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PEDIATRIC RADIOLOGY

ORIGINAL ARTICLE

Computed tomography findings of orbital floor trapdoor fractures in children

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PURPOSE

Orbital floor trapdoor fracture is a special type of blowout fracture seen primarily in children, and it can cause entrapment of intraorbital tissue and the inferior rectus (IR) muscle. It may be overlooked because the radiologic findings can be subtle. This study reviews the clinical and computed tomography (CT) findings in children with orbital floor trapdoor fractures.

METHODS

We retrospectively analyzed the clinical and CT findings of children with orbital floor trapdoor fractures over a 20-year period.

RESULTS

A total of 43 patients (35 boys, 8 girls; age range, 2–17 years; mean age, 11.5 years) were included in the study. Nineteen patients had intraorbital tissue herniation through the fracture into the maxillary sinus with abnormal alignment and traction of the IR muscle toward the fracture site, termed a tethered muscle (group 1). Thirteen patients had only intraorbital tissue herniation with the IR muscle in a normal position (group 2). Eleven patients demonstrated herniation and entrapment of both the intraorbital tissue and the IR muscle (group 3). Ocular motility restriction occurred in 74% of patients in group 1, 38% of patients in group 2, and 100% of patients in group 3.

CONCLUSION

When assessing CT scans of children with blunt orbital trauma, the orbital floor and the roof of the maxillary sinus should be carefully evaluated for fractures and soft tissue entrapment. Special attention should be paid to the alignment and shape of the IR muscle. IR muscle tethering is the most common muscle abnormality in orbital floor trapdoor fractures.

CLINICAL SIGNIFICANCE

On CT, orbital floor trapdoor fractures in children may be underestimated because of the small size of the herniated tissue and the subtle nature of the bone displacement. Detailed CT findings may improve radiologists' awareness of this condition.

KEYWORDS

Children, orbit, trauma, orbital floor trapdoor fractures, computed tomography

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Orbital floor blowout fractures resulting from blunt trauma exhibit unique features in the pediatric population compared with adults.[1,2] In children, more flexible bones and resilient periosteum lead to narrower bone separation and transient displacement of a bone flap that subsequently snaps back into its original position, termed a trapdoor fracture.[3,4] This can result in entrapment of the adjacent extraocular soft tissue and muscle. The infraorbital rim remains intact. However, in adults, brittle orbital bones and fragile periosteum lead to a wider fracture area (open-door or comminuted-type fractures).[1,2] The fracture line and herniated soft tissue are more extensive, and symptoms are primarily related to enophthalmos.[5]

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Orbital floor trapdoor fractures can cause severe clinical consequences such as ocular motility restriction and diplopia. Early surgical release of the entrapped tissue is recommended to achieve better functional outcomes.[1,3,6-12] Computed tomography (CT) is the preferred imaging modality for diagnosing orbital fractures. However, pediatric trapdoor fractures are often missed or underrecognized on CT, potentially causing considerable delays in diagnosis and treatment.[5,7,13-15] Despite their clinical importance, studies on these fractures in the pediatric radiology literature remain scarce. This study reviews the clinical and radiologic findings of orbital floor trapdoor fractures in children.

Methods

The medical records and images of patients aged ≤ 17 years with orbital floor trapdoor fractures were retrospectively reviewed. Cases were identified by searching the institutional medical and radiologic databases for the term "trapdoor fracture" between May 2005 and February 2025. Institutional Review Board of Bursa Uludağ University Faculty of Medicine approval for data collection was obtained (protocol number: 2025/832/15-13; approval date: 10.09.2025). Because of the retrospective nature of the study and the use of anonymized clinical data, the requirement for informed consent was waived by the ethics committee. Demographic data, mechanism of injury, clinical findings, and the interval between presentation and imaging were recorded. Patients with other craniofacial and/or orbital fractures or CT scans of inadequate diagnostic quality were excluded.

Because of the long study period, three different CT scanners were used. One was a single-detector spiral CT scanner (Siemens, Emotion, Erlangen, Germany), and the others were 16-slice (Siemens Somatom Perspective, Erlangen, Germany) and 64-slice (Siemens Somatom Definition AS+, Erlangen, Germany) multidetector CT scanners. Patients were scanned in the prone position using contiguous 3-mm coronal sections with the single-detector spiral CT scanner. Multidetector CT images were acquired in the supine position with a collimation of 1.5 mm or less. Coronal images were reconstructed in a plane perpendicular to the orbital axis, and sagittal images were reconstructed in a plane parallel to the axis of the inferior rectus (IR) muscle, using the same slice thickness as the source image data.

Two radiologists with 22 and 10 years of experience in pediatric radiology evaluated the images by consensus using the Sectra Workstation IDS7 (Sectra Medical Systems AB, Linköping, Sweden). Although the reviewers were aware that all cases involved orbital floor trapdoor fractures, they were blinded to the clinical data and the original CT reports. All patients had either coronal image acquisition or coronal multiplanar reformations (MPRs). Coronal images were reviewed first, followed by sagittal images when MPRs were available. All images were evaluated using both bone and soft-tissue window settings. The fracture location relative to the infraorbital groove, the contents of the incarcerated structures (intraorbital tissue and muscle), and the presence of an air-fluid level in the maxillary sinus were recorded. The thickness, morphology, and course of the IR muscle were compared with those on the contralateral side.

CT findings were not compared with surgical findings. During surgery, the herniated tissue is released from its periphery. Actively probing the herniated tissue to determine its contents may increase tissue damage; therefore, such exploration is generally avoided.[16]

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro–Wilk test. Normally distributed continuous variables were compared using the Student's t-test for two-group comparisons or one-way analysis of variance for comparisons among three or more groups. Non-normally distributed continuous variables were compared using the Mann–Whitney U test. Categorical variables were compared using the chi-square test or Fisher's exact test.

Results

Clinical findings

A total of 47 children were initially identified for the study. Two patients were excluded because of associated orbital fractures, and two were excluded because of insufficient image quality (Figure 1). Of the remaining 43 children, 35 were boys, and 8 were girls, with a mean age of 11.5 years (median, 12 years; range, 2–17 years). In all patients, the fracture resulted from blunt trauma. The mechanisms of injury included accidental impacts during games or sports-related activities (n = 21), falls (n = 12), assaults (n = 7), and traffic accidents (n = 3).

Main points

- Computed tomography of pediatric orbital floor trapdoor fractures showed that the amount of soft tissue herniating into the maxillary sinus is usually small, and bone displacement at the fracture site is often not apparent.
- The most common change involving the inferior rectus (IR) muscle in pediatric orbital floor trapdoor fractures is tethering of the muscle itself. True muscle incarceration is less common.
- Ocular motility restriction occurred in 100% of patients with IR muscle herniation, 74% of patients with a tethered muscle, and 38% of patients with the IR muscle in a normal position.

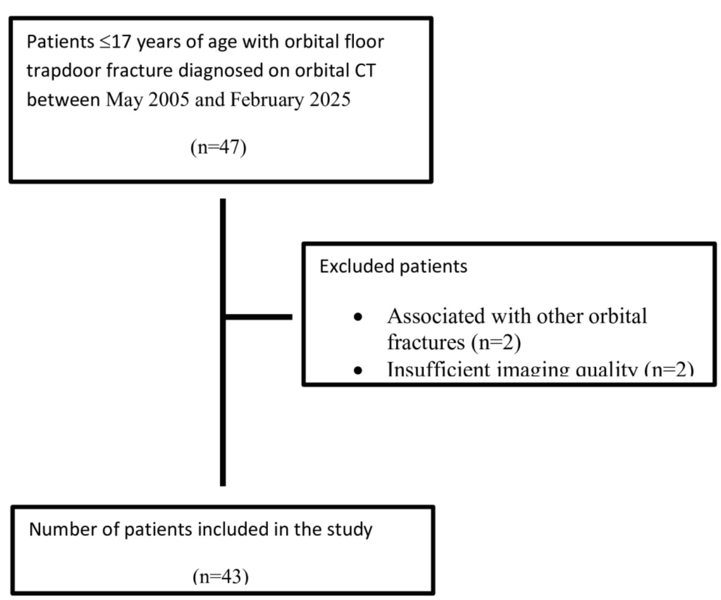

Figure 1. Patient inclusion and exclusion flowchart. CT, computed tomography.

External signs included eyelid swelling, ecchymosis, skin abrasions, mild enophthalmos, mild hypoglobus, mild hyper- or hypotropia, and/or subconjunctival hemorrhage. Transient nausea and vomiting were recorded in 31 patients.

Clinical records documented diplopia in 26 patients and restricted eye movements in 30 patients (restricted upward gaze in 19 patients, restricted upward and downward gaze in 10 patients, and restricted downward gaze in 1 patient) (Figure 2). Four patients with restricted upward gaze also had restricted horizontal gaze. Twelve patients had no gaze restriction. One 2-year-old patient had normal horizontal ductions; however, vertical ductions could not be assessed during the examination.

Computed tomography findings

The CT scanners used included a single-detector spiral CT scanner in 9 patients and 16-slice and 64-slice multidetector CT scanners in 17 and 7 patients, respectively. The remaining 10 patients underwent CT imaging at outside institutions (8 with multidetector CT and 2 with single-detector spiral CT). CT was performed on the day of trauma in 23 patients. For the remaining 20 patients, the mean interval between trauma and imaging was 4 days (range, 2–15 days).

All fractures were linear and located medial to the infraorbital groove. Bone displacement either did not exceed the thickness of the orbital floor or consisted of minimal displacement of the medial fragment, slightly exceeding the thickness of the orbital floor.

We categorized the patients into three groups according to the herniated contents and the IR muscle findings. Group 1 (n = 19) had intraorbital tissue herniation without muscle herniation, but the IR muscle was slightly pulled toward the fracture line, with increased thickness and/or loss of its normal elliptical shape. This constellation of findings was termed the tethered muscle (Figures 3 and 4). Group 2 (n = 13) had only intraorbital tissue herniation into the maxillary sinus, with the IR muscle remaining in its normal position (Figure 5). In five of these cases, the

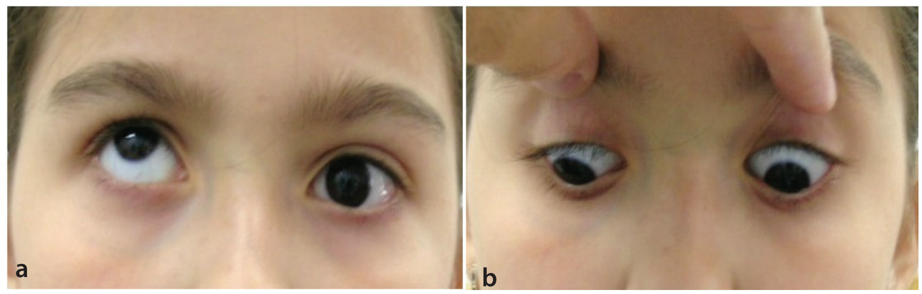

Figure 2. An 8-year-old girl presented with a left orbital floor trapdoor fracture due to an accidental injury during a game. **(a)** Marked limitation of left globe movement on attempted upward gaze. **(b)** Slight limitation of left globe movement on attempted downward gaze. (Informed consent was obtained from the patient's parents for the publication of this image.)

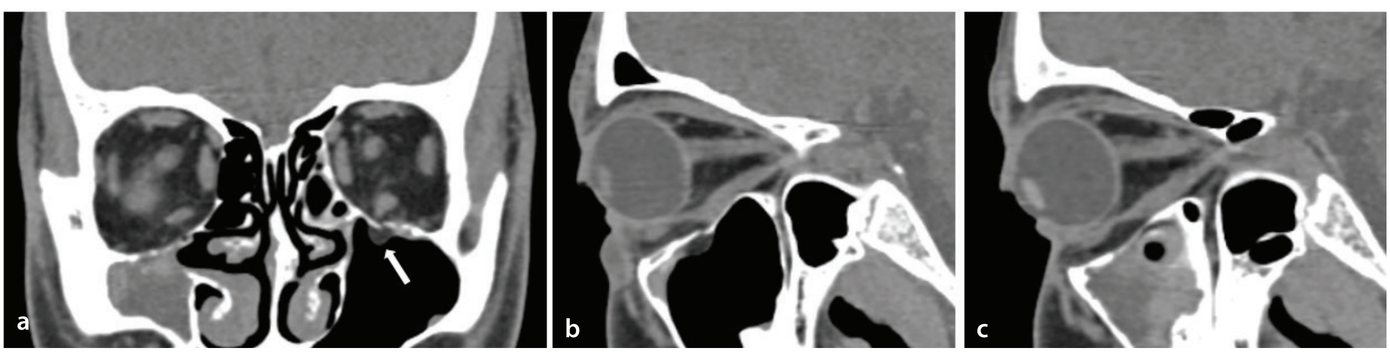

Figure 3. A 14-year-old boy presented with a left orbital floor trapdoor fracture due to an assault. **(a)** Coronal computed tomography (CT) image shows a linear fracture with a subtly depressed medial fracture edge of the left orbital floor. At the roof of the left maxillary sinus, note the herniated and entrapped intraorbital fat tissue (teardrop sign) (arrow). The left inferior rectus muscle is thickened and rounded compared with the contralateral muscle and is also slightly retracted toward the fracture site. **(b)** Sagittal CT image shows that the anterior portion of the left inferior rectus muscle is retracted inferiorly. **(c)** Sagittal CT image of the right orbit for comparison with the inferior rectus muscles.

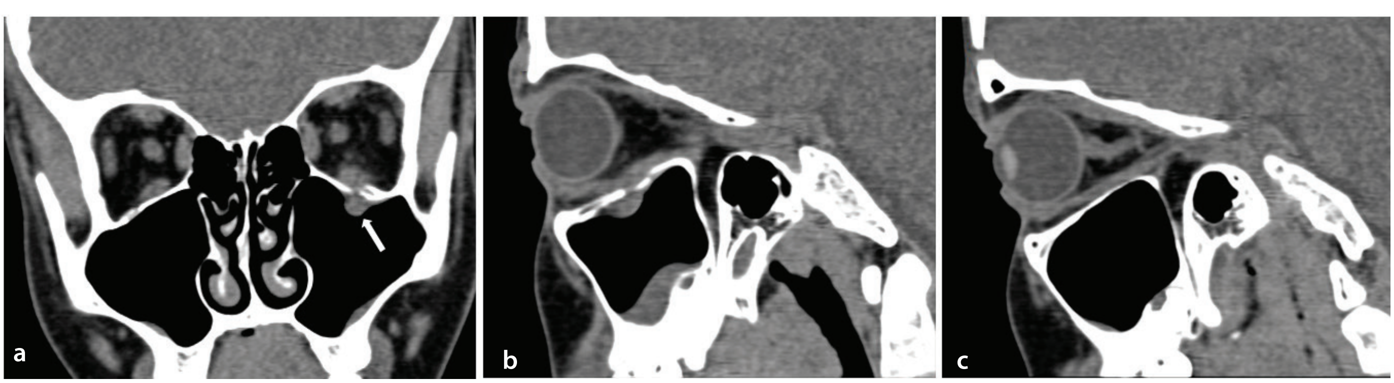

Figure 4. A 14-year-old girl presented with a left orbital floor trapdoor fracture due to a fall. Coronal **(a)** and sagittal **(b)** computed tomography (CT) images show a non-displaced fracture of the left orbital floor with intraorbital soft tissue herniation and entrapment into the left maxillary sinus. The attenuation of the herniated tissue is high, most likely because of hemorrhage and/or edema (arrow). The thickened and rounded left inferior rectus muscle remains within the orbit. However, it is pulled toward the fracture. **(c)** Sagittal CT image of the right orbit for comparison with the inferior rectus muscles.

ipsilateral IR muscle was mildly more rounded and thicker than the contralateral muscle (Figure 6). Group 3 (n = 11) had herniation of both the intraorbital tissue and the IR muscle, which was termed the incarcerated muscle (Figure 7).

On coronal images, the maximum height of the herniated tissue protruding through the fracture into the maxillary sinus (the teardrop sign) ranged from 1.5 to 11 mm (mean, 5.5 mm; median, 5 mm; 5 mm or less in 67.5% of cases). The mean height was 5.2 mm for group 1 (range, 3–8 mm), 5.4 mm for group 2 (range, 1.5–9 mm), and 6.2 mm for group 3 (range, 3–11 mm). There was no statistically significant difference in the height of the herniated contents among the groups (P = 0.348).

The herniated contents contained visible fat density in 26 of 43 patients (60%). In the remaining patients, the herniated contents had a higher attenuation than fat. Subcutaneous emphysema was detected in nine patients. Small air foci were present within the herniated contents in three patients. An air-fluid level was present in the ipsilateral maxillary sinus in 13 patients. These patients underwent CT on the day of the trauma (n = 9) or the following day (n = 4).

In patients who underwent multidetector CT, sagittal images did not alter the interpretation based on the coronal images. However, the osseous abnormalities were more

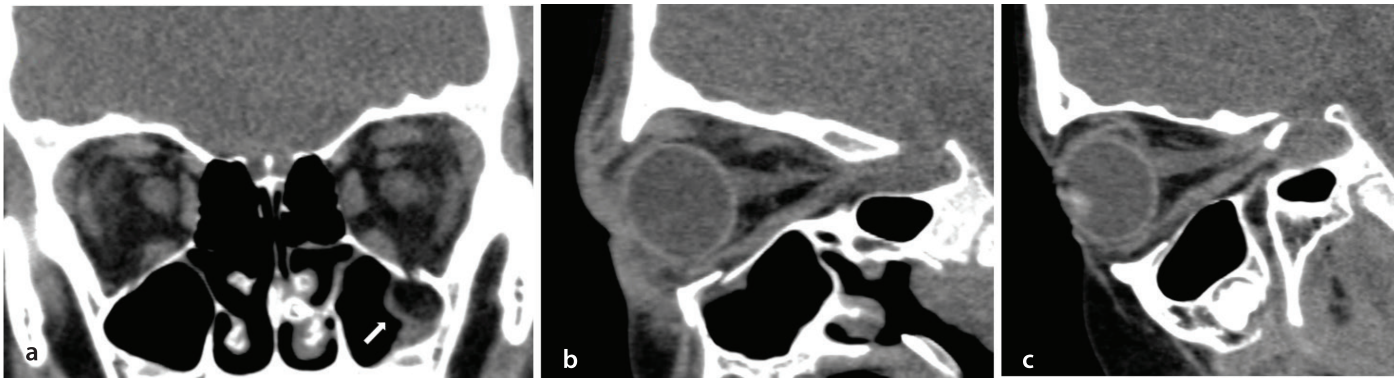

Figure 5. A 7-year-old boy presented with a left orbital floor trapdoor fracture due to a fall. **(a)** Coronal computed tomography (CT) image demonstrates a linear fracture located medial to the infraorbital groove with minimal inferior displacement of the medial fragment. The herniated and entrapped intraorbital soft tissue contains fat (arrow). **(b)** Sagittal CT image shows the fracture. The left inferior rectus muscle has a normal shape and course. The eyelids are swollen. **(c)** Sagittal CT image of the right orbit for comparison with the left inferior rectus muscle.

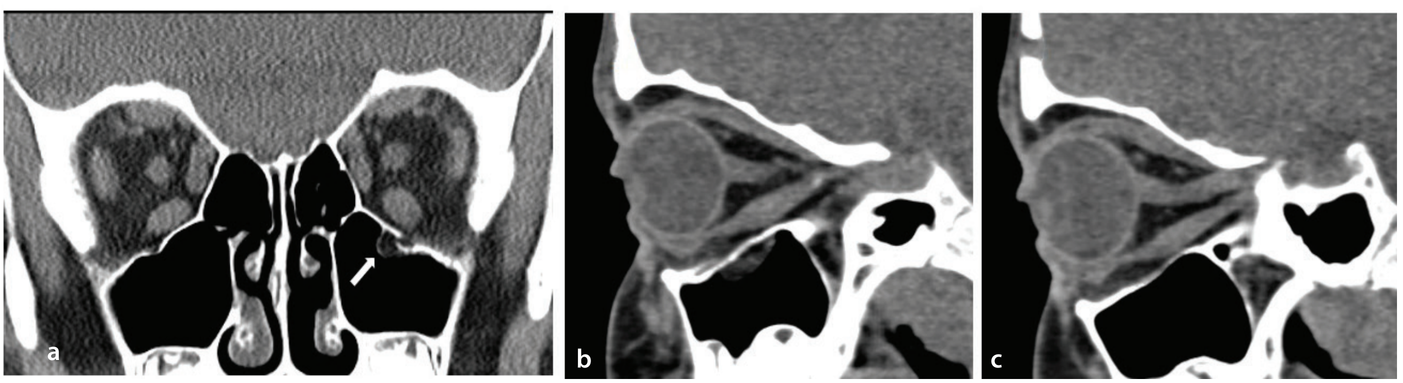

Figure 6. A 12-year-old boy presented with a left orbital floor trapdoor fracture due to a fall. **(a)** Coronal computed tomography (CT) image shows a non-displaced linear fracture of the left orbital floor with minimal herniation of the orbital soft tissue at the roof of the left maxillary sinus (arrow). The left inferior rectus muscle is slightly thicker and rounder than the contralateral muscle. (b and **c)** Sagittal CT images of the left **(b)** and right **(c)** orbits.

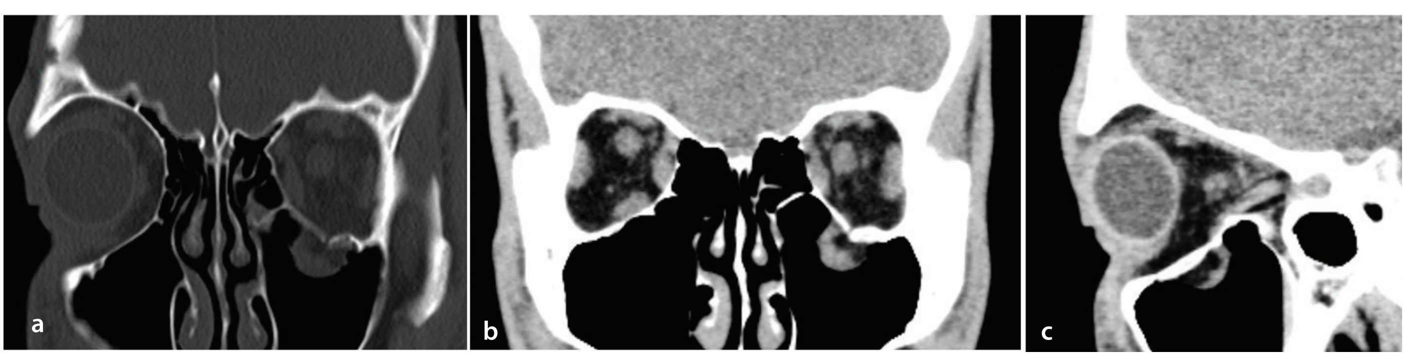

Figure 7. A 17-year-old boy presented with a left orbital floor trapdoor fracture due to an assault. **(a)** Coronal computed tomography (CT) image in a bone window setting shows a linear fracture of the left orbital floor. Coronal **(b)** and sagittal **(c)** CT images in a soft-tissue window setting show inferior rectus muscle incarceration. Note the absent left inferior rectus muscle on the coronal image **(b)**.

evident on sagittal images in some cases (Figures 3–5). This increased the radiologists' level of diagnostic confidence in 15 cases.

Correlation of computed tomography and clinical findings

The distribution of the 30 patients with restricted eye movement among the radiologic groups was as follows: 74% of patients in group 1 (n = 14), 38% of patients in group 2 (n = 5), and 100% of patients in group 3 (n = 11). A significant overall difference in the distribution of restricted eye movement was observed among the three groups (Pearson's chi-square test, P = 0.004). There was no significant difference between group 1 and group 3 (P = 0.129). However, group 2 showed statistically significant differences compared with both group 1 and group 3 (P = 0.046 and P = 0.002, respectively).

Of the 31 patients who underwent surgery, 14 were in group 1, 6 were in group 2, and 11 were in group 3. Twenty-eight of these 31 patients had restricted eye movement. The remaining three patients (2 in group 1 and 1 in group 2) underwent surgery despite having no ocular motility restriction; in these cases, the surgeons opted for surgery because of the large volume of the herniated tissue. Two patients in group 1 with restricted gaze were lost to follow-up after diagnosis.

Among the remaining 9 patients with normal ocular motility (2 in group 1 and 7 in group 2), no restrictive ocular dysmotility developed during follow-up (range, 15 days–33 months). One 2-year-old patient in group 1, whose vertical gaze could not be assessed during the initial evaluation, had normal ocular motility at the 6-week follow-up. There was no significant difference in the height of the herniated tissue between patients with and without restricted eye movement (mean, 5.8 mm; range, 3–11 mm vs. mean, 4.7 mm; range, 1.5–8 mm, respectively; P = 0.456).

Discussion

In this study, we categorized the CT findings of pediatric orbital floor trapdoor fractures according to the position and morphology of the IR muscle. We found isolated intraorbital tissue herniation without any positional change of the IR muscle in 13 patients (group 2; 30%) and true muscle herniation in 11 patients (group 3; 26%) on CT. In the remaining 19 patients (group 1; 44%), we observed subtle deformity of the IR muscle compared with the contralateral side, along with soft tissue herniation. We interpreted this finding as inferior displacement and stretching of the muscle toward the fracture line and termed it a tethered muscle.

The IR muscle is the most commonly entrapped muscle in trapdoor fractures.[3,17] Our series found true muscle incarceration in only 26% of the cases. This result is in agreement with previous studies.[7,18] Pure soft-tissue entrapment is more common than muscle incarceration in orbital trapdoor fractures.

As seen in all of our cases, orbital floor trapdoor fractures are mainly localized medial to the infraorbital groove, which has an anatomical weakness and few supporting structures.[19,20] Bone displacement at the fracture site is usually not apparent.[9] The sagittal plane may complement the coronal plane in demonstrating bone changes. Entrapped soft tissue in the maxillary sinus can be seen as a cyst hanging from the roof of the maxillary sinus in the shape of a teardrop. The size of the herniated tissue is usually small. In our series, two-thirds of the cases had herniated tissue measuring 5 mm or less in longitudinal extent.

Additionally, a significant percentage (40%) of cases did not have readily identifiable fat density within the herniated tissue. However, the absence of fat density does not exclude intraorbital tissue herniation, as hemorrhage and/or edema in the entrapped tissue may increase fat attenuation. In some cases, changing the window setting from the bone window to the soft-tissue window may help detect fat tissue.

An air-fluid level in the maxillary sinus after orbital trauma can be an indirect sign of an orbital floor fracture and may be related to paranasal sinus hemorrhage.[21] In our series, an air-fluid level in the ipsilateral maxillary sinus was detected in 30% of cases. Notably, all of these cases underwent CT on the day of trauma or the following day, suggesting that fluid within the maxillary sinus can be rapidly resorbed after trauma.

Restricted eye movement occurred in 100% of patients in group 3, with group 1 and group 2 following in descending order. The overall difference among the three groups was statistically significant. The restriction of eye movement in group 1 was likely related to muscle tethering. A complex network of fibrous septa connects the sheath of the IR muscle, the surrounding fibro-fatty tissues, and the periosteum of the orbital floor.[22] Because of this orbital pulley network, incarceration of the perimuscular tissue within the herniated segment may lead to muscle tethering and limit its movement.[15,23-25] However, muscle tethering was not observed in group 2, although the height of the herniated tissue did not differ from that in group 1. In some cases, the remaining muscle in its normal position despite intraorbital tissue incarceration may be related to disruption of the fascial sling. Restricted eye movement was detected in 74% of group 1 and 38% of group 2, and this difference was statistically significant.

Six of the group 2 cases had diplopia, and in 5 of these cases, the IR muscle was slightly more rounded and thickened than the contralateral one. The diplopia in these cases might be attributed to direct injury to the extraocular muscles or the innervating nerves rather than to mechanical restriction of the muscle. A study by Neinstein et al.[6] on morphometric CT analysis reported increased length and diameter of the IR muscle on the side of trapdoor fractures, although the differences did not reach statistical significance. In another study, the IR muscle had a more rounded morphology in orbital floor fractures, which might be secondary to loss of bone-soft tissue support, according to the authors.[26]

The literature on pediatric orbital floor trapdoor fractures, which consists primarily of articles in ophthalmology, plastic and reconstructive surgery, and head and neck surgery, reports a high rate of misdiagnosis by radiologists and recommends that surgeons personally evaluate the CT scans.[1,3,5-8,13-15] In three clinical studies, CT evidence of fracture and soft tissue entrapment was missed or underestimated by radiologists in 50%–58% of cases.[5,13,15] Even when a radiologist does not overlook these findings, they can be misinterpreted as retention cysts.[13] However, for most orbital surgeons, surgical exploration and treatment are indicated in the presence of restricted vertical eye movement and other typical clinical findings, even if the CT scan lacks evidence of an orbital floor trapdoor fracture.

High-resolution CT is essential, as the findings of orbital floor fracture and soft tissue herniation may be barely noticeable in pediatric cases.[14] Reviewing the patient charts for findings such as restricted ocular motility and diplopia may alert the radiologist to the possibility of a trapdoor fracture. However, the absence of restricted ocular motility does not rule out the presence of this type of fracture.[3] In 30% of our cases, ocular motility was normal.

If possible, surgery should be performed within a few days of the initial trauma, and the herniated tissue should be completely removed from the maxillary sinus. Delayed surgery may be associated with difficulty in reducing the soft tissue and a higher rate of residual diplopia.[3,6,7,13] The herniated contents and the surgical technique may also be important factors affecting the postoperative prognosis.[11]

The primary limitation of the current study is the potential bias resulting from the observers' non-blinded assessment of the diagnosis. Other limitations include the relatively small number of cases, the retrospective nature of the study, and the relatively long study period, which led to heterogeneity in the CT scanners and imaging parameters used. A prospective study using a uniform imaging technique is needed to evaluate the exact features of orbital floor trapdoor fractures.

In pediatric cases of blunt orbital trauma, CT scans should be carefully evaluated for orbital floor fractures, as well as orbital soft tissue herniation and the alignment and shape of the IR muscle compared with the contralateral side. A teardrop-shaped soft tissue density at the roof of the maxillary sinus suggests a trapdoor fracture. The most common IR muscle-related finding in pediatric orbital floor trapdoor fractures is muscle tethering. True muscle incarceration is less common than soft tissue entrapment. The herniated soft tissue is usually small and lacks fat density in a considerable number of cases. An air-fluid level in the maxillary sinus may provide another clue to an underlying orbital floor fracture. Sagittal reformatted images may also be helpful in the diagnosis of trapdoor fractures.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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