fracture characteristics. Fracture classification was done according to the Anderson criteria. Clinical outcome was assessed by completing two questionnaires, radiological outcome by computed tomography imaging, and functional outcome by measuring active cervical range of motion using a Cybex EDI-320.

Statistical Analysis Used: A Fisher's exact Test was used in categorical variables and a one-sample *t*-test for comparing means of active cervical range of motion in occipital fracture patients with normal values. An independent samples *t*-test was carried out to compare the means of groups with and without accompanying cervical fractures for each motion.

Results: Thirty-nine patients were included (4 type I, 16 type II, and 19 type III). Twenty-seven patients completed follow-up, of whom 26 were treated conservatively. Fracture healing was established in 25 of 28 fractures at a median follow-up of 19 months. Eleven patients had none to minimal pain or disability at follow-up, 12 had mild, and two had moderate pain or disability on questionnaires. No statistically significant difference in active cervical range of motion was identified comparing means stratified for accompanying cervical fractures.

Conclusions: Conservatively treated patients with an OCF generally show favorable radiological and clinical outcome.

Keywords: Fracture healing, neck disability index, neck pain and disability scale, occipital condyle fractures, range of motion

INTRODUCTION

Occipital condyle fractures (OCFs) are associated with high energetic blunt trauma, in particular road traffic accidents and falls. Its clinical presentation varies greatly and is nonspecific as other concomitant traumatic injuries may have a more urgent presentation. Symptoms range from asymptomatic to death.[1,2]

The incidence of OCFs within the high energetic trauma population ranges between 4 and 30/1000 per year.[3-6] An increase in incidence over the past decades is explained by the introduction of computed tomography (CT) scanning protocols. Plain radiographs are insufficient in diagnosing cervical spine and cerebral injuries, so CT is the method of choice.[7-10] However, OCFs may still go unnoticed or be misinterpreted on CT on a regular basis.[11]

Access this article online	
Website: www.jcvjs.com	Quick Response Code
DOI: 10.4103/jcvjs.JCVJS_100_20	

Stijn J van der Burg, Martin H Pouw, Monique Brink[1], Helena Dekker[1], Henricus P M Kunst[2,3], Allard J F Hosman

Departments of Orthopaedic Surgery, [1]Medical Imaging and [2]Otorhinolaryngology, Radboud University Nijmegen Medical Centre, Nijmegen, [3]Department of Otorhinolaryngology, Maastricht University Medical Centre, Maastricht, Netherlands

Address for correspondence: Dr. Stijn J van der Burg, Spiegeltuin 104, 5223MZ, 's-Hertogenbosch, Netherlands. E-mail: stijn@burgenco.nl

Submitted: 27-Jun-20 **Accepted:** 09-Jul-20
Published: 14-Aug-20

How to cite this article: Van der Burg SJ, Pouw MH, Brink M, Dekker H, Kunst HP, Hosman AJ. Clinical relevance of occipital condyle fractures. J Craniovert Jun Spine 2020;11:173-9.

Sir Charles Bell first described OCFs in 1817. Since then, several classification systems have been proposed. Those introduced by Anderson and Montesano[12] in 1988 and Tuli *et al*.[13] in 1997 are most commonly used in the literature.[1,2] Other, more recent, suggested OCF classifications, all have their own recommendations about treatment.[3,5,14] This reflects the lack of evidence and absence of consensus about OCF management. Different treatment options and durations are advocated: functional mobilization, soft/semi-rigid/rigid cervical collar, sterno-occipital-mandibular-immobilizer (SOMI), Halo-vest, and surgical stabilization.[3,5,6,14-18]

Literature on OCFs is scarce and mainly consists of case reports and series.[1,2] Until now, only two prospective follow-up studies are published,[5,6] together with some retrospective ones.[3,4,14-18] Moreover, no consensus about classification, treatment, and clinical relevance of OCFs exists.

This study follows up a large group of patients with OCFs in a level-1 trauma center over a 3-year period. The aim of this study is to prospectively investigate long-term radiological, clinical, and functional outcomes of patients with OCFs and to thereby determine its clinical relevance.

MATERIALS AND METHODS

Study population

After approval of the institutional ethics committee, we retrospectively selected all patients diagnosed with an OCF who were included in an observational, prospective study from May 2005 to May 2008. This study included 1047 patients with a high energetic trauma who underwent a CT scan of the cervical spine, chest, and abdomen in a level-1 trauma center as described in Brink *et al*.[19]

A secondary survey of initial cervical CT scans with a focus on the occipital condyle region was performed to trace overlooked OCFs. One radiologist and a researcher reviewed initial CT scans to determine side and fracture type according to the Anderson criteria [Figure 1].[12]

- Type I: An impaction fracture with comminution of the occipital condyle, associated with axial load injury and considered stable due to none to minimal fragment displacement
- Type II: A basilar skull fracture with continuation through the condyle, associated with direct, blunt trauma to the head and considered stable due to the intact tectorial membrane and alar ligaments
- Type III: An avulsion fracture of the inferiomedial aspect of the condyle where the alar ligament attaches, and associated with forced rotation and/or lateroflexion and considered unstable due to disruption of stabilizing ligaments.

After inclusion, patient files were reviewed for retrieving patient and fracture characteristics.

Relevant clinical information included trauma mechanism, Injury Severity Score (ISS), Glasgow Coma Scale, concomitant cervical/brain/skull/cranial nerve injuries, and received treatment for OCF. Conservative treatment contained functional mobilization and immobilization with a collar, SOMI, or Halo-vest.

Included patients were contacted for the follow-up to determine the radiological, clinical, and functional outcomes.

Radiological outcome

Radiological outcome was defined by fracture healing as determined by the same radiologist who conducted the secondary survey.

Fracture healing was confirmed with total fracture ossification or with callus formation. Nonhealed fractures showed no callus deposit across the fracture. Follow-up CT imaging was evaluated at least 10 weeks after injury.

A Somatom Sensation 16-multidetector CT scanner (Siemens Medical Solutions) with automated tube modulation was used. Scans were made from skull base to the first thoracic vertebra at a tube potential of 120 kV with a reference value of effective tube current–time product of 200 mAs and a detector configuration of 16 mm × 1.5 mm. Bone and soft-tissue reconstructions were respectively made in a section thickness of 1.5 mm and 3 mm, with coronal and sagittal reconstructions in the bone setting.

Clinical outcome

Clinical outcome was based on two questionnaires: Neck Disability Index (NDI)[20] and Neck Pain and Disability Scale (NPAD).[21] They measure self-reported pain intensity and disability and indicate to what extent neck complaints influence daily activities. The NDI consists of 10 items that are scored from 0 to 5, except for one that scores from 0 to 4. The NPAD consists of 20 items that are scored from 0 to 5 on a Visual Analog Scale. The NPAD is invalidated if >15% of items are missing. No such restriction exists for NDI. To achieve total scores in partially completed NDI and NPAD, missing answers were calculated as the mean of completed questions (examples).[22]

The higher the cumulative score per questionnaire, the more pain and/or disability patients experience. Scores are divided

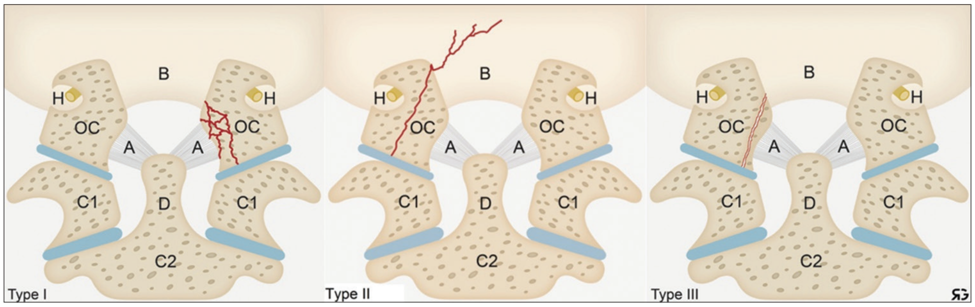

Figure 1: Schematic coronal view of Anderson et al. classification system. FLTR Type I; Type II; Type III. (A) Alar ligament. (B) Basilar skull. (OC) Occipital condyle. (C1) Atlas. (C2) Axis. (D) Dens. (H) Hypoglossal canal

Table 1: Interpretation of scores per questionnaire (points)

Class	NDI[20]	NPAD[21]
1	None (0-4)	None to minimal (0-22)
2	Mild (5-14)	Mild (23-40)
3	Moderate (15-24)	Moderate (41-57)
4	Severe (25-34)	Moderate to severe (58-74)
5	Complete (35-49)	Severe (75-92)
6		Extreme (93-100)

NDI – Neck Disability Index; NPAD – Neck Pain and Disability Scale

into an ordinal scale [Table 1]. To achieve a combined score for clinical outcome, a rounded-up average of classes was taken. Both the questionnaires are validated in the Dutch language.[23,24]

Functional outcome

Two raters measured half-cycle active cervical range of motion (ACROM) for flexion, extension, right rotation, left rotation, right lateroflexion, and left lateroflexion. Flexion, extension, and lateroflexion were measured in a seated position with the head in a neutral position. Rotatory movements were measured in a supine position. Instructions were to solely move the cervical spine maximally, going through possible pain. Full-cycle values are the sum of half-cycle values.

A Cybex EDI-320 (Saunders Digital Inclinometer) was used for its ease of use and its acceptable inter- and intrarater reliability in patients with and without cervical pain.[25,26]

Statistical analysis

Statistical calculations were carried out with the use of SPSS version 25 (IBM Corp., Armonk NY). A Fisher's exact test was used for significance testing in categorical variables: fracture healing, fracture type, received treatment, questionnaire scores, presence of accompanying cervical fractures, and presence of traumatic brain injury.

A one-sample *t*-test was performed to compare means of ACROM in OCF patients with normal values.[27] In addition, an independent samples *t*-test was carried out to compare the means of groups with and without accompanying cervical fractures for each motion. The selected significance level was $P = 0.05$.

RESULTS

Demographics

This study included 39 patients with an OCF out of 1047 over a 3-year period, giving an incidence of 37.2 per 1000 per year within initial high energetic trauma (HET) survivors who underwent CT [Figure 2].

During follow-up, ten patients died at a median of 5 days after injury (range: 0–158 days), giving a survival rate of 74%. Severe neurological trauma, sepsis, or cardiac arrest was the cause of death in nine patients. The cause of death in one patient was unknown, as he died at home 158 days post trauma.

Two of 29 survivors were unavailable for follow-up because of personal or medical reasons, giving a response rate of 93%. Two patients were lost to follow-up at CT imaging and two failed to complete the NPAD to a validated extent. Another patient was unavailable for functional follow-up, as he could not visit the outpatient clinic. ACROM measurement could not be completed by two patients because of tetraparesis. Furthermore, two patients were excluded from calculations since they either had a fixed spine due to M. Bechterew or received spondylodesis [Figure 2].

Table 2 shows patient and fracture characteristics. Almost all included patients received conservative treatment, of which 65% were managed with functional mobilization. The only invasively treated patient received posterior spondylodesis from occiput to C2 for a left-sided atlanto-occipital dislocation and a right-sided dislocated OCF and got a Halo-vest afterward. OCF management of one patient could not be retrieved.

Radiological results

Follow-up CT-imaging was done in 25 patients at a median of 19 months after trauma (range: 2–43 months). Fracture healing

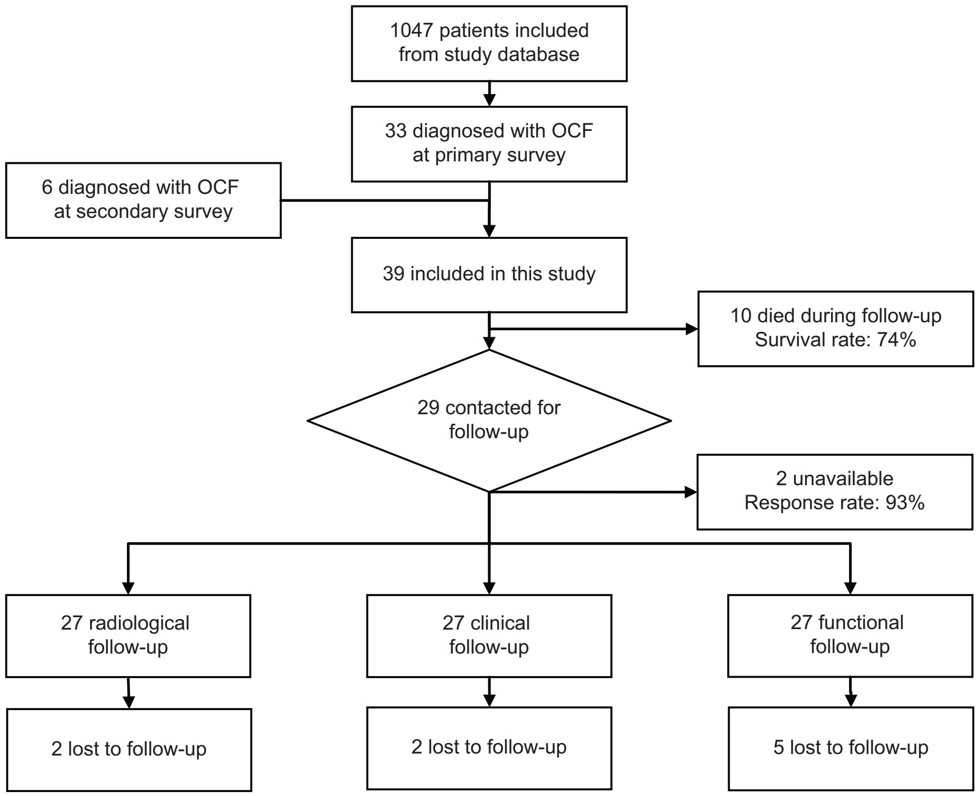

Figure 2: Flowchart of the study design

was determined in 24 patients with 25 fractures. One type II fracture showed no signs of healing and two type I OCFs were lost to follow-up. There were no significant differences between healed OCFs for classification type or received treatment.

Clinical results

Questionnaires were taken from 27 patients at a median of 22 months after trauma (range: 2–43 months). Table 3 shows the interpretation of questionnaires distributed for completion.

Altogether, with exclusion of the invalidated NPADs, a combined score of none to minimal was scored in 11, mild in 12, and moderate in 2 cases, and none scored severe. Two patients with an invalidated NPAD scored moderate and severe on the NDI.

There was no statistically significant difference for outcome on NDI ($P = 0.34$ and 0.98), NPAD ($P = 0.44$ and 0.46), and combined score ($P = 0.67$ and 0.38) in regard to classification or treatment, respectively. In addition, no statistically significant differences were detected for clinical outcomes in regard to the presence of accompanying cervical fractures or traumatic brain injury.

Functional results

Calculations on ACROM were done in 22 patients that were measured at a median of 20 months after trauma (range: 2–43 months). Accompanying cervical fractures were present in 9 and absent in 13 patients.

Values for extension and right rotation, and therefore also full-cycle values, were significantly decreased in patients with OCFs compared to normal values [Table 4]. However, no statistically significant differences in ACROM existed between patients with OCFs with or without accompanying cervical fractures [Table 4].

DISCUSSION

Comparative results

This study showed an incidence of 37.2/1000°CFs per year within initial HET survivors.

Mueller *et al*. and Malham *et al*., respectively, recorded an incidence of 11.9 and 28.3 per 1000 per year within the high energetic trauma population who received CT imaging of the neck.[5,6] However, it is likely that these numbers are an underestimation for two reasons. First, mortality in patients with OCF is high due to the high impact of trauma and associated injuries. Second, OCFs are easily missed despite improved diagnostic modalities. This study showed that six patients had a missed OCF at the primary survey of the initial images. Goradia *et al*. reported that 24% of 50°CFs were missed at the primary survey.[11] To improve the true incidence of OCF, we included inhospital deceased patients and OCFs diagnosed at the secondary survey.

The survival rate in this study was 74%, while previously reported rates generally lie above 80%.[3,4,14,18] Mueller *et al*. and Malham *et al*. had survival rates of 84% and 89%, respectively.[5,6] As a tertiary referral center, with level-1 trauma status and a department of neurosurgery, even patients with a poor prognosis are referred to our center. Our data showed a higher ISS and more patients had moderate-to-severe traumatic brain injury compared to other studies. The mean ISS in this study was 34 compared to 25.8 and 29 reported by Mueller *et al*. and Malham *et al*., respectively.[5,6] Our data showed lower survival rates since concomitant moderate-to-severe traumatic brain injury was present in 72% of the patients in this study compared to 46% reported by Malham *et al*.,[6] although it must be stated that ISS was missing in 14 cases, which could result in a skewed display.

Our data confirm that type III is the most common fracture type of OCF.[2] Mueller *et al*. showed that the fracture type differs in literature and states that the OCF classification has no clinical consequences.[5] We endorse this statement as our data showed no significant statistical differences between the classification of OCF and the ISS, mortality, received treatment, and radiological and clinical outcomes.

Our retrospective data showed that most OCFs were treated conservatively and showed favorable radiological and clinical outcomes. Except for one, all OCFs showed fracture healing regardless of treatment or classification. Other studies also showed favorable radiological outcomes in conservatively treated OCF patients.[5,6] However, often, the treatment was some sort of brace, while most patients in our study were treated with functional mobilization. Most of the conservatively treated patients scored none to minimal or mild on questionnaires. Only two patients scored a moderate combined score on questionnaires despite fracture healing, of which one patient also suffered a lateral mass fracture of C1 and multiple facial fractures and was treated in a Halo-vest for 3 months and the other patient received spondylodesis for an atlanto-occipital dislocation and had several other spinal fractures. Mueller *et al*. and Malham *et al*. reported a

Table 2: Patient and fracture characteristics

Patient characteristics	*n* (%)
Median age (range)	46 years (14-92)
Male: female ratio (males)	2.3:1 (69)
Glasgow coma scale (mean)	9
Injury severity score (mean)	34
Accompanying Cervical Fractures	16 (41)
Axial (C1-C2)	6
Subaxial (C3-C7)	6
Axial and subaxial	4
Traumatic brain injury	36 (92)
Mild/concussion	8 (20)
Moderate/severe	28 (72)
Cranial nerve palsy	6
Cranial nerve III	5
Cranial nerve V_2	1
Cranial nerve VII	2
Cranial nerve IX-XII	1
Treatment	26
Functional mobilization	17 (65)
Soft cervical collar	2 (8)
SOMI	2 (8)
Halo-vest	4 (15)
Posterior spondylodesis	1 (4)
Fracture characteristics	
Side	39
Left	16 (41)
Right	21 (54)
Bilateral	2 (5)
Classification	39
Type I	4 (10)
Type II	16 (41)
Type III	19 (49)
Basilar skull fracture	21
Type II	16
Isolated	5

SOMI - Sterno-occipital-mandibular-immobilizer

Table 3: Interpretation of NDI and NPAD

a. Interpretation of NDI distributed for completion of NDI (%)					
	None	Mild	Moderate	Severe	Total
Partial completion	2	3	2	1	8 (30)
Full completion	9	9	1	0	19 (70)
Total	11 (41)	12 (44)	3 (11)	1 (4)	27 (100)
b. Interpretation of NPAD distributed for completion of NPAD (%)					
	None to minimal	Mild	Moderate	Invalidated	Total
Partial completion	10	3	1	2	16 (59)
Full completion	8	3	0	0	11 (41)
Total	18 (67)	6 (22)	1 (4)	2 (7)	27 (100)

NDI – Neck Disability Index; NPAD – Neck Pain and Disability Scale

Table 4: Comparing means of ACROM

a. Comparing means (°) of half- and full-cycle ACROM values with normal values one-sample *t*-test									
	Normative value[27] (SD)			OCF patients (n=22) (SEM)			*P*		
	Half-cycle		Full-cycle	Half-cycle		Full-Cycle	Half-cycle		Full-cycle
F-E	52 (7)	71 (5)	126 (12)	53 (3)	60 (3)	113 (5)	0.71	0.003*	0.02*
LLF-RLF	42 (2)	44 (0)	86 (5)	42 (2)	44 (3)	86 (4)	0.97	0.97	1.00
LR-RR	71 (11)	73 (-)	151 (23)	65 (4)	63 (3)	128 (6)	0.09	0.004*	0.002*
b. Comparing means (°) of half- and full-cycle ACROM values stratified for ACF (SEM) independent sample t- test									
	Patients without ACF (n=13)			Patients with ACF (n=9)			*P*		
	Half-cycle		Full-cycle	Half-cycle		Full-cycle	Half-cycle		Full-cycle
F-E	50 (4)	55 (4)	105 (8)	57 (4)	66 (5)	123 (6)	0.29	0.10	0.07
LLF-RLF	42 (2)	43 (3)	85 (5)	42 (4)	45 (5)	87 (9)	0.91	0.72	0.79
LR-RR	64 (5)	64 (5)	128 (10)	66 (5)	62 (3)	127 (7)	0.80	0.73	0.98

*Indicates statistical difference (P<0.05). ACROM – Active cervical range of motion; ACF – Accompanying cervical fracture; SD - Standard deviation; SEM – Standard error of the mean; F – Flexion; E – Extension; LLF – Left lateral flexion; RLF – Right lateral flexion; LR – Left rotation; RR – Right rotation

median NDI of 10.5 and a mean NPAD of 23.1, respectively, which corresponds with mild pain and disability.[5,6] In addition, a quality-of-life questionnaire by Mueller *et al*. showed a significant reduction in all areas but was dictated by the overall pattern of injury instead of the OCF itself.[5] Other studies showed comparable results.[3,15,17] Although no statistical association could be identified between concomitant injuries and clinical outcomes in this study, the authors believe that concomitant injuries may play a more distinctive role in clinical outcomes than OCF itself.

As for the functional outcome, extension and right rotation were both significantly decreased in OCF patients compared to normal values. However, this should be interpreted with some restraint. The values presented as normal by Chen *et al*. have a standard error of the mean, although these numbers could not be deduced from their meta-analysis.[27] Therefore, the one-sample *t*-test used for significance testing between normal values and our own data comes with a certain degree of uncertainty. Thus, there is little to say about the difference in ACROM in healthy controls and patients with OCF. Moreover, a decrease in ACROM of only a few degrees is unlikely to be of any clinical importance. Accompanying cervical fractures were present in 41% of the cases, which is similar to the 42% reported by Malham *et al*.[6] They are statistically not associated with ACROM in OCF patients. Other variables that are of influence are age, gender, degenerative, and systemic disorders.[27,28] Fright and avoiding behavior in anticipation of pain might also be a factor of influence in OCF patients.

Strengths and limitations

This study has some strengths. It is one of the few that reports on prospective, long-term follow-up in a large group of OCF patients, and it is the first to take ACROM into account. Furthermore, the response rate of 93% was particularly high compared to other studies.[5,6]

Our study also has several limitations. Unfortunately, some patients were lost to follow-up or did not complete the questionnaires. Furthermore, the questionnaires and measurement of ACROM are not specifically designed for OCFs and the occipito-atlantal joints. Calculating total scores for incomplete NDI/NPAD is not a validated method and the same accounts for combining these scores, although calculated and rough scores differed little and the interpretation of the scores stayed unchanged. Moreover, in the worst-case scenario, the interpretation is an overestimation since scores were rounded up. Therefore, the consequences were minimal.

Implications and future research

Instability and neurovascular complications are the main indications for surgical intervention in OCF. This study opted for spondylodesis in one patient with a contralateral atlanto-occipital dislocation and Halo-vest in patients with unstable accompanying cervical fractures. Mueller *et al*. defined instability based on the presence of atlanto-occipital dislocation and stated that this is an indication for surgical stabilization.[5] Malham *et al*. treated patients with Halo-vest if alar ligaments were disrupted or unstable accompanying cervical fractures were present.[6] Furthermore, the variety of indications for various conservative treatment options is unsubstantiated in OCF treatment. Selection of conservative treatment options is based on other cervical fractures and is not determined by having an OCF or not. All in all, instability of the cranio-cervical junction fails a clear-cut classification and establishing definite criteria is essential to provide optimal treatment for OCF patients.

CONCLUSIONS

Conservatively treated patients with an OCF generally show favorable radiological and clinical outcomes. Clinical outcome depends on concomitant injuries rather than by having an OCF or not. Furthermore, the classification by Anderson *et al*. is purely descriptive and has no clinical consequences.

Acknowledgment

The authors thank the TRACT-group for their effort, thoroughly fulfilling the high energetic trauma protocol.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Musbahi O, Khan AH, Anwar MO, Chaudery H, Ali AM, Montgomery AS. Immobilisation in occipital condyle fractures: A systematic review. Clin Neurol Neurosurg 2018;173:130-9.
2. Theodore N, Aarabi B, Dhall SS, Gelb DE, Hurlbert RJ, Rozzelle CJ, *et al*. Occipital condyle fractures. Neurosurgery 2013;72 Suppl 2:106-13.
3. Hanson JA, Deliganis AV, Baxter AB, Cohen WA, Linnau KF, Wilson AJ, *et al*. Radiologic and clinical spectrum of occipital condyle fractures: Retrospective review of 107 consecutive fractures in 95 patients. Am J Roentgenol 2002;178:1261-8.
4. Krüger A, Oberkircher L, Frangen T, Ruchholtz S, Kühne C, Junge A. Fractures of the occipital condyle clinical spectrum and course in eight patients. J Craniovertebr Junction Spine 2013;4:49-55.
5. Mueller FJ, Fuechtmeier B, Kinner B, Rosskopf M, Neumann C, Nerlich M, *et al*. Occipital condyle fractures. Prospective follow-up of 31 cases within 5 years at a level 1 trauma centre. Eur Spine J 2012;21:289-94.
6. Malham GM, Ackland HM, Jones R, Williamson OD, Varma DK. Occipital condyle fractures: incidence and clinical follow-up at a level 1 trauma centre. Emerg Radiol 2009;16:291-7.
7. Link TM, Schuierer G, Hufendiek A, Horch C, Peters PE. Substantial head trauma: value of routine CT examination of the cervicocranium. Radiology 1995;196:741-5.
8. Aulino JM, Tutt LK, Kaye JJ, Smith PW, Morris JA Jr. Occipital condyle fractures: clinical presentation and imaging findings in 76 patients. Emerg Radiol 2005;11:342-7.
9. Blacksin MF, Lee HJ. Frequency and significance of fractures of the upper cervical spine detected by CT in patients with severe neck trauma. AJR Am J Roentgenol 1995;165:1201-4.
10. Bloom AI, Neeman Z, Slasky BS, Floman Y, Milgrom M, Rivkind A, *et al*. Fracture of the occipital condyles and associated craniocervical ligament injury: incidence, CT imaging and implications. Clin Radiol 1997;52:198-202.
11. Goradia D, Blackmore CC, Talner LB, Bittles M, Meshberg E. Predicting radiology resident errors in diagnosis of cervical spine fractures. Acad Radiol 2005;12:888-93.
12. Anderson PA, Montesano PX. Morphology and treatment of occipital condyle fractures. Spine (Phila Pa 1976) 1988;13:731-6.
13. Tuli S, Tator CH, Fehlings MG, Mackay M. Occipital condyle fractures. Neurosurgery 1997;41:368-76.
14. Maserati MB, Stephens B, Zohny Z, Lee JY, Kanter AS, Spiro RM, *et al*. Occipital condyle fractures: clinical decision rule and surgical management. J Neurosurg Spine 2009;11:388-95.
15. Maddox JJ, Rodriguez-Feo JA, Maddox GE, Gullung G, McGwin G, Theiss SM. Nonoperative treatment of occipital condyle fractures: an outcomes review of 32 fractures. Spine 2012;37:E964-8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22414996. [Last accessed on 2020 May 08].
16. Capuano C, Costagliola C, Shamsaldin M, Maleci A, Di Lorenzo N. Occipital condyle fractures: A hidden nosologic entity. An experience with 10 cases. Acta Neurochir (Wien) 2004;146:779-84.
17. Byström O, Jensen TS, Poulsen FR. Outcome of conservatively treated occipital condylar fractures-A retrospective study. J Craniovertebr Junction Spine 2017;8:322-7.
18. West JL, Palma AE, Vilella L, Fargen KM, Branch CL, Wolfe SQ. Occipital condyle fractures and concomitant cervical spine fractures: Implications for management. World Neurosurg 2018;115:e238-43. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29656152. [Last accessed on 2020 May 08].
19. Brink M, Deunk J, Dekker HM, Edwards MJ, Kool DR, van Vugt AB, *et al*. Criteria for the selective use of chest computed tomography in blunt trauma patients. Eur Radiol 2010;20:818-28.
20. Vernon H, Mior S. The Neck Disability Index: A study of reliability and validity. J Manipulative Physiol Ther 1991;14:409-15.
21. Wheeler AH, Goolkasian P, Baird AC, Darden BV 2nd. Development of the Neck Pain and Disability Scale. Item analysis, face, and criterion-related validity. Spine (Phila Pa 1976) 1999;24:1290-4.
22. Vernon H. The Neck Disability Index: State-of-the-art, 1991-2008. J Manipulative Physiol Ther 2008;31:491-502.
23. Jorritsma W, de Vries GE, Geertzen JH, Dijkstra PU, Reneman MF. Neck Pain and Disability Scale and the Neck Disability Index: Reproducibility of the Dutch Language Versions. Eur Spine J 2010;19:1695-701.
24. Jorritsma W, de Vries GE, Dijkstra PU, Geertzen JH, Reneman MF. Neck Pain and Disability Scale and Neck Disability Index: Validity of Dutch language versions. Eur Spine J 2012;21:93-100.
25. Tousignant M, Boucher N, Bourbonnais J, Gravelle T, Quesnel M, Brosseau L. Intratester and intertester reliability of the Cybex electronic digital inclinometer (EDI-320) for measurement of active neck flexion and extension in healthy subjects. Man Ther 2001;6:235-41.
26. Hoving JL, Pool JJ, van Mameren H, Devillé WJ, Assendelft WJ, de Vet HC, *et al*. Reproducibility of cervical range of motion in patients with neck pain. BMC Musculoskelet Disord 2005;6:59.
27. Chen J, Solinger AB, Poncet JF, Lantz CA. Meta-analysis of normative cervical motion. Spine (Phila Pa 1976) 1999;24:1571-8.
28. Swinkels RA, Swinkels-Meewisse IE. Normal values for cervical range of motion. Spine (Phila Pa 1976) 2014;39:362-7.