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Utility of post mortem computed tomography in clivus fracture diagnosis. Case illustration and literature review

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ABSTRACT

Clivus fractures are usually associated with head blunt trauma due to traffic accident and falls. A 23 – year-old man died immediately after a smash-up while he was stopping on his motorcycle. Post-mortem Computed tomography (PMCT), performed before autopsy, revealed a complex basilar skull base fractures associated with brainstem and cranio-vertebral junction injuries, improving the diagnostic performance of conventional autopsy. Imaging data were re-assessable and PMCT offers the possibility to perform multiplanar and volume rendered reconstructions, increasing forensic medicine knowledge related to traumatic injuries.

1. Introduction

The clivus is the strongest bone of the skull base, provides mechanical support for the cranial vault and protection for the brainstem and adjacent major vascular structures. Despite its deep location is very susceptible to related fractures with consequent high mortality rate or poor outcome for survivors [1,2].

Clivus fractures may be observed in a serious head blunt trauma due to traffic accidents and falls and the mortality rate and/or poor prognosis of the survivors is mainly due to concomitant injuries of the brainstem [3–8], lower cranial nerves [1,9,10] and vertebro-basilar artery [1,11–14].

In general, clivus fractures are difficult to detected in both conventional and digital radiography, instead cross-sectional imaging techniques as CT may detect fracture and add autoptic finding.

As reported by Corradino et al. [15], the clival fractures are classified according their CT imaging as longitudinal, transverse and oblique. Longitudinal types are associated with the highest mortality (67–80%), related to the concomitant injuries of the brainstem, lower cranial nerves and vertebro-basilar artery. The oblique or transverse clival fractures have been often implicated in damage of the carotid arteries [1,15,16].

The use of post mortem CT (PMCT), and the subsequent multiplanar and volume rendering reconstructions techniques, allows to obtain non-invasive, objective operator-independent imaging data set that could be also reviewed by others specialists. PMCT with multiplanar (MPR) 3D maximum intensity projection (MIP) and volume rendered reconstructions images (VR), implement forensic knowledge related to traumatic injuries [17–19].

2. Case history

We report a case of a 23-year-old man who died immediately after a smash-up while he was stopping on his motorcycle. It was not possible to exclude the presence of the helmet that was found far from the body in the accident site. The cause of death was related to a complex fracture of the skull base with brainstem and severe cranio-cervical injuries.

3. Post mortem CT: technique and findings

The post mortem interval between PMCT and the medico legalautopsy was about six hours.

PMCT was performed with a 128 slices MDCT scanner (Somatom Definition AS®, Siemens Healthcare Erlangen Germany). Volume acquisition was performed with thin collimation of 1 mm. Scan parameters were a tube voltage of 120 kVp, with an effective tube current of 120–160 effective mAs, gantry rotation time of 0.5 s, beam pitch of 1.2 and table speed of 46 mm per gantry rotation.

Images were reviewed using PACS (Elephant.net suite® AGFA HealthCare N.V., Belgium) and dedicated workstation (Singovia® Siemens Healthcare Erlangen Germany).

During the reading sessions, axial and MPR images were reviewed with a soft tissue and bone edge window manual adjustments made when needed.

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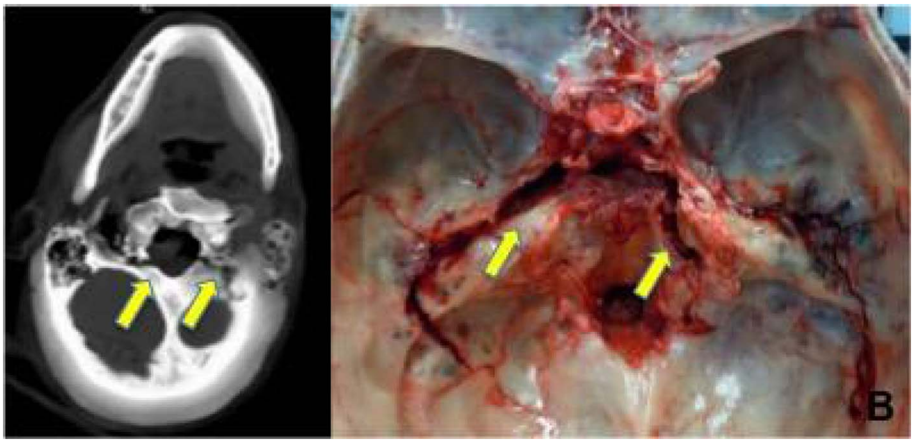

A B

Fig. 1. 3D-MIP axial reconstruction image looking ideally the skull from the neck (A) focused on skull base, clearly shows bilateral clivus fracture (arrows) as conventional autopsy (arrows) (B).

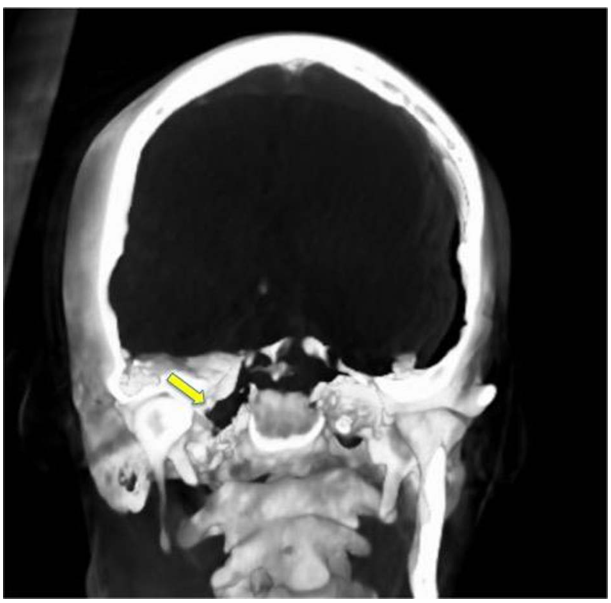

Fig. 2. 3D-MIP coronal reconstruction comprehending the skull from the base to vertex, showing clivus fracture with high-confidence in representing bone extremities detachment, particularly on the right side (arrow).

3D-MIP and VR three-dimensional reconstructions were performed in the skull and cranial base. Data set of images obtained was then compared with conventional autopsy report (Figs. 1–4).

PMCT showed fracture of the occipital foramen reaching anteriorly to the sphenoidal clivus and the mastoid on the left. The contralateral side of the occipital foramen was also involved. Fracture of plank head from the medial third of the occipital suture to left parietal bone near orbital cavity, was identified. The PMCT scan also allowed to identify odontoid process fracture, left atlanto-occipital diastase and anterior dislocation of C2. Nevertheless, the cervical spine was carefully explored to exclude the presence of haemorrhage due to direct trauma.

4. Autopsy findings

The body was 168 cm in length weighing 63 kg. At external examination only few bruises were found in the back on the left. The macroscopic examination of the brain showed diffuse oedema, (brain weight: 1260 g). Subarachnoid haemorrhage of the base and a traumatic laceration of brainstem were observed (Fig. 5). In serial cross-sections of the brain there was no evidence of intra-parenchymal haemorrhages.

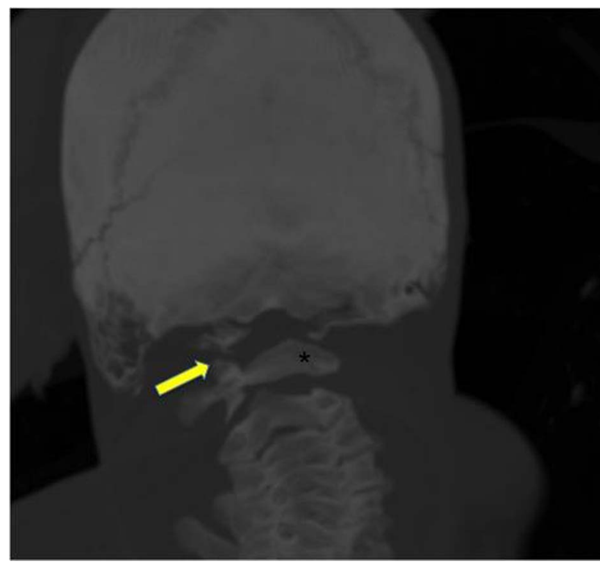

Fig. 3. VR coronal skull reconstruction with posterior view, showing clivus fracture (arrow), separation between skull base and first vertebra (*), abnormally rotate, between first and second vertebra, with consequent odontoid process fracture.

A complex skull basilar fracture (Fig. 1) was detected in the PMCT investigation. Cervical spine was carefully explored and sectioned to exclude the presence of superficial haemorrhage due to direct trauma. Other organs did not show any significant abnormality.

5. Histological findings

There were haemorrhage and oedema around the brainstem laceration. No pathological evidence other than congestion was found.

6. Toxicological analysis

Neither drugs nor ethanol were detected by screening toxicological analysis.

7. Discussion

There is some evidence on effectiveness of digital autopsy in determining the cause of death due to blunt trauma [20–23]. Noteworthy, Kasahara et al. [24] reviewed 339 forensic autopsy cases observed that causes of death could be determined based on PMCT findings alone in 7% of the cases, based on suggestive PMCT findings with additional information in 54% and could not be determined in 38%.

Fig. 4. VR para-axial reconstruction of skull base through an internal view of the bone components removing digitally the brain.

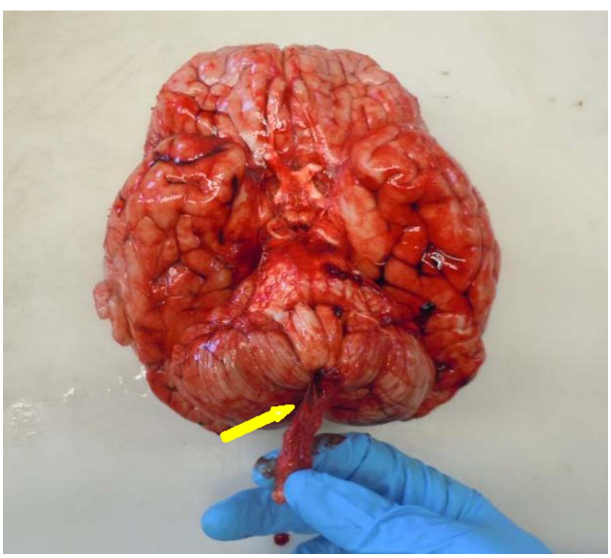

Fig. 5. Brainstem laceration showing no haemorrhage.

PMCT is becoming a commonly performed imaging examination in forensic medicine with the aim to identify the extension and localization of the skull base fractures and investigate the cranium cervical junction lesions, supporting conventional autopsy approach [20–24]. Three-dimensional reconstruction of bone fractures can, also improve the diagnostic accuracy, particularly of cervical spine examination [25]. Generally the presence of a cervical spine injury should induce an investigation (both conventional and/or digital X-ray and PMCT) because contiguous spinal column injuries may occur in 10%–15% of these cases [25].

In reported case, the cause of death was due to a complex skull base fractures associated with brainstem and cranio-vertebral junction injuries without concomitant spine injuries. In trauma center the localization of the head injuries, according with witnessed evidence, suggested a huge impact with subsequent violent anterior flexion of the victim neck may cause fractures of the clival region. These findings may reflect different mechanism of injury, whereby displaced fractures have a higher propensity for injury due to rotational force, causing ligamentous failure and chip- ping of the clivus while sparing surrounding structure [3].

PMCT findings addressed the autopsy section approach making a wide autopsy dissection of cervical spine unnecessary. PMCT findings also supported the autopsy evaluation of skull fractures, showing an excellent concordance between both the approaches proving the utility of performing a PMCT scan before conventional autopsy. On the other hand, the conventional autopsy showed a traumatic laceration of the brainstem, which was undetected by CT scan.

In all cases in which the spine may be involved, it is important to perform PMCT scan for demonstrating bone lesions and underline PMCT findings that may suggest the presence of major ligamentous injuries. In fact, loss of the normal contours of the spine, is a relevant finding in PMCT scan for pathologist that can be highlighted using MPR, 3D-MIP and VR images. Retropharyngeal soft tissue swelling greater than 5 mm at a level of C3 raises the suspicion of an underlying anterior arch fracture. The clivus, on a sagittal view, should point toward the tip of the odontoid process with the tip of the clivus within 5 mm of the odontoid. A separation greater than 5 mm between the atlas and the occipital bone is also considered abnormal [26].

Furthermore the identification of intra cranial air [27], fluid [28] in the sinus or opacification of the mastoid cells [27] should suggest the presence of a fracture involving the cranial fossa. Accurate search of these findings can substantially improve the assessment of fractures [29]. The fractures of cranium-vertebral junction can be also suspected when there is a cervical epidural hematoma, which is characteristic after trauma [30].

PMCT is rarely a substitute for conventional autopsy, while may be a significantly support for forensic pathologist in determining injuries in trauma victims and support evidence of the cause of death.

References

[1] A. Menkü, R.K. Koç, B. Tucer, A.C. Durak, H. Akdemir, Clivus fractures: clinical presentations and courses, Neurosurg. Rev. 27 (2004) 194–198.
[2] A. Winkler-Schwartz, J.A. Correa, J. Marcoux, Clival fractures in a Level I trauma center, J. Neurosurg. 122 (2015) 227–235.
[3] O.P. Gautschi, P.R. Woodland, R. Zellweger, Complete medulla/cervical spinal cord transection after atlanto-occipital dislocation: An extraordinary case, Spinal Cord. 45 (2007) 387–393.
[4] B.L. Zhu, L. Quan, K. Ishida, M. Taniguchi, S. Oritani, M.Q. Fujita, H. Maeda, Longitudinal brainstem laceration associated with complex basilar skull fractures due to a fall: an autopsy case, Forensic Sci. Int. 126 (2002) 40–42.
[5] V. Zivković, S. Nikolić, D. Babić, F. Juković, The significance of pontomedullar laceration in car occupants following frontal collisions: A retrospective autopsy study, Forensic Sci. Int. 10 (2010) 13.
[6] V. Živković, S. Nikolić, Pontomedullary lacerations and concomitant injuries: a review of possible underlying mechanisms, Srp. Arh. Celok. Lek. 141 (2013) 542–547.
[7] H. Maeda, T. Higuchi, M. Imura, K. Noguchi, M. Yokota, Ring. fracture of the base of the skull and atlanto-occipital avulsion due to anteroflexion on motorcycle riders in a head-on collision accident, Med. Sci. Law 33 (1993) 266–269.
[8] P. Guigui, M. Milaire, G. Morvan, B. Lassale, A. Deburge, Traumatic atlanto-occipital dislocation with survival: case report and review of the literature, Eur. Spine J. 4 (1995) 242–247.
[9] L. Bonilha, Y.B. Fernandes, J.P.V. Mattos, W.A.A. Borges, G. Borges, Bilateral internuclear ophthalmoplegia and clivus fracture following head injury: case report, Arq. Neuro. Psiquiatr. 3 (2002) 636–638.
[10] M. Katsuno, H. Yokota, Y. Yamamoto, A. Teramoto, Bilateral traumatic abducens nerve palsy associated with skull base fracture–case report, Neurol. Med. Chir. 7 (2007) 307–309.
[11] A. Bala, N. Knuckey, G. Wong, G.Y. Lee, Longitudinal clivus fracture associated with trapped basilar artery: unusual survival with good neurological recovery, J. Clin. Neurosci. 11 (2004) 660–663.
[12] Y. Taguchi, M. Matsuzawa, H. Morishima, H. Ono, K. Oshima, M. Hayakawa, Incarceration of the basilar artery in a longitudinal fracture of the clivus: case report and literature review, J. Trauma 48 (2000) 1148–1152.
[13] S. Sato, H. Iida, H. Hirayama, M. Endo, T. Ohwada, K. Fujii, Traumatic basilar artery occlusion caused by a fracture of the clivus-case report, Neurol. Med. Chir. 41 (2001) 541–544.
[14] V. Triolo, A. Argo, S. Zerbo, G. Bono, A. Bonifacio, P. Pugnetti, P. Procaccianti, Lethal rupture of post-traumatic aneurysm of the vertebral artery case report, J.

Forensic. Leg. Med. 16 (2009) 168–171.

[15] G. Corradino, A.L. Wolf, S. Mirvis, J. Joslyn, Fractures of the clivus: classification and clinical features, Neurosurgery 27 (1990) 592–596.

[16] G.P. Ochalski, R.M. Spiro, A. Fabio, A.B. Kassam, D.O. Okonkwo, Fractures of the clivus: a contemporary series in the computed tomography era, Neurosurgery 65 (2009) 1063–1069.

[17] A. Argo, S. Zerbo, E. Maresi, A. Rizzo, C. Sortino, E. Grassedonio, M. Midiri, Utility of post mortem MRI in definition of thrombus in aneurismatic coronary arteries due to incomplete Kawasaki Disease in infants, J. Forensic Radiol. Imag. 7 (2016) 17–20.

[18] P.M. Leth, The use of CT scanning in forensic autopsy, Forensic Sci. Med. Pathol. 3 (2008) 65–69.

[19] W. Scweitzer, T. Ruder, M. Thali, M: Ringl, Skull fractures in post-mortem CT: VRT, flat and skin surface projections in comparison, J. Forensic Radiol. Imag. 2 (2015) 214–220.

[20] C. Jacobsen, B.H. Bech, N. Lynnerup, Comparative study of cranial, blunt trauma fractures as seen at medicolegal autopsy and by Computed Tomography, BMC Med. Imag. 16 (9) (2009) 18.

[21] K. Poulsen, J. Simonsen, Computed tomography as routine in connection with medico-legal autopsies, Forensic Sci. Int. 171 (2007) 190–197.

[22] M.J. Thali, C. Jackowski, L. Oesterhelweg, S. Ross, R. Dirnhofer, Virtopsy – the Swiss virtual autopsy approach, Leg. Med. 9 (2007) 100–104.

[23] P.M. Leth, The use of CT scanning in forensic autopsy, Forensic Sci. Med. Pathol. 1 (2007) 65–69.

[24] S. Kasahara, Y. Makino, M. Hayakawa, D. Yajima, H. Ito, H. Iwase, Diagnosable and non-diagnosable causes of death by postmortem computed tomography: a review of 339 forensic cases, Leg. Med. 14 (2012) 239–245.

[25] A. Persson, J. Falk, J. Berge, C. Jackowski, Atlanto-axial rotatory subluxations in postmortem CT: radiologists be aware of a common pitfall, Forensic Sci. Int. 225 (2013) 9–14.

[26] M.P. Burke, Forensic Pathology of Fractures and Mechanisms of Injury: Postmortem CT Scanning, CRC Press Taylor & Francis, 2011 ISBN 9781439881484.

[27] M. Cihangiroglu, H. Ozdemir, O. Kalender, F. Ozveren, A. Kabaalioglu, Transverse sinus air after cranial trauma, Eur. J. Radiol. 48 (2003) 171–174.

[28] E.M. Laasonen, A. Servo, H. Sumuvuori, Sphenoid sinus fluid level in skull base fracture, Eur. J. Radiol. 1 (1982) 5–7.

[29] S.E.J. Connor, A. Flis, The contribution of high resolution multiplanar reformats of the skull base to the detection of skull base fractures, Clin. Radiol. 60 (2005) 878–885.

[30] P.M. Porto de Melo, P.A. Do Seixo Kadri, J.G. De Oliveira, I. Capraro Suriano, S. Cavalheiro, B. Menezes, Cervical epidural haematoma with clivus fracture. Case report, Arq. Neur. Psiquiatr. 61 (2003) 499–502.