Use of Computed Tomography in Orbital Trauma Diagnostic: Literature Review

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Abstract

Computed tomography (CT) is widely used in orbital trauma visualisation that provides rapid and detailed evaluation of bony structures and soft tissues of the orbit. CT is sensitive in detection of orbital foreign bodies, and often guides clinical and surgical management decisions in orbital trauma (Rehm, 1995). Depending of their location, fractures are classified into two groups: isolated (only one orbital wall is involved) and combined (more than one orbital wall is involved). Clinical and radiological findings play major role in management of orbital trauma.

The aim of this study is to summarise and analyse literature about the use of the CT in orbital structures visualisation, trauma diagnostic and compare CT with other radiological methods.

A literature search was conducted electronically in databases PubMed, EBSCO and manually in RSU scientific resources. The search was limited to articles published in the English and Latvian languages between 1990 and 2016.

In all, 141 articles were found, 44 of which met the aforementioned requirements and thus were included and analysed in the study. 97 scientific papers could not be included in the literature review due to the fact that they were written prior to 1990 or do not meet the aforementioned requirements. This article comprises and analyses materials about computed tomography role in orbital trauma diagnostic and management.

The use of high-resolution multidetector CT has become the gold standard of reference in evaluating patient with orbital trauma. Bony fractures and displacements, small comminuted fragments and radio-opaque foreign body are best seen on CT but vascular and nerve injury, and intracranial hematomas are better evaluated with MRI.

Radiological diagnostics and orbital posttraumatic clinical findings have a key role in orbital fracture diagnosis and trauma management.

Keywords: orbital fracture, computed tomography, midface fracture, orbit radiology, maxillofacial radiology.

Introduction

Facial trauma currently constitutes a social and public health problem of relevance because of its frequency and magnitude as well as for its close association with car accidents and episodes of violence and insecurity (Bord, 2008). Due to anatomical proximity, craniofacial trauma often involves injury to the eye and orbit. Orbital fractures are consequence of middle third facial trauma and occur as a result of the application of forces that overcome resistance of bone structures forming the orbital cavity (Reyes, 2013). These fractures are very frequently associated with damage to the surrounding soft tissue and they sometimes damage orbital cavity contents or communicate the orbit with adjacent structures (cranial cavity, paranasal sinuses or nasal cavity) (Cruz, 2004).

The bony orbit is a pyramidal-shaped space with a roof, medial wall, floor, and lateral wall (Aaron, 2014). The orbital walls vary considerably in their thickness. Whereas superior lateral and inferior rims tend to be rather thick, bones just posterior to these and medial rim are usually fairly thin (Frenkel, 1990). The orbit is a relatively small and anatomically complex space that contains many critical structures. This can make CT evaluation of orbital-facial injuries challenging.

Computed tomography (CT) is widely used in the initial evaluation of patients with craniomaxillofacial trauma that provides a rapid and detailed evaluation of bony structures and soft tissues of the orbit (Rehm, 1995). Other imaging modalities, such as plain radiography, reconstructed three dimensional CT, magnetic resonance imaging (MRI), ophthalmic ultrasonography, colour Doppler imaging, and angiography may provide necessary additional information in specific conditions but CT scans have become the standard of care in evaluating orbital injuries (Dunkin, 2011). A trauma CT scan series generally involves 10 mm axial cuts of the cranium and 5 mm cuts through the facial region (Miloro, 2004).

Obviously, the role of CT in orbital injuries is very important and injuries imaging is essential for proper diagnosis and treatment of orbital trauma. It is necessary to understand the treatment plan and decide to pursue immediate surgery, delayed surgery, or no operative management.

Aim

The aim of this study is to summarise and analyse literature about the use of the CT in orbital trauma diagnostic and comparison of CT with others radiological modalities in orbital trauma diagnostics.

Material and Methods

Literature was selected through search in PubMed (Medline), EBSCO and RSU Library scientific resources. The search was restricted to papers published in English and Latvian, in the period 1990–2016. Keywords used for search were orbital fracture, computed tomography, midface fracture, and orbit radiology. Additionally, a manual search in Latvian and European medical journals was performed. Only articles which met the requirements were included in the review. After selection of the literature, 44 articles were used: 16 controlled studies and 28 literature reviews. Different types of orbital fractures and different radiological diagnostic modalities were market.

Results

In total, 141 articles were found. 44 met the aforementioned requirements and thus were included and analysed in the study. 97 scientific papers could not be included in the literature review due to the fact that they were written prior to 1990, contained outdated information and descriptions of obsolete methods.

Two major groups were distinguished that include orbital trauma: isolated orbital fracture and combined fractures. Isolated orbital fractures were divided in orbital floor fracture, medial wall fracture and orbital roof fracture. The combined fractures that include orbital cavity walls are zygomaticomaxillary complex fracture (ZMC), Le Fort fractures and nasoorbitoethmoid (NOE) fractures.

All orbital trauma diagnostic methods were discussed (conventional radiography, ultrasound, magnetic resonance imaging and computed tomography). Aforementioned methods were compared with each other.

Isolated Orbital Fractures

Isolated orbital fractures are less common than combined maxillofacial trauma. In a study carried out in Latvia from 2011 to 2012, 538 patients with maxillofacial trauma were analysed. In 133 cases was diagnosed combined orbital trauma and only 32 patients had isolated orbital wall fractures (Muceniece, 2016).

Orbital Floor Fracture. The orbital floor is formed primarily by the orbital process of the maxilla. Anterolaterally it is formed by a portion of the zygomatic bone, and posteriorly by a small portion of the palatine bone (Som, 2003).

Orbital floor injuries may occur in isolation or in conjunction with higher level Le Fort injuries, ZMC and NOE fractures, panfacial trauma. They often occur in combination with fractures of the medial orbital wall (Bell, 2002).

The mechanism of injury typically involves direct anteroposterior blunt trauma to the globe and orbital margins. Proposed mechanisms for this fracture include hydraulic energy and buckling of the floor from impact to the inferior orbital margin (Waterhouse, 1999).

The computed tomography helps to define the displacement degree of the fracture fragment and relative area of the fracture fragment that are important discriminators in predicting the need for surgery (Schouman, 2012).

The optic nerve is the only nerve within the orbit that can be meaningfully and consistently evaluated by CT in trauma. Transverse fracture size and presence of soft tissue herniation on CT imaging can play an important role in predicting persistent diplopia in isolated orbital floor fractures (Linnau, 2003).

Medial Wall Fracture. After the orbital floor, the medial wall is the next most commonly fractured orbital wall. Medial wall fractures most commonly occur in association with orbital floor fractures, but can be seen as an isolated fracture (Linnau, 2003).

The medial orbital wall is composed anterior to posterior by a portion of the maxillary, lacrimal, ethmoid and sphenoid bones. Medial wall is formed by the extremely thin 0.2–0.4 mm lamina of the ethmoid bone (Miloro, 2004). Non-displaced fractures of the lamina papyracea or the ethmoid are difficult to visualise and should be considered in the presence of ethmoid air-cell opacification or herniation of orbital fat (Pelton, 1998). Orbital emphysema and diplopia are another indirect indicators of medial wall fracture (Liss, 2010). The radiologist should take an account medial wall's anatomical structures such as medial canthal tendon, lacrimal apparatus, superior oblique muscle, orbital nerves, vessels and origin of the orbital muscles (Cruz, 2004).

Orbital Roof Fracture. Orbital roof consists mainly of the frontal bone, with the anterior cranial fossa superior to it. In adults orbital roof fractures are more likely to be associated with complex high energy facial trauma (Aaron, 2014).

Fracture fragments of the orbital roof may be superiorly, inferiorly displaced or non-displaced and often is associated with intracranial complications. Orbital roof fractures may also extend to the orbital rim with or without frontal sinuses involvement. Involvement of the adjacent superior rectus and superior oblique muscles may lead to entrapment and impaired ocular motility (Buitrago-Tellez, 2002). Anterolaterally there is a smooth broad fossa that houses the lacrimal gland. At the most medial extent is the trochlea that has a dual insertion of the superior oblique muscle tendon (Som, 2003).

Any fracture of the orbital roof or lamina papyracea should prompt careful analysis of the optic canal and ophthalmic vein. The superior ophthalmic vein is the only vascular structure of the orbit that is consistently visualized on CT imaging (Yousem, 2010).

Combined Fractures

Combined fractures of orbital cavity are often associated with zygomaticomaxillary complex, maxilla fractures, and nasoorbitoethmoidal complex.

Zygomaticomaxillary Complex Fractures. Zygomaticomaxillary complex fractures are the most common fracture with orbital involvement. Due to anatomical structures of the zygomatic bone, fractures of the lateral wall of the orbit usually present in association with more complex patterns of maxillofacial injury (Patel, 2012).

Blunt trauma to the lateral face and orbit may fracture the four legs of the ZMC. On CT imaging, this will show fractures of the lateral orbital margin, inferior orbital margin with extension into the anterior wall of the maxillary sinus, zygomatic arch, and internal lateral orbital wall (Winegar, 2010).

There may be multiple orbital or ocular sequelae of ZMC fracture. Severe lateral angulation of the internal lateral wall of the orbit increases orbital volume and leads to exophthalmos, requiring orbital exploration as part of the surgical repair (Wright, 1998). ZMC fractures are also frequently associated with orbital floor fractures. CT is critical in characterising angulation and comminution of the internal lateral orbital wall fracture, as well as determining if there is coexistent orbital floor fracture (Jamal, 2009).

Maxillary Fractures. Maxillary fractures are classified into Le Fort I, Le Fort II and Le Fort III types. This classification scheme describes three variants of partial or complete dissociation of the maxillary bone from the skull base (Noffze, 2011).

Le Fort II and III fractures involve orbital wall fractures, whereas a pure Le Fort I fracture does not involve the orbit. All three Le Fort fractures are presented for completeness and to emphasize that multiple variants of Le Fort fractures can coexist (Patel, 2012).

Le Fort I fracture occurs when there is horizontal fracture involving the anterior and medial walls of the maxillary sinus and the nasal septum. Coronal CT depicts interruption of the zygomaticoalveolar arch and the piriform sinus by a fracture line. Dislocation frequently occurs in a posterior or lateral direction causing a floating palate and malocclusion with an “open bite”. Concomitant dental root fractures are delineated by CT, panoramic view or dental films (Manson, 1999).

In Le Fort II fracture, there is oblique fracture of the zygomaticomaxillary articulation, involving the anterior maxillary sinus wall, inferior orbital rim, and medial orbital margin. Variations in the course of fractures with regard to the maxilla, nasal bones, the anterior ethmoid and vomer or perpendicular plate are readily displayed by coronal CT images (Linnau, 2003).

A Le Fort III fracture is present when there is fracture of the medial and lateral walls of the orbit, as well as fracture of the zygomatic arch. CT is particularly important to recognize potential optic canal, cribriform plate and ethmoid roof involvement (Aaron, 2014).

Nasoorbitoethmoidal Complex Fractures. Nasoorbitoethmoidal fracture is a severe craniofacial injury pattern that involves high-energy impact to the nasoethmoidal region of the midface (Remmler, 2004). The blunt injury to the nasoethmoid region causes fracture of the ethmoid sinuses and medial orbital wall. Fractures through the medial orbital wall and the entire NOE complex may result in telecanthus due to medial canthal tendon injury (Sargent, 2007). Up to 20 % of patients have nasolacrimal duct involvement, and may result in abnormalities of tear drainage. Medial orbital wall fractures fragments associated with NOE complex injuries may be dislocated to the NOE complex or orbit side (Yamashita, 2007).

The degree of comminution of an NOE injury pattern describes the severity of injury and may guide clinical and surgical management (Hopper, 2006). These fractures create cosmetic deformities with a flattening of the nasal dorsum and a widening of the intercanthal distance (Miloro, 2004).

Discussion

Common modalities for imaging the orbit and eye include radiography, ultrasound, MRI and CT. The sensitivity of CT for fractures is higher than that of radiography, and three-dimensional reformations after image acquisition can sometimes help to guide subsequent surgical treatment. For orbital trauma, the optimal protocol is thin-sliced CT scan with 1–2 mm cut through the orbit performed with a helical CT. The advantages of the high resolution orbital CT include (Winegar, 2015):

1) much shorter scanning time;
2) reduced motion artefact;
3) much lower radiation exposure.

Conventional Radiography. Plain radiographs may show orbital fractures but are usually of limited value due to the difficult anatomy of the region and they fail to distinguish between the various soft tissues involved. Plain radiographs are limited in assessing the degree of soft tissue injury and displacement of bony fragments. Their sensitivity for fractures is only 15–50 % (Schuknecht, 2005). Plain radiographs may reveal herniation of orbital fat into the maxillary sinus giving rise to the so called tear drop appearance on the Waters' view (Brady, 2001).

Ultrasonography. The use of ultrasound as an alternative to radiography of facial fractures has been explored. Its principal benefit remains in the high-resolution evaluation of superficial soft tissue injury of the face and orbit (Shah et al., 2016). Ultrasonography is an available method for the diagnosis of medial and inferior orbital wall fractures and can be used as the modality of choice for the investigation of orbital wall fracture. Ultrasonography shows normal orbital bones structure as an echogenic line. Orbital bones fracture manifests as disruption of echogenic lines and local hematoma (Johari, 2016). However, if eyeball rupture is suspected than ultrasonography should be avoided.

Magnetic Resonance Imaging. Magnetic resonance imaging (MRI) has a specific role in the evaluation of orbital injuries, providing additional information in cases of cranial nerve deficits, vascular and intracranial complications (Rootman, 2003). Magnetic resonance imaging is contraindicated if there is suspicion of a metallic foreign body within the globe that could potentially move in the strong magnetic field and worsen the eye damage. This diagnostic method is superior to CT in assessing the degree of damage to the globe and optic nerve and differentiation between edema and hemorrhage (Varnamkhasti, 2010).

Table 1. Diagnostic methods compare

Diagnostic methods	Advantages	Disadvantages	Indications
CT	• Possible to evaluate structures in different planes • Successfully visualise bony structures, in outside of the orbit, its opening and its relationship with the skull • Fast image acquisition and easy patient positioning	• Less useful in imaging the ocular globe and adnexae • High radiation dosage	• Isolated and complex orbital fractures • Orbital haematoma • Evaluation of orbital volume • Orbital structure reconstruction
MRI	• Provide excellent images of soft tissues contained in orbital cavity • Possible to evaluate structures in different planes • No radiation	• Contraindicated to metal foreign body detection • Less useful in imaging the orbital bones and paranasal cavities	• Vascular injuries • Optic nerve visualisation • Intraorbital soft tissue damages • Non-metal foreign body detection • Edema and haemorrhage differentiation
Conventional radiography	• It makes it possible to consider orbital bone structures and paranasal sinuses • Low radiation dosage	• Plain radiographs are limited in assessing the degree of soft tissue injury and displacement of orbital bony fragments • For diagnosis of orbital wall fracture required to do x-rays in different projections • A patient must be conscious • Structures overlay each other	• Isolated and non-isolated orbital fracture • Metal foreign body detection
Ultrasonography	• It allows to diagnose orbital soft tissue damage in combination with isolated fractures in real time • No radiation	• One of the major limitations of ultrasonography in orbital complex fractures is the detection of the other associated fractures of the facial bone • Specific knowledge and experience in working with ultrasonography • Rupture of eyeball	• Foreign body detection • Evaluation of orbital volume • Intraorbital soft tissue damages • Medial and inferior orbital wall fractures • Globe disruption • Lens dislocation • Vitreous haemorrhage • Vascular injuries

Conclusion

Due to anatomical proximity, craniofacial trauma often involves injury to the eye and orbit. Orbital trauma may occur as an isolated injury or in context of a more severe craniofacial injury.

The use of high resolution CT has become the gold standard of reference in evaluating patient with orbital trauma. Axial and coronal CT scans can provide information on the location and size of the orbital fracture. Use an axial CT scans allow to measure orbital volume that often is useful in orbital trauma diagnostic. With its widespread availability, fast image acquisition and easier patient positioning, it has largely replaced conventional radiographs.

Bony fractures and displacements, small comminuted fragments and foreign body are best seen on CT. Vascular and nerve injury and intracranial haematomas can be diagnosed by CT; however, MRI is superior to CT in soft tissue visualisation. MRI imaging is an alternative to CT in evaluating orbital trauma.

The imaging method of choice for orbital is thin section CT that can effectively predict prognosis and surgical indication. High resolution thin slice CT of the orbit is ideal for assessing the extent of the bony involvement and it allows three dimensional and multiplanar reformatting.

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