Analysis and Frequency of Computed Tomography Findings in Traumatic Globe Injuries: Are the Anterior Chamber Depth and Optic Nerve Sheath Diameter Affected in Globe Injuries?

Travmatik Glob Yaralanmalarında Orbita Bilgisayarlı Tomografi Bulgularının Analizi ve Frekansı: Glob Yaralanmalarından Ön Kamara Derinliği ve Optik Sinir Kılıfı Çapı Etkileniyor mu?

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ABSTRACT

Objective: Our aim was to evaluate the characteristic computed tomography (CT) findings in globe and other orbital injuries, investigate the changes in the anterior chamber depth (ACD), and determine whether globe injuries affect the optic nerve sheath diameter (ONSD).

Material and Methods: A total of 691 patients who underwent orbital CT due to orbital trauma were retrospectively analyzed. Two radiologists evaluated the CT images and measured the ONSD at 3 mm and 5 mm posterior to the globe for both eyes in addition to the ACD, without knowledge of ophthalmologic examination findings. The reliability of the measurement of the two observers was evaluated by inter-class correlation (ICC) analyses.

Results: There were 486 men and 205 women in the study group. Globe injuries were detected in 55 patients (8%). Blunt traumas constituted 92% of all orbital traumas, and globe injuries were detected in 3.5% of blunt traumas. Lens dislocation and vitreous hemorrhage were the most common CT findings in closed-globe injuries. ICC between the observers was found to be excellent in ONSD and ACD measurements. ACD was lower in globe rupture (p=0.001). The best cut-off value for ACD for detecting globe rupture was 2.475 mm. There was no statistically significant difference between the injured and non-injured globes on ONSD measurement.

Conclusion: It is well known that ophthalmologic examination is the key method for the rapid and accurate diagnosis of most ocular injuries. In cases where ophthalmological examination cannot be performed properly such as severe facial injury, radiological imaging becomes a powerful tool in the diagnosis of ocular injury when combined with ophthalmological examination. Globe contours in closed-globe injuries are generally normal, and the identification of changes in the shape and position of the lens and an anterior chamber depth lower than 2.5 mm are significant for globe rupture.

Keywords: Anterior chamber, Multidetector computed tomography, Ocular rupture, Orbital fractures

ÖZ

Amaç: Çalışmadaki amacımız, göz küresi ve diğer orbital yaralanmalardaki karakteristik bilgisayarlı tomografi (BT) bulgularını değerlendirmek, ön kamara derinliğindeki değişiklikleri araştırmak ve göz yaralanmalarında optik sinir kılıf çapının etkilenip etkilenmediğini belirlemektir.

Gereç ve Yöntemler: Travmaya bağlı orbita BT çekilen 691 hasta acil radyoloji konusunda deneyimli 2 radyoloji uzmanı tarafından retrospektif olarak analiz edildi. Üç ve 5. mm'lerde optik sinir kılıf çapları ve ön kamara derinlikleri oftalmolojik muayene bulgularından habersiz olarak ölçüldü. İki gözlemcinin ölçümünün güvenilirliği gözlemciler arası korelasyon analizleri ile değerlendirilmiştir.

Bulgular: Çalışma grubunda 486 erkek ve 205 kadın vardı. 55 (% 8) hastada göz yaralanması saptandı. Künt travmalar tüm orbital travmaların % 92'sini oluşturmaktaydı ve künt travmaların % 3,5'inde göz yaralanması saptandı. Kapalı tip göz yaralanmalarında göz küresi hacmi normal olup, duvar defekti saptanmazken lens dislokasyonu ve vitröz hemoraji en sık karşılaşılan BT bulgularıydı. Ön kamara derinliği ve optik sinir kılıf çapı ölçümlerinde gözlemciler arası uyum mükemmeldi.

Yaralanan gözde ön kamara derinliği normal göze göre düşüktü (p=0.001). Göz yaralanması açısından, ön kamara derinliğinde en iyi kesim noktası 2.475 mm olarak hesaplandı. Optik sinir kılıf çapı ölçümlerinde yaralanmış ve normal göz arasında istatistiksel olarak anlamlı bir fark yoktu.

Sonuç: Oküler yaralanmaların hızlı ve doğru tanısında anahtar yöntem oftalmolojik muayenedir. Ciddi yüz yaralanması gibi oftalmolojik muayenenin uygun yapılamadığı durumlarda, radyolojik görüntüleme, oftalmolojik muayene ile kombine edildiğinde oküler yaralanma tanısında güçlü bir araç hâline gelir. Kapalı göz yaralanmalarında göz konturları genellikle normal olup lensdeki şekil ve pozisyon değişiklikleri ve 2,5 mm'den daha dar ön kamara göz yaralanması tanısı açısından anlamlıdır.

Anahtar Sözcükler: Göz yaralanması, Multidedektör bilgisayarlı tomografi, Orbita fraktürleri, Ön kamara

INTRODUCTION

Traumatic globe injury is an important cause of vision loss and deficit. The overall prevalence of trauma-related ocular injury is between 2% and 6%, and most cases (97%) result from blunt trauma (1). Motor vehicle accidents and sports-related injuries are common causes of orbital trauma (2, 3).

An ophthalmologic examination is difficult in patients with severe eye injury. The eye may be swollen, which makes a funduscopic examination impossible. The patient may not be able to cooperate or respond, making it difficult to assess visual acuity or ocular movement (1,2,4,5). Radiologists should be familiar with potential eye injuries and their imaging correlations for an accurate and rapid radiological diagnosis to provide appropriate guidance for treatment (1,2,5). The imaging method to be preferred in orbital trauma is computed tomography (CT). Ultrasound (US) is contraindicated in suspected cases of ruptured globe. Magnetic resonance (MR) imaging is not only difficult to perform in emergent cases but it is also contraindicated in patients suspected to have metallic intraorbital foreign bodies. The best results are also obtained with CT in fracture and intraocular foreign body explorations (1-5). High-resolution images and 3D reconstruction can be obtained by multidetector computed tomography (MDCT) (4).

The lens divides the globe into the anterior segment containing the aqueous humor and the posterior segment containing the vitreous humor. The iris divides the anterior segment into the anterior and posterior chambers (1,2). The vast majority of injuries occur in the anterior part of the globe. The iris may prolapse into the anterior chamber in corneal lacerations, in which case the anterior chamber becomes shallow (1-3,5). On the other hand, it is reported that the anterior chamber may become deeper than the normal side in posterior scleral ruptures (6).

Any ruptured globe or open-globe injury should be investigated in patients with orbital trauma, because blindness may develop in such injuries (1,2). A change in globe contour and decrease in globe volume are the major CT findings of globe rupture (2,3,7). There is no full-thickness interruption on the surface of the eyeball in closed-globe injuries which usually present with retinal detachment and vitreous hemorrhage (8, 9). Lens dislocations are also reported in closed-globe injuries (10).

In this study, our aim was to evaluate patients with orbital trauma in terms of globe and orbital injuries on CT, reveal the characteristic CT findings, and investigate the changes in the anterior chamber depth (ACD). Increased intracranial pressure secondary to traumatic brain injuries causes an increase in the optic nerve sheath diameter (ONSD) (11, 12). In order to answer the question of whether globe injuries affect ONSD, we measured this diameter in patients with globe injury.

METHODS

Ankara City Hospital Clinical Research Ethics Committee approval was taken for the study (Decision number and date: 20-492, 30/04/2020). The study was carried out in accordance with the Helsinki Declaration principles and research and publication ethics were followed. A total of 691 patients who underwent non-contrast orbital CT due to orbital trauma between Feb 20, 2019 and Jan 30, 2020 were included in the study. Patients with previous eye disease, surgery, or trauma history were not included. A complete or incomplete ophthalmologic examination was performed before the CT examination. CT was performed using a MDCT scanner (Revolution EVO, GE Healthcare 128 detectors, USA) with the following standard acquisition parameters: 249 mA, 120 kVp, 0.75 pitch, and 0.5-s rotation time. Images in the transaxial plane between the inferior rim of the maxillary sinus and the middle portion of the frontal region parallel to the optic nerve with a 0.625 mm slice thickness were obtained, and additional coronal reformatted images with a 0.6 mm slice thickness and sagittal reformatted images with a 1.5 mm slice thickness were added to the protocol using the multidetector CT (MDCT) technique. Two radiologists experienced in emergency radiology retrospectively analyzed the CT sections without knowledge of ophthalmologic findings. Globe integrity, presence of foreign bodies, anterior and posterior chambers, retroorbital adipose tissue, lens position and shape, intraorbital muscles, and orbital bones were examined in terms of traumatic findings. The measurements were undertaken on the picture archiving and communication system (PACS) workstation using electronic calipers. Two radiologists independently performed the measurement of bilateral ONSD at distances of 3 mm and 5 mm behind the globe, immediately below the sclera in a perpendicular vector with reference to the linear axis of the nerve. Furthermore, the ACD of the globe was measured at the level of the equator of the globe, from the posterior of the cornea to the anterior surface of the lens, along a line perpendicular to the long axis of the lens in a soft tissue window setting. ACD was not measured in cases where the lens was dislocated or not visible.

Statistical Analysis

Statistical analysis was performed using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA). In descriptive statistics, the normally distributed data were determined by the one-sample Kolmogorov-Smirnov test and the continuous variables that were not normally distributed were expressed as median (min-max), while categorical variables were expressed in numbers and percentages. The Mann Whitney-U test was used to compare the continuous variables between the two groups. The differences between the categorical variables were calculated by the chi-square test. The reliability of the measurement of the two observers was evaluated by inter-class correlation (ICC) analyses. After this calculation, the mean of the measurements of the two observers was included as the exact diameter to perform further analyses. The predictive value of the anterior chamber diameter in globe rupture was shown by ROC analyses, and the best cut-off point, sensitivity and specificity were calculated. A p value of <0.05 was considered statistically significant.

RESULTS

There were 486 men and 205 women in the study group. The age of the patients ranged from five to 102 years (mean, 40±22.1 years). Globe injuries were seen in 8.0% of all patients (n=55). Forty percent (n=22) of the globe injuries were blunt, 47.3% (n=26) were penetrating, and 12.7% (n=7) were blast injuries (Table 1). Globe injuries constituted 3.5% of all blunt injuries, whereas seven (77.8%) globe injuries were detected in nine blast trauma cases. Three patients had bilateral globe injuries secondary to blast exposure. Among patients with globe injuries, lens injury was seen in 41 (74.5%) of 55 patients and vitreous hemorrhage in 32 (58 %). While the rate of

Table I: Demographic characteristics and computed tomography findings according to type of trauma.

		Total	Type of trauma		
			Blunt	Penetrating	Blast
		n=691 (%)	n=636 (%)	n=46 (%)	n=9 (%)
Age (years)		40 ± 22.1	40.5 ± 22.3	34.4 ± 17.8	32.9 ± 23.3
Gender	Male	486 (70.3)	446 (70.1)	37 (80.4)	3 (33.3)
	Female	205 (29.7)	190 (29.9)	9 (19.6)	6 (66.7)
Lens	Intact	650 (94.1)	617 (97)	30 (65.2)	3 (33.3)
	No lens	19 (2.7)	10 (1.6)	5 (10.9)	4 (44.4)
	Traumatic cataract	11 (1.6)	2 (0.3)	8 (17.4)	1 (11.1)
	Dislocation	5 (0.7)	4 (0.6)	-	1 (11.1)
	Subluxation	2 (0.3)	1 (0.2)	1 (2.2)	-
	Traumatic cataract + dislocation	3 (0.4)	2 (0.3)	1 (2.2)	-
	Traumatic cataract + subluxation	1 (0.1)	-	1 (2.2)	-
Globe volume	Normal	663 (95.9)	623 (98)	36 (78.3)	4 (44.4)
	Reduced	24 (3.5)	11 (1.7)	9 (19.6)	4 (44.4)
	Increased	4 (0.6)	2 (0.3)	1 (2.2)	1 (11.1)
Foreign bodies in the globe		15 (2.2)	-	12 (24.1)	3 (33.3)
Orbital wall fracture		149 (21.6)	136 (21.4)	6 (13)	7 (77.8)
Blowout fracture		38 (5.5)	37 (5.8)	1 (2.2)	-
Intraorbital hematoma		38 (5.5)	27 (4.2)	5 (10.9)	6 (66.7)
Rectus sheath hematoma		35 (5.1)	28 (4.4)	5 (10.9)	2 (22.2)
Accompanying brain injury		24 (3.5)	21 (3.3)	-	3 (33.3)

vitreous hemorrhage was 54% in blunt traumas, this rate was 85% in blast traumas (Table 2). The globe volume was normal in 27 (49.1%) of 55 globe injury cases, while volume changes were detected in 28 (50.9%) patients, of whom 24 had a decreased volume (Figure 1). The most common CT findings in closed-globe injuries were lens dislocation (n=4) and vitreous hemorrhage (n=2) (Figure 2). In these patients, the globe volume was normal, and there was no wall defect, which were also confirmed by an ophthalmologic examination. There were two optic nerve injuries, one blunt and the other due to penetrating trauma. In one, the connection of the left globe with the optic nerve and rectus muscles was completely impaired. The left globe was visualized in the pre-maxillary region outside the orbit (traumatic enucleation) (Figure 3). In 11 (7.4%) of 149 patients with orbital wall fractures, the fracture was accompanied by globe injuries (p=0.769).

ICC between the observers was found to be excellent in ONSD and ACD measurements (Table 3). ONSDs were similar in injured and non-injured globes, and there was no statistically significant difference between the two groups (Table 4). ACD measurements were successfully performed in 20 patients. The median ACD was 1.90 mm (1.25-3.40) in injured globes and 2.75 mm (1.60-3.65) in non-injured globes (p=0.001) (Table 4) (Figure 4).

ACD was lower in patients with globe rupture (p=0.001) (Figure 5). The ROC curve of ACD in identifying globe rupture is shown in Figure 6. The area under the curve (AUC) was 0.799 (range, 0.653-0.945 at the 95% confidence interval). The best cut-off point of ACD in the ROC curve was calculated as 2.475 mm. At this cut-off, ACD had a sensitivity of 73.7% and specificity of 88% in detecting globe rupture.

DISCUSSION

In this study, blunt traumas constituted the majority of orbital injuries (92%). However, the rate of globe injuries was lower (3.5%) in blunt traumas compared to penetrating and blast traumas. This rate was highest in blast traumas at 77% (7/9 patients). Today, blast injuries are increasing

Table II: The characterization of globe rupture on computed tomography according to type of trauma.

	Total n (%)	Type of trauma		
		Blunt n (%)	Penetrating n (%)	Blast n (%)
Globe rupture	55 (8)	22 (3.5)	26 (56.5)	7 (77.8)
Open-rupture	47 (85.5)	14 (63.6)	26 (100)	7 (100)
Closed-rupture	8 (14.5)	8 (36.3)	-	-
Side (globe rupture)				
Right	22 (40)	8 (36.4)	13 (50)	1 (14,3)
Left	30 (54.5)	14 (63.6)	13 (50)	3 (42,9)
Bilateral	3 (5.5)	-	-	3 (42,9)
Vitreous hemorrhage				
Absent	23 (41.8)	10 (45.5)	12 (46.2)	1 (14.3)
Present	32 (58.2)	12 (54.5)	14 (53.8)	6 (85.7)

Table III: Inter-observer agreement in measurements.

	Observer 1	Observer 2	ICC	95% confidence interval		p
	Mean ± SD			Lower limit	Upper limit	
ONSD3 - right	5.4 ± 0.8	5.6 ± 0.8	0.928	0.879	0.958	<0.001
ONSD3 - left	5.4 ± 0.9	5.5 ± 0.9	0.870	0.783	0.923	<0.001
ONSD5 - right	4.9 ± 0.8	5.2 ± 0.8	0.932	0.884	0.960	<0.001
ONSD5 - left	5.0 ± 0.8	5.1 ± 0.8	0.922	0.869	0.954	<0.001
Anterior chamber - right	2.7 ± 0.6	2.6 ± 0.6	0.934	0.883	0.963	<0.001
Anterior chamber - left	2.7 ± 0.6	2.6 ± 0.6	0.950	0.910	0.972	<0.001

SD: standard deviation, **ICC:** inter-class coefficient, **ONSD:** optic nerve sheath diameter, **ONSD3:** measurement at 3 mm, **ONSD5:** measurement at 5 mm

Figure 1: Axial non-contrast CT image of a 33-year-old man after blunt trauma. Prominent volume loss and contour irregularity are seen in the left globe secondary to open-globe injury.

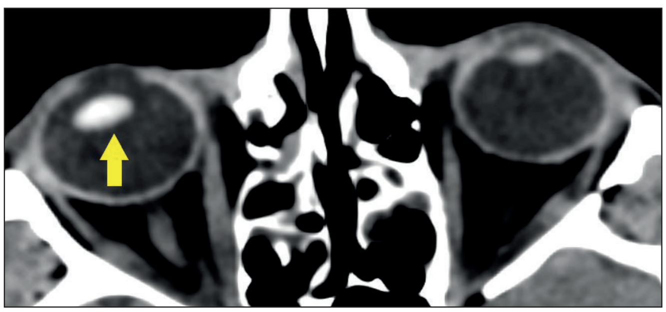

Figure 2: Closed-globe injury with normal globe contours in a 62-year-old man. Dislocation of the lens into the vitreous humor is seen in the right eye (arrow).

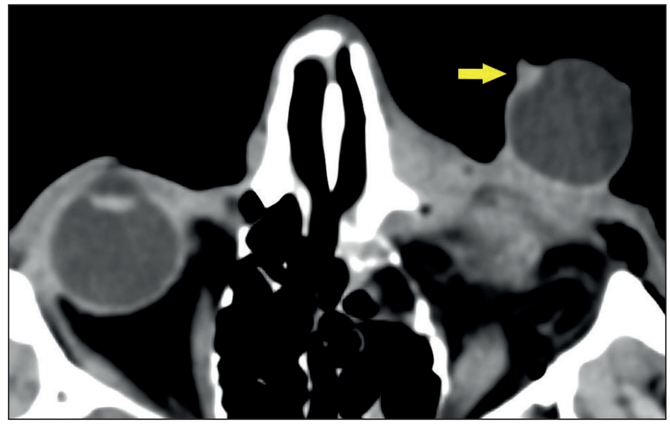

Figure 3: Axial non-contrast CT image of a 43-year-old man who had fallen onto the faucet in the bath. The left globe is displaced in the premaxillary region. Note the totally ruptured optic nerve (arrow).

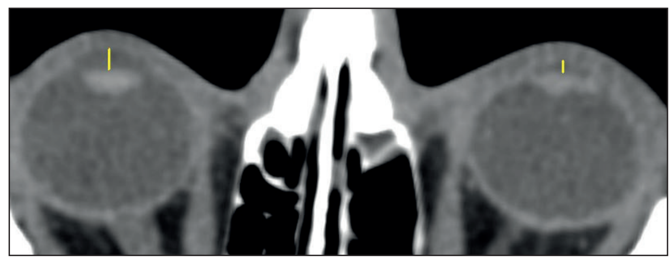

Figure 4: A shallow anterior chamber on the left side compatible with a globe injury in a 28-year-old man. The left lens is flattened with reduced density (traumatic cataract).

Table IV: Pathologies and tomographic measurements in globe injuries.

	Globe injury		p*
	Present n (%)	Absent n (%)	
Gender			
Female	20 (9.8)	185 (90.2)	0.257*
Male	35 (7.2)	451 (92.8)	
Type of trauma			
Blunt	22 (3.5)	614 (96.5)	<0.001*
Penetrating	26 (56.5)	20 (43.5)	
Blast	7 (77.8)	2 (22.2)	
Orbital wall fracture	11 (7.4)	138 (92.6)	0.769*
Blowout fracture	-	38 (100)	0.064*
Rectus sheath hematoma	3 (8.6)	32 (91.4)	0.753*
Accompanying brain injury	3 (12.5)	21 (87.5)	0.429*
	Injured globe	**Non-injured globe**	
ONSD3 (mm)	5.35 (3.7-7.8)	5.4 (3.8-7.7)	0.907**
ONSD5 (mm)	5.05 (3.4-7.2)	4.90 (3.5-7.40)	0.569**
ACD (mm)	1.90 (1.25-3.40)	2.75 (1.60-3.65)	0.001**

*Chi-square test, **Mann-Whitney-U test, **ONSD:** optic nerve sheath diameter, **ONSD3:** measurement at 3 mm, **ONSD5:** measurement at 5 mm

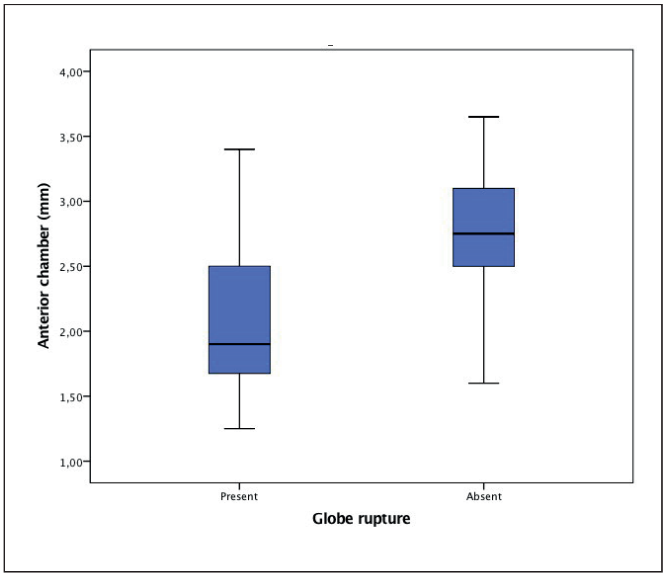

Figure 5: The depth of the anterior chamber according to globe rupture.

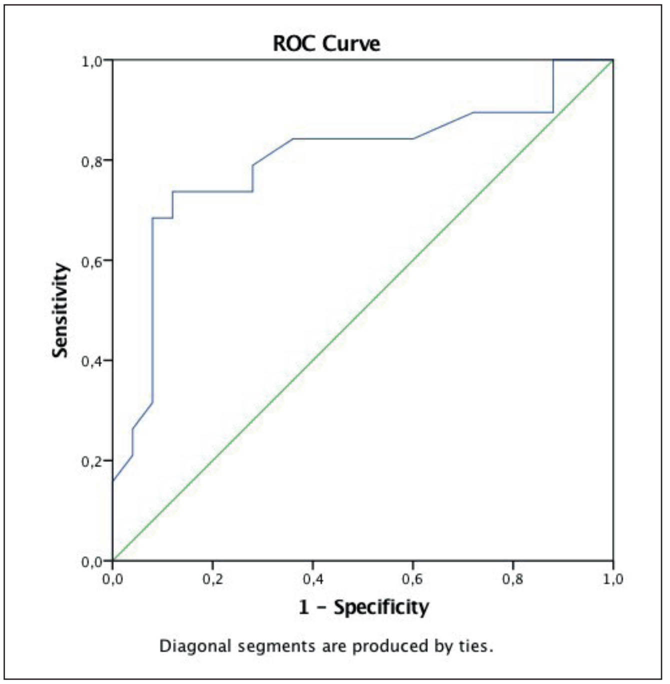

Figure 6: The ROC curve of the anterior chamber depth according to globe rupture.

in parallel to the growing number of explosions related to terrorism. Globe injuries can be in the form of primary or secondary blast injuries. Blast waves are the cause of primary blast injuries in which direct tissue damage occurs. Secondary blast injuries (SBIs) are penetrating injuries caused by explosive particles or environmental fragments. SBIs are the most common injury type in explosion events (1, 13). The most common eye injuries in blast injuries are corneal lacerations, open-globe injuries, intraocular foreign bodies, and vitreous hemorrhage (1). The most common blast eye injuries in our study were open-globe injury, vitreous hemorrhage, and lens injury. We detected bilateral globe injury in three patients, and all were blast injuries.

The reported sensitivity of CT for detecting an open-globe injury is 56 to 75% (1,7,14). Changes in the attenuation, position and shape of the lens assist in the diagnosis in cases where the globe is normal in contour and volume. In our study, we detected lens injury in 41 (74%) of 55 patients diagnosed with globe injuries. The presence of lens dislocation facilitated the diagnosis in four of the eight closed-globe injuries in which the globe contour and volume were normal. Without the lens dislocation finding, these injuries may have been overlooked. The maximum average depth of the normal anterior chamber is between 2.4 and 3.5 mm, and the depth may vary depending on the age and gender of the patient (4). The difference between the ACDs of normal and injured eyes and shallow AC on the affected side are indirect findings of the globe injury (2, 4, 7). In patients detected to have a shallow AC, Yuan et al. measured the average ACD as 1.5 mm on the injured side and 3.1 mm in the non-injured side (4). Kim et al. considered a difference in ACD exceeding 0.4 mm between the two globes as a diagnostic finding of globe rupture (7). In our study, ACD was measured as 1.9 mm on the injured side and 2.85 mm on the non-injured side. The anterior chamber was statistically significantly shallower in the injured globe than in the non-injured globe. The best cut-off value for ACD in identifying globe injury was calculated as 2.475 mm.

The relationship between intracranial pressure increase secondary to head trauma and ONSD measurements is frequently reported in the literature. An enlarged ONSD is an independent factor for mortality, poor prognosis, and severity of traumatic brain injury (11,12,15). However, we did not find any study in the literature that evaluated the effect of intraocular pressure changes in globe ruptures on ONSD. In the current study, in which this relationship was investigated for the first time, we did not observe a statistically significant difference in the ONSD measurements performed on the injured and non-injured sides at 3 and 5 mm.

CT is the ideal imaging method in fracture evaluation (1-4). Orbital wall fractures may be accompanied by globe injuries. In the literature, the risk of ocular injury in trauma-related facial fractures has been reported to vary between 0.32% and 10.8% (16). In their study on orbital wall fractures, Cook et al. found orbital injuries requiring an urgent ophthalmological intervention in 23 (6.3%) of

365 orbital fractures, of which two were identified as globe rupture (17). In our study, only 11 of the 149 patients (7.4%) who had orbital wall fractures also presented with globe injuries, indicating no significant relationship between orbital wall fractures and globe injuries. Again in our study, 38 of the fractures were blow-out and 37 occurred secondary to blunt trauma, and the most common type of blunt trauma was physical assault (63.1%). None of the cases with blow-out fractures were accompanied by globe injuries. Shere et al., who evaluated midfacial and blow-out fractures among American soldiers, reported the rate of globe rupture in cases with blowout fractures as 2.6% (30/1141) (18). In another study exploring the relationship between orbital fractures and ocular injuries, He et al. found two (0.83%) patients with globe rupture among 240 cases of blow-out fractures (19).

There are some limitations to this study. The ophthalmological examination findings were only evaluated in cases in which globe injuries were detected by CT. Therefore, false negative cases were not evaluated. In the future, a comprehensive study by evaluating the ophthalmologic findings of patients with normal tomographic findings is planned. Furthermore, it is sometimes not possible to place trauma patients in a proper position in the gantry. In such cases, a symmetrical appearance in both eyes cannot be achieved in every patient. In the current study, a symmetrical appearance was obtained using a dedicated workstation to perform measurements. Lastly, the small size of the anatomical structures made the measurement process difficult in certain cases.

CONCLUSION

Traumatic eye injuries are associated with blindness and visual loss; thus rapid diagnosis of the injuries is essential. An ophthalmological examination is the first and most important diagnostic method, but in the presence of serious injuries that obstruct this examination, characteristic CT findings can also assist in diagnosis and guide treatment. In closed-globe injuries where globe contours are normal, changes in the shape, position and density of the lens and a shallow anterior chamber (<2.475 mm) can help diagnosis of the globe rupture.

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Conflict of Interest: The authors declare that there is no conflict of interest.

Ethics Committee Approval: This research complies with all the relevant national regulations, institutional policies and is in accordance the tenets of the Helsinki Declaration, and has been approved by the Ankara City Hospital No.1 Clinical Research Ethical Committee, Ministry of Health (approval number: 2020/20-492).

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