Changing Trends in Paintball Sport–Related Ocular Injuries

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Objectives: To describe the type and severity of ocular injuries caused by paintballs, to summarize the outcomes, to determine if the injury occurred in a commercial or noncommercial setting, to compare the number of injuries in each setting as a function of time, and to ascertain whether eye-protective devices were worn and why they were removed.

Design: Retrospective analysis of 35 patients who sustained ocular injuries caused by paintballs and underwent evaluation and treatment at an eye hospital from January 1, 1985, to September 30, 1998. Thirty-five eyes of 35 patients underwent a complete ocular examination, diagnostic testing, and surgical intervention when indicated.

Results: All patients were male (average age, 22 years). Twenty-six patients (74%) had an initial visual acuity of 20/200 or worse, and visual acuity in 16 (46%) remained 20/200 or worse on follow-up (range, 2 weeks to 22 months). Traumatic hyphema was seen in 21 patients (60%). Twenty-two patients (63%) had access to goggles, 7 (33%) of whom removed them due to fogging before the injury. Injuries sustained after 1995 were 5.8 times (relative risk, 5.8; 95% confidence interval, 1.5-22.4) more likely to occur during a noncommercial war game than those occurring in 1995 or before.

Conclusions: As the popularity of war games increases, so does the potential for serious ocular injury caused by paint pellet guns. Most injuries seen after 1995 occurred in noncommercial war game settings, where the use of eye-protective devices is not required. Industry standards for eye protection have been developed recently and should be implemented.

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The term “war game” refers to an outdoor recreational activity in which 2 competing teams attempt to capture their adversary’s flag while shooting one another with paintballs fired from carbon dioxide (CO2)-powered guns. The paintballs are small (17 mm in diameter) gelatin projectiles filled with nontoxic, water-soluble paint that are intended to explode on contact with an object (Figure 1). When a paintball strikes a player, it releases the paint and marks the player as hit and out of the game. The CO2-powered guns (Figure 2) fire the paintballs at speeds up to 90 m/s (300 ft/s). The increasing popularity of war games, the use of paintball guns for certain military training exercises, and the increasing availability of these weapons for informal use has contributed to an epidemic of ocular injuries.

In this series, we describe 35 patients who sustained ocular injuries after being struck by paintballs. The clinical findings and reasons for failure to wear eye-protective devices (EPDs) are discussed. A review of the current literature, including recently developed industry standards for eye protection, is provided.

RESULTS

The 35 patients (35 eyes) were referred to Wills Eye Hospital. The results are summarized in the Table. Patient age ranged from 13 to 51 years (mean, 22 years). All patients were male. Twenty-six patients (74%) had an initial visual acuity of 20/200 or worse. Twenty-seven patients (77%) required hospital admission; 14 (40%) required ocular surgery. Visual acuity in 16 patients (46%) remained 20/200 or worse on follow-up ranging from 2 weeks to 22 months (mean follow-up, 7 months).

The ocular injuries sustained included choroidal rupture (Figure 3) in 6 eyes (17%), traumatic hyphema (Figure 4) in 21 eyes (60%), commotio retinae (Figure 5) in 16 eyes (46%), vitreous hemorrhage in 17 eyes (49%), trau-
PATIENTS AND METHODS

From January 1, 1985, through September 30, 1998, a total of 35 patients who sustained ocular injury secondary to a paintball fired from a paintball gun underwent evaluation in the emergency department or were referred to specialty services at Wills Eye Hospital, Philadelphia, Pa. A retrospective analysis of these cases reviewed the following information from the patients' medical records: age, sex, initial and follow-up visual acuities, results of ophthalmic physical examination, results of other ancillary studies, medical or surgical treatment, whether EPDs were worn, and the reason for removal of goggles, if applicable.

Ocular injuries caused by paintballs are similar to those occurring after other types of blunt ocular trauma. The mechanisms of injury to the globe involve coup and contrecoup injuries and anterior-posterior compression with equatorial expansion (Figure 6). Large objects that cause diffuse periorbital impact usually cause mild ocular damage because the force is absorbed by the orbital margin. In contrast, a sharply localized impact usually results in significant ocular damage, especially with small, high-speed objects. In addition, Zwaan et al8 point out that since paintballs are designed to rupture on impact, there is no exit wound, and all of the energy is released at the site of impact. Therefore, tissue damage is proportional to the product of projectile mass and the square of the impact velocity. The small size, relatively high mass, and most important, high velocity of paintballs fired from CO2-powered guns explain their ability to cause severe ocular injury.

The most common anterior segment injuries following blunt ocular trauma include hyphema, dislocation of the crystalline lens, traumatic cataract, angle recession, and iridodialysis. Indeed, the most common anterior segment injury seen in our series was hyphema, occurring in 60% of the injured eyes. This finding is similar to those of previous studies by Easterbrook and Pashby7 and Zwaan and associates,6 who reported hyphemas in 86% and 82% of cases, respectively. Traumatic cataract occurred in 20% of eyes in our series, of which 2 required cataract extraction.

The most common posterior segment injuries following blunt ocular trauma include commotio retinae, choroidal rupture, retinal breaks and dialyses, and vitreous hemorrhage. Similarly in our series, the most common posterior segment injuries were vitreous hemorrhage and commotio retinae, occurring in 49% and 46% of the injured eyes, respectively. Choroidal rupture, retinal detachment, retinal dialysis, and open globe injury were also seen. Five patients required exploration for an open globe injury, 4 required a scleral buckle procedure, 2 required a pars plana vitrectomy, and 2 underwent enucleation.

All of the patients in this series were male. Male patients are 4 times more likely than female to sustain ocular injuries, many of which are sports related. Younger persons are also more likely to have ocular injuries.

Figure 1. Paintballs are small gelatin projectiles filled with nontoxic, water-soluble paint.

Figure 2. Paintball guns are powered by compressed carbon dioxide and fire the paintballs at speeds up to 90 m/s (300 ft/s).
mean age of patients sustaining paintball injuries in this series was 22 years, the youngest patient, aged 13 years.

Most of the previous case reports and case series regarding ocular injuries during war games involve commercialized war games. Standard practice procedures for paintball field operation have been established by the American Society for Testing and Materials (ASTM), which specify minimum safety requirements, including the presence of referees; required eye, ear, and face protection; and the use of gun barrel plugs that prevent inadvertent discharge of a paintball. More recently, the military has adopted paintball guns in training exercises, and ocular injuries were described in military personnel who removed their goggles during such exercises. Because the potential for injury had been recognized and addressed by commercial war game sponsors and the military, the use of an EPD is mandatory in all commercial war games and military exercises where paintballs are used. In Canada, the number of yearly eye injuries resulting from war games decreased from 26 in 1985 to 3 in 1992. This dramatic decrease was attributed to education in the proper use of EPDs and litigation. However, eye injuries are still occurring during unsupervised, non-commercial war games. In our series, injuries sustained after 1995 were 5.8 times more likely to occur during a non-commercial war game than those occurring in or before 1995. This increased risk for eye injuries associated with non-commercial war games may be related to less use of EPDs. In our series, 12 (92%) of 13 patients injured during commercial war games used an EPD, whereas only 9 (41%) of 22 patients injured during non-commercial war games did.

It is estimated that the proper use of EPDs may lead to the prevention of up to 90% of injuries in sports and recreational activities. Changing and enforcing game rules and providing proper eye protection has proved very beneficial in Canadian hockey, racket sports, war games, and other sports. In 1997, the ASTM issued standard...
specifications for EPDs used in paintball sports. These standards are intended to minimize the risk for injury to the eyes and adnexa without hampering the performance of the sport. An EPD that meets ASTM standards will not permit eye contact from paintball fragments or any component of the EPD during a paintball impact at velocities up to 120 m/s (400 ft/s) (Figure 7). Optical requirements ensure that the visual function of the players will not be adversely affected by the EPD.

There is no question that EPDs are effective in preventing eye injuries during war games. However, cases have been reported where the EPD was worn by the participant and an eye injury still occurred. In 1 case, the paintball entered under a mask; in another, the paintball displaced the goggles; and in 3 cases, the goggles themselves were projected into the eye. In our series, 3 of the ocular injuries (in patients 11, 13, and 26) occurred while the EPD was being worn. In patient 11, the patient was hit between the goggles and mask; in patient 13, the paintball traveled under the goggles; and in patient 26, the paintball shattered the goggles. None of the patients were wearing an EPD meeting the current ASTM standards. We know of no case where an ocular injury resulted while an ASTM-approved EPD was worn properly.

Although properly worn EPDs may reduce significantly the incidence of ocular injuries in recreational activities, in practice this has been difficult to achieve. Similar difficulties are encountered regarding the use of EPDs with air and BB guns and with military combat. Although 63% of the patients in this series used an EPD, 86% of these patients removed the EPD before the injury. The major identifiable reasons for removal of an EPD in this study were fogging and paint splattering, which obscured
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REFERENCES


the central viewing zone. These results are similar to those reported by Zwaan and associates,6 who reviewed 76 cases of ocular injuries caused by paintballs and found that in 68 cases, patients were not wearing goggles at the time of the injury, and 20% removed them because they became fogged or covered with paint released from the paintball.

The extreme physical nature of the paintball sport makes fogging a common occurrence. Although the ASTM specifications do not involve testing the EPD in its ability to resist fogging, they require the manufacturer to attach a warning to those EPDs without antifog treatment indicating that fogging may occur and recommending the application of an antifog solution.13 The paintball industry has recognized the negative impact of EPD fogging on performance and has developed a variety of antifog devices such as antifog lens inserts, antifog solutions or lens cloths, and battery-operated fans that attach to the EPD. Although antifog lens inserts are not included as standard equipment in most paintball goggles sold in the United States, they are available for purchase. Zero-Fog (JT USA, Chula Vista, Calif) and Combat Vision inserts (Modern World Ventures, Emeryville, Calif) are examples of antifog lenses that fit inside the goggle lens and resist fogging. The Zero-Fog insert is an acetate lens with hydrophilic properties that absorbs humidity and prevents lens fogging. The Combat Vision insert is a polycarbonate lens with a urethane-based coating (Figure 8). This hydroscopic coating resists fogging by sheeting water from the lens. Players with prescription glasses also can have their corrective prescription filled in a special frame that fits inside the goggle frame.

Paint splattering across the central viewing zone of the EPD also may prompt the player to remove the EPD for cleaning. Players should be educated to wipe the EPD without removing it from its proper position. To facilitate removal of paint splatter, clear, disposable acetate strips (Tear Off Strips; JT USA) that adhere to the outside of the EPD lens may be used. When paint splatters on the product, it is peeled off the lens and discarded, leaving a clean surface.

Although ocular injuries due to paintballs may result in permanent loss of vision, most of these injuries are probably preventable with proper eye protection. Participants in commercial and noncommercial war games should be educated always to wear an EPD meeting ASTM speci-