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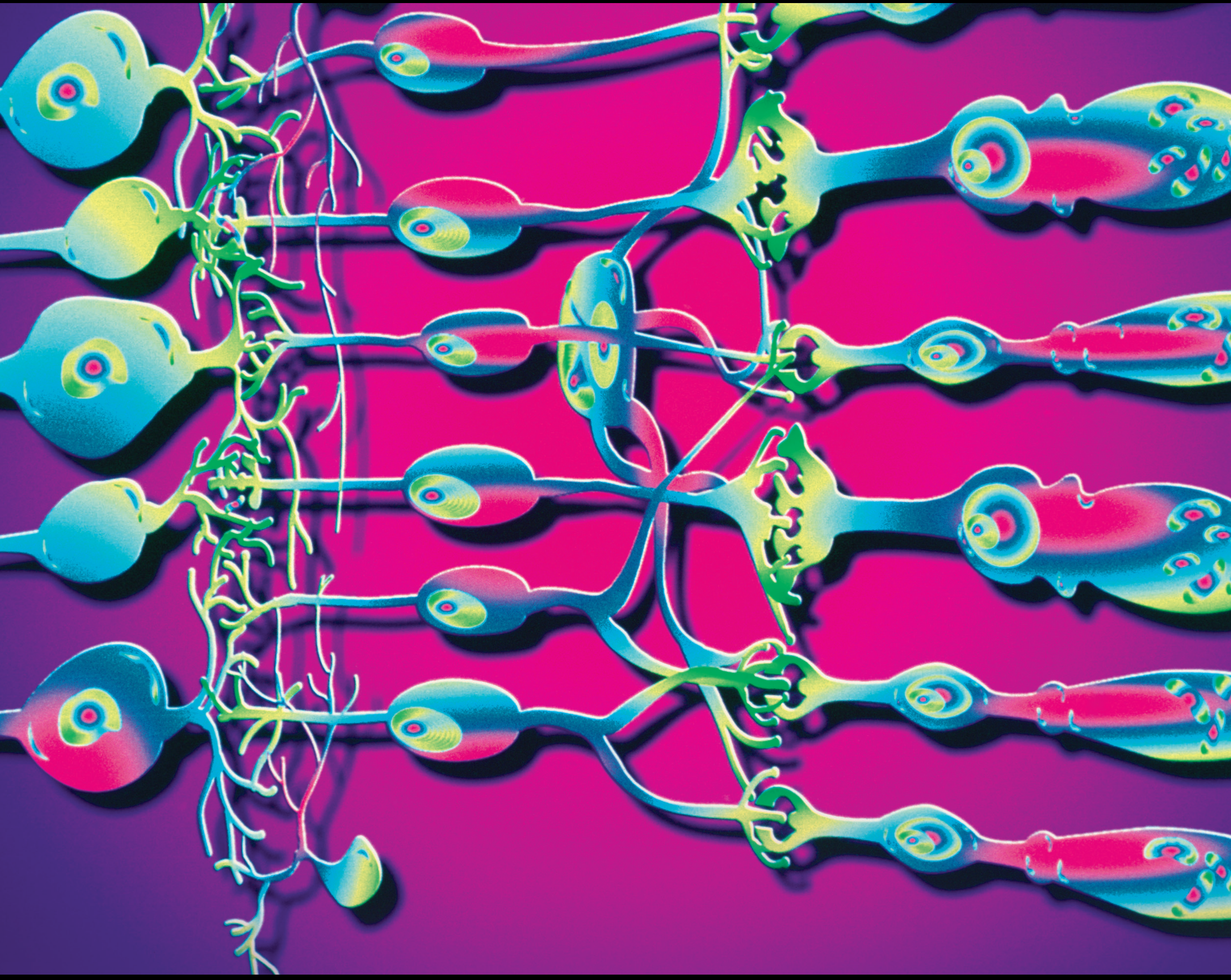
Posterior Segment Ocular Trauma: Timing and Indications for Vitrectomy

Lead Guest Editor: Robert Rejdak
Guest Editors: Anselm G. Juenemann and Sundaram Natarajan



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Editorial Board

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Editorial

Posterior Segment Ocular Trauma: Timing and Indications for Vitrectomy

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Posterior segment ocular trauma is still an important cause of visual loss and disability in working-age population. With modern surgical approaches, many eyes can be salvaged with retention of vision. Both open (penetration injury, intraocular foreign body, and eye rupture) and closed (retinal detachment, vitreous hemorrhage, and macular hole) eye injuries may be indications for vitrectomy. Timing of vitrectomy is still a matter of discussion and depends on surgeon's experience and capabilities.

The most urgent indication for vitrectomy is endophthalmitis. Y. Sheng et al. performed a systematic review of the Chinese literature on pediatric posttraumatic endophthalmitis and described the epidemiology, management, causative organisms, and visual acuity outcomes of the reported cases in twenty years. They found that *Staphylococcus epidermidis* was the most common isolated organism and the use of a disposable syringe needle was the most common cause of ocular injuries in pediatric posttraumatic endophthalmitis in China.

Another indication for vitrectomy is intraocular foreign body. In this issue, D. A. Guevara-Villarreal and P. J. Rodríguez-Valdés described extraction surgical techniques, timing, and indications for vitrectomy due to intraocular foreign body. Potential advantages of immediate IOFB removal include a possible decrease in risk of endophthalmitis, a decrease in the rate of proliferative vitreoretinopathy (PVR), and a single procedure for the patient. Early surgery was not significantly associated with greater visual improvement but had a significant impact on the development of posttraumatic endophthalmitis. The authors conclude that the most important factor at the time to perform IOFB extraction is the experience of the surgeon.

G. Sborgia et al. evaluated the safety and outcomes in patients with open eye injury with retained foreign body that underwent early 25-gauge vitrectomy. They concluded that pars plana vitrectomy is considered the most effective and safest approach for the removal of retained ocular foreign bodies and repair of retinal injuries correlated. Advances in small-gauge (25-gauge or 27-gauge) vitrectomy instrumentation as well as surgical techniques have increased indications for complex cases.

R. Rejdak et al. evaluated visual and safety outcomes of 23-gauge pars plana vitrectomy with application of perfluorocarbon liquid for intraoperative protection of the macula during intraocular foreign body removal. They have not observed any iatrogenic injury of the macula during PPV for metallic IOFB removal with PFCL use in our group of 42 patients. However, falling of IOFB was reported in 3 patients without retinal injury within the macula. Thus, the macula can be a shield from IOFB drop during its extraction by reduction of impact force of falling IOFB or by deflecting its trajectory toward the peripheral retina.

Traumatic retinal detachment is another indication for vitrectomy in posterior ocular trauma. There are currently no evidence-based guidelines on the appropriate time to perform vitreoretinal surgery to repair a traumatic retinal detachment. Early intervention, within seven days of the inciting trauma, may decrease proliferative vitreoretinopathy and postoperative endophthalmitis. Later intervention may yield a reduced risk of inflammation and hemorrhage, particularly in cases of concomitant open globe injuries. M. Orban et al. reviewed the literature on the management of retinal detachments associated with ocular trauma from the years 2006 to 2016. Preliminary data indicate that endophthalmitis rates may be lower when early vitreoretinal surgery is performed.

K. Nowomiejska et al. evaluated functional and anatomical results of pars plana vitrectomy in the retinal detachment followed by severe eye trauma in the retrospective analysis of medical records of forty-one consecutive patients treated with 23-gauge PPV due to traumatic retinal detachment. They concluded that among analysed pre- and intra- and postoperative factors, absence of PVR, postoperative retinal attachment, and silicone oil as a tamponade were related to significantly improved visual acuity.

W. Liu et al. reviewed current management of traumatic macular holes and they state that it is not a rare clinical condition, especially in young population. Although TMH commonly occurs in closed globe injuries caused by blunt ocular trauma, the mechanism of the hole formation remains controversial. Due to the relatively high rate of spontaneous closure of traumatic macular hole, it has been suggested that adult patients may be observed for 3 to 6 months after the hole formation, especially in young patients with small holes, good visual acuity, and posterior vitreous adhesion to the hole edges. Surgery may be recommended earlier for pediatric patients to prevent amblyopia, depending on the age of the child. Modern vitrectomy surgery plays an important role in the treatment of traumatic macular hole, although the functional outcomes may be compromised by the concomitant retinal pathologies.

H. H. Ghoraba et al. reported the difference in either anatomical or functional outcome of vitreoretinal intervention in cases of gunshot perforating eye injury if done 2–4 weeks or after the 4th week after the original trauma. Patients were treated with pars plana vitrectomy and silicon oil. There was no statistically significant difference between the two groups in either anatomical or functional results. The authors conclude that the visual outcome after gunshot perforating eye injury depends on the site of entry and exit (the route of gunshot).

In summary, this issue includes different surgical approaches and will provide valuable clinical information that should be helpful in clinical practice for vitreoretinal surgeons. This will improve management of patients after severe eye trauma with posttraumatic endophthalmitis, intraocular foreign body, posttraumatic retinal detachment, and traumatic macular hole.

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Clinical Study

Intraoperative Macula Protection by Perfluorocarbon Liquid for the Metallic Intraocular Foreign Body Removal during 23-Gauge Vitrectomy

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Purpose. To evaluate visual and safety outcomes of 23-gauge (G) pars plana vitrectomy (PPV) with application of perfluorocarbon liquid (PFCL) for intraoperative protection of the macula during intraocular foreign body (IOFB) removal. *Methods.* Retrospective study of 42 patients who underwent 23 G PPV for IOFB removal from posterior segment with intraoperative PFCL application for the macula shielding. Collected data included corrected distance visual acuity (CDVA), size of IOFB, and complication rate. The mean follow-up period was 12 months. *Results.* The mean preoperative CDVA was 0.54 logMAR (SD 0.46), and the final mean CDVA was 0.68 logMAR (SD 0.66). All IOFBs were metallic with mean dimensions of 4.6 mm × 2.1 mm. Twenty-two IOFBs were removed through the corneal tunnel and 20 IOFBs through the sclerotomy. No intraoperative iatrogenic lesion of the macula was observed. As a tamponade, silicon oil was applied in 31 eyes, SF_6 gas in 5 eyes, air in 4 eyes, and 2 eyes required no tamponade. Secondary retinal detachment was observed in 17% of cases, but at the end of the follow-up, all the retinas were attached. *Conclusion*. PFCL application during PPV is a safe method of protecting the macula from unexpected falling of the metallic IOFB during its removal.

1. Introduction

Open globe injuries remain the most severe eye trauma. The annual incidence of open globe injuries is estimated from 3 to 7 per 100,000 per year [1, 2]. Depending on the population, open globe injuries are complicated with the presence of intraocular foreign body (IOFB) in 10 to 41% of cases. This type of injury is one of the major causes of visual impairment in a group of young males in their productive age. Most frequently, open globe injuries are work-related and occur in mechanism of hammering [3–5]. Visual prognosis depends on the localization of the entry of IOFB and damaged structures of the eye. Timing of IOFB removal is important with regard to the risk of endophthalmitis and siderosis and is a matter of discussion [6–9], whereas improper surgical technique can result in iatrogenic lesion and increased need for secondary operation.

Removal of IOFB is one of the most challenging surgery in ophthalmology. The objectives of this procedure are to remove IOFB from the eyeball in minimally invasive way and to treat lesions caused by trajectory of IOFB. In the past, all the magnetic IOFBs were extracted from the eye with an external magnet [10]. This method allowed for easy but unfortunately uncontrolled removal of the IOFB, resulting in high risk of retinal detachment (RD), caused by iatrogenic retinal breaks, produced by uncontrolled pulling of IOFB embedded in the retina or in the vitreous bands. This procedure was also associated with a high risk of vitreous haemorrhage and proliferative vitreoretinopathy (PVR) [11].

Pars plana vitrectomy (PPV) is currently a standard procedure in the treatment of pathologies located in the posterior segment of the eye. In case of IOFB, PPV allows for good visualization of IOFB, precise inspection of retinal lesions, and laser treatment of retinal breaks [7]. However, during PPV approach, IOFBs are more frequently unintentionally dropped on the macula compared to removal through a sclerotomy with the external electromagnet [12].

Perfluorocarbon liquid (PFCL) was introduced firstly to vitreoretinal surgery by Stanley Chang as a temporary tamponade [13]. It has been shown that PFCL has no ability to dampen the impact force of falling IOFB measured on a force transducer [14]. A more recent study has shown experimentally that PFCL has the facility to shield the macula from the impact of dropped metallic IOFB by deflecting its trajectory on the PFCL-balanced salt solution (BSS) interface [15].

The aim of this study was to analyse the clinical results of 23-gauge (G) PPV with intraoperative application of PFCL to protect the macula from unexpected falling of metallic IOFB during its removal.

2. Materials and Methods

Data were collected retrospectively from medical reports of 42 consecutive patients treated at the Department of General Ophthalmology, Medical University of Lublin, Poland, between August 2009 and November 2015. The treatment chosen in the study was a part of a standard care. All patients were routinely fully informed about the risk and benefits of the surgery and the written consent was obtained. The study was performed in accordance with the Declaration of Helsinki.

Pre-, intra-, and postoperative data were collected. Preoperative data included demographic data, corrected distance visual acuity (CDVA) measured with Snellen's decimal scale converted to logMAR, intraocular pressure (IOP), pre-existing pathology, entry site of the IOFB, lesion of eye structures, history of the disease, and time interval between accident and operation. For CDVA analysis, finger counting and hand movement were calculated in decimal values [16]. Presence of IOFB in the posterior segment of the eye was confirmed by preoperative computed tomography (CT) examination of the orbit and eyeball. Intraoperative data included localization of site of IOFB removal, course of the operation, type of intraocular tamponade, and intraoperative complications.

Postoperative data from follow-up visits included CDVA, slit lamp findings, and IOP. The schedule of postoperative examinations was as follows: on the first day, one week, one month, and 4, 6, 9, and 12 months after surgery.

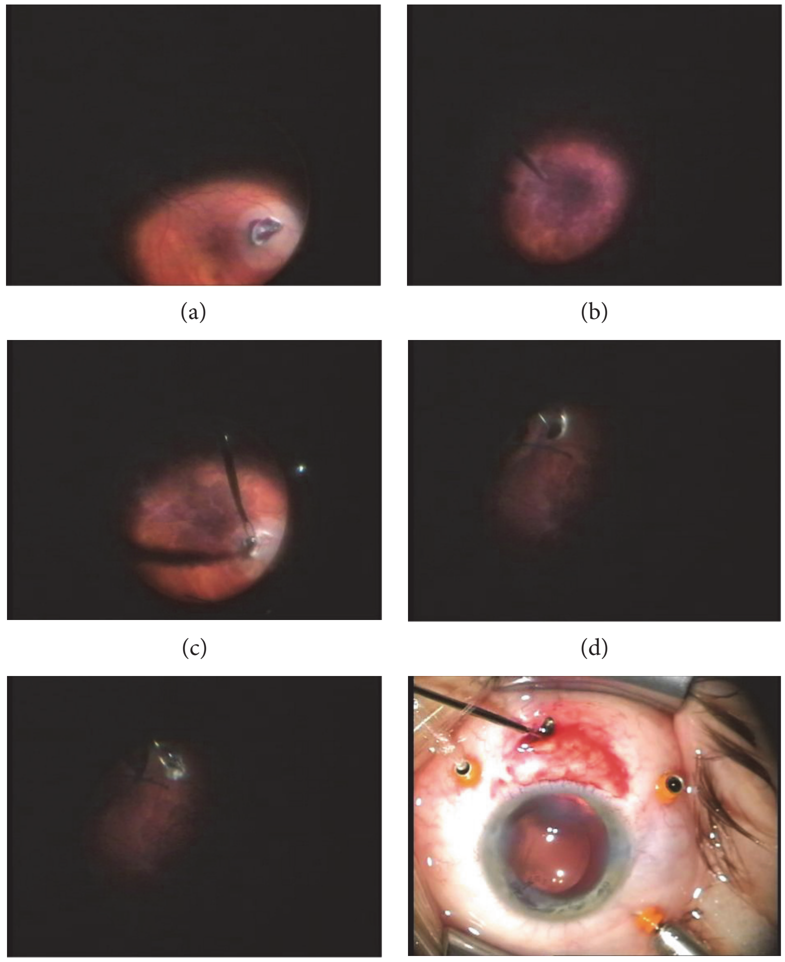
Dimensions of metallic IOFB were measured with a micrometre.

2.1. Surgical Technique. All surgeries were performed under general anaesthesia by experienced vitreoretinal surgeons. All patients were treated with 23 G PPV (Constellation, Alcon, Fourth Worth, USA). First, the site of corneal entry of IOFB was sutured with Nylon 10.0 sutures and the sclera with Vicryl 7.0 sutures. Crystalline lens considered to be opaque or injured was removed with phacoemulsification or cutter, and when possible, foldable, acrylic intraocular lens (IOL) was implanted to the capsule or the sulcus during the primary surgery. The posterior hyaloid detachment was induced in each patient with assistance of triamcynolone. After performing complete vitrectomy with indentation in all cases, intraoperative PFCL (F-Decalin, Fluoron GmbH, Ulm, Germany) was applied to protect the macula during IOFB removal. The PFCL was applied in the amount of 1 ml to cover the posterior pole to arcades including the macula. IOFB was removed through sclerotomy (Figure 1) or clear corneal tunnel incision (Figure 2). All retinal breaks were treated with laser endophotocoagulation. At the end of the operation, PFCL was removed completely. If intraocular tamponade was necessary, air, 25% sulfur hexafluoride (SF_6) gas, or 5000 Cst silicone oil was used. In case of primary macula laceration, internal limiting membrane (ILM) was peeled with assistance of indocyanine green (ICG). Vancomycin dissolved in the infusion fluid in concentration of 0.2 mg/ml suggested by Rejdak et al. [17] was used intraoperatively as endophthalmitis prophylaxis. In postoperative period, all cases received locally steroids and fluoroquinolones.

2.2. Statistical Analysis. For statistical analysis, Mann-Whitney test to compare two groups and one-way ANOVA test for more than two groups were applied. Pearson's correlation coefficient test was applied to measure the association between two variables (GraphPad Software Inc., La Jolla, USA). Differences were considered statistically significant at the level of $p < 0.05$.

3. Results

All cases were men with the mean age of 45 years (min. 15 years, max. 76 years, median 46 years, and SD 15 years). All IOFBs were metallic with mean dimensions of 4.6 mm × 2.1 mm (min. 1.6 × 1.1 mm, max. 9.5 mm × 6.8 mm, median 3.3 mm × 1.8 mm, and SD 3.3 × 1.4). Preoperative mean CDVA was 0.54 logMAR (min. no light perception, max. 0, median 1.52, and SD 0.46). Entry wound was localized in the cornea in 23 eyes and within the sclera in 19 eyes. Preoperative laceration of the retina was diagnosed in 20 eyes. Unintended IOFB fall onto PFCL was reported in 3 eyes (7%), but no eye revealed intraoperative iatrogenic lesion of the macula induced by dropped IOFB. Mean time interval between trauma and operation was 48 days (min. 0 days, max 900 days, median 1.5 days, and SD 178 days). All IOFBs were removed with 23 G forceps. Twenty-two IOFBs were removed through clear corneal tunnel incision and 20 through sclerotomy. Crystalline lens was removed in 39 eyes; IOL was implemented during primary surgery in 20 eyes and during secondary operation in 13 eyes. At the end of follow-up, 6 eyes remained aphakic. As an intraocular tamponade, silicon oil was applied in 31 eyes, SF_6 in 5 eyes, air in 4 eyes, and 2 eyes required no tamponade.



(a) (b) (c) (d) (e) (f)

Figure 1: (a) Intraretinal localization of IOFB, (b) application of PFCL on the macula, (c) grabbing IOFB and attempt of its removal, (d) free-floating IOFB on the surface of PFCL after its unintentional fall, (e) grasping IOFB from PLCL surface, and (f) IOFB removal through sclerotomy.

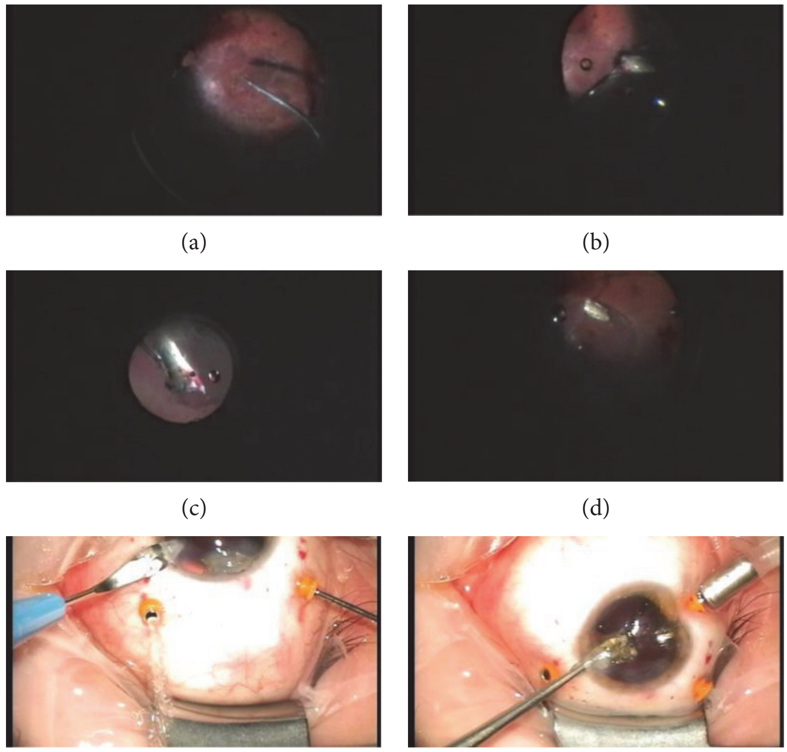
Mean observation time was 11.7 months (min. 1 month, max. 47 months, median 11 months, and SD 10.5 months). At the end of the follow-up, mean CDVA was 0.68 logMAR (min. no light perception, max 0.04, median 0.82, and SD 0.66). Compared to preoperative results, it improved in 18 (42.9%) cases, was equal in 9 (21.4%) cases, and decelerated in 15 (35.7%) eyes. Final CDVA better than 0.3 logMAR was observed in 6 (14.3%) eyes. All 3 eyes (7.1%) with no light perception at the initial visit had no light perception at the end of follow-up. No statistical significant differences of final CDVA between the eyes without lens removal, primary implantation, secondary IOL implantation and the aphakic eyes were observed ($p = 0.72$), as well as no differences between scleral and corneal entry wound localizations ($p = 0.92$) and between scleral and clear corneal localizations of the IOFB removal site ($p = 0.92$) or between air, SF_6, silicon oil, and no tamponade ($p = 0.96$). Moderate downhill correlation between maximal dimension of IOFB and final CDVA was found ($r = -0.33$).

At the end of follow-up, mean IOP was 15.6 mmHg (min. 3 mmHg, max. 30 mmHg, median 16 mmHg, and SD 5.3 mmHg). Increased IOP was controlled with topical antiglucomatous medications in 12 eyes filled with silicon as a tamponade. Seven (16.6%) eyes required reoperation due to secondary RD. At the end of follow-up, the retina was attached in all the eyes. No eye had signs of endophthalmitis and atrophy and no eye required enucleation.

4. Discussion

In the present study, we have reported for the first time that the application of PFCL is the safe method for shielding the macula from falling metallic IOFB during PPV. We have not observed any iatrogenic injury of the macula during PPV for metallic IOFB removal with PFCL use in our group of 42 patients. However, falling of IOFB was reported in 3 patients without retinal injury within the macula.

PFCL is optically clear and has a specific gravity greater than that of water and high interfacial tension in water. High specific gravity enables removal of subretinal fluid by primary retinal breaks, eliminating the need for a retinotomy in RD. PFCL flattens the retina and mechanically fixates it, reducing the tractional forces. PFCLs are applied intraoperatively during vitrectomy for complicated RD, PVD, giant



(a) (b) (c) (d) (e) (f)

Figure 2: (a) Application of PFCL on the macula, (b) grabbing IOFB, (c) elevating IOFB toward the anterior chamber, (d) deflection of its trajectory by PBS-PFCL interface from the macula toward the peripheral retina during unintentional IOFB fall, (e) clear corneal incision enlargement, and (f) IOFB removal through corneal tunnel incision.

tears, and trauma [13]. Because PFCL has direct toxic effect for retinal pigment epithelium cells and induces mechanical damage of retinal ganglion cells, all PFCL should be removed from the eye at the end of surgery [18]. PFCL has been used already to protect the macula while removing luxated lens material or IOL [19]. The dislocated lenses or IOLs float in PFCL not only by its high gravity but also mostly by its high-PFCL-BSS interfacial tension, which is responsible for deflecting dropped IOFB trajectory along the interface toward the peripheral retina and thus protecting the posterior segment of the eye.

The macula can be a shield from IOFB drop during its extraction by reduction of impact force of falling IOFB or by deflecting its trajectory toward the peripheral retina. Ernst and coworkers examined the ability of different substances to dampen the impact force of an IOFB dropped inside the model of the eye and demonstrated that it could be achieved with silicone oil and viscoelastic, whereas PFCL accelerate IOFB falling compared with BSS. It is explained with lower viscosity of PFCL, what allows falling IOFB to reach a higher velocity [14]. This finding is not in contrary to the observation that the high interfacial tension of PFCL in BSS allows to deflect trajectory of dropped IOFB on the PFCL-BSS interface which was shown experimentally by Shah and colleagues [15]. These properties could be utilized only when a small bubble of PFCL is applied; otherwise, IOFB would accelerate and cause greater damage. It was proven experimentally by Shah and colleagues that the larger PFCL bubble, the higher the final speed of IFOB [15]. In the presented study, we used 1 ml of PFCL, which was sufficient to form a bubble that covered the macula with vascular arcades. This amount of PFCL was small enough not to accelerate falling IOFB. The correlation between size and shape of IOFB was shown: the protective barrier of PFCL-BSS interface could be broken by sharp and heavy IOFB [15]. In our clinical practice, we observed that even unexpected falling of IOFB does not cause lesion of the macula, as PFCL protects the posterior pole.

Nowadays, vitreoretinal surgery allows managing of the posterior segment injuries associated with IOFBs successfully. Visual outcome of PPV for IOFB removal is associated with posterior localization of the lesion and correlates with the state of macula [4, 5]. Posterior segment can be injured primary or secondary in mechanism of iatrogenic lesion caused by a falling IOFB during its extraction, which can damage the macula and optic disc and cause retinal breaks and haemorrhages and increase the risk of macular pucker. Despite recent surgical advances, RD remains the most devastating complication after ocular injury with IOFB [9, 20, 21].

In our study, we found that the rate of secondary RD is 17%. In older studies, performing PPV decreased the risk of RD in the period following IOFB extraction from 79% to 11–23% [18, 19]. The presence of secondary RD could be explained by PVR development or not correctly treated or overlooked retinal breaks. PVR can cause a traction tear or reopen treated retinal break resulting in a late onset rhegmatogenous RD. PVR development is stimulated by retinal penetration of IOFB resulting from its primary localization or by iatrogenic breaks caused by uncontrolled manipulations during its extraction [22].

Our study has some limitations: retrospective character and relatively small subgroup sample size. There is no control group as we perform routinely PPV with PFCL for IOFB removal.

5. Conclusion

Application of PFCL seems to be a safe and affordable method of macular protection during metallic IOFB removal during PPV. To our knowledge, it is the first clinical case series confirming physical properties of BSS-PFCL interface which deflects trajectory of falling IOFB.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

Authors' Contributions

Robert Rejdak and Tomasz Choragiewicz contributed equally.

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Review Article

Current Management of Traumatic Macular Holes

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Traumatic macular hole (TMH) is not a rare clinical condition, especially in young population. Its prognosis is of complexity and uncertainty, with a relatively high rate of spontaneous closure in some cases. Modern vitrectomy surgery plays an important role in the treatment of TMH, although the functional outcomes may be compromised by the concomitant retinal pathologies. Decision-making about the time of vitrectomy, especially in pediatric patients, remains to be clarified further.

1. Introduction

Macular hole is a full-thickness defect of neuroretina in the foveal center, which can cause significant central vision loss. The most common type of macular hole is idiopathic macular holes (IMH), which is caused by the both anteroposterior and tangential vitreous traction on the foveal center [1].

Traumatic macular hole (TMH) is the second most common cause of macular hole. It is defined to macular hole caused by mechanic blunt injury of the eye. Although TMH occurs in 1.4% among closed globe injury cases and to a less extent (0.15%) among open globe injury cases [2], it may sometimes lead to permanent significant vision loss, due to being usually associated with other retinal pathologies, including commotio retinae, diffuse retinal edema, retinal hemorrhage, vitreous hemorrhage, choroidal rupture, photoreceptor and RPE damage, and retinal tears and dialysis.

TMH is more common in younger population, since the young age group is usually associated with sport, recreation, work, and transportation, which is subject to ocular trauma [2, 3]. In a retrospective comparison study with IMH, Huang et al. found that TMH patients were younger (27.11 versus 61.98 y), mainly male (86.3% versus 27.7%), and with worse vision (LogMar VA 1.23 versus 1.06) [3].

2. Methodology

The authors performed a literature search through PubMed for reports on traumatic macular hole in human and in English language and also through wanfangdata.com.cn for reports on the same subject in Chinese language. The following key words were used: traumatic macular hole, spontaneous closure, vitrectomy, and optical coherence tomography. Fifty-four articles dating from 1983 to 2016 were chosen for the final analysis.

3. Pathogenesis

Although TMH commonly occurs in closed globe injuries caused by blunt ocular trauma, the mechanism of the hole formation remains controversial.

Yokotsuka et al. previously theorized that sudden vitreous separation was the cause of a TMH [4]. Yanagiya et al. noted that most eyes in their 15 cases with a TMH have an attached vitreous; they theorized that it was the force of the impact transmitted to the macula that resulted in rupture of the fovea [5]. In 2001, Johnson et al. proposed contrecoup mechanism of TMH formation [6]. A sudden decrease in the globe's anterior-posterior diameter causes a compensatory equatorial expansion. Such a dynamic change within the volume-fixed globe can lead to horizontal forces and splitting of the retinal layers at the fovea. Yamashita et al. proposed two distinct mechanisms of traumatic macular formation: one that causes immediate visual loss due to primary dehiscence of the fovea and the other that leads to delayed visual loss due to dehiscence of the fovea secondary to persistent vitreofoveal adhesion [7]. Similarly, Hirata and Tanihara proposed that mechanism of the rapid-onset TMH formation was the stretching of the posterior pole as a result of anteroposterior compression of the eyeball [8].

Due to the individual uncertainty of the force imposed on the eye and the inherent structural features of the eye, the extent of the retinal injury and the progression of TMH are still difficult to predict clinically.

4. Role of Optical Coherence Tomography

Optical coherence tomography (OCT), especially the latest generation of spectral domain OCT, is the key technique in the management of TMH, which allows detailed assessment of the macular holes parameters, vitreoretinal interface, and other associated macular changes at each presentation. Such detailed observation plays an important role in understanding the pathogenesis of TMH formation [9, 10].

In 1996, Yanagiya et al. observed that most TMHs were elliptical and not round [5]. Huang et al. reported 73 consecutive eyes with TMH with detailed OCT analysis; they proposed 5 different types of TMH according to the presence of cystic edema, retinal detachment, and retinal thinning. Their study demonstrated that the diversity and complexity in clinical presentation are the characteristics of TMH [11]. In another retrospective comparison study with IMH, Huang et al. found that TMHs were more eccentric in shape than the typically circular IMH and had larger basal diameter (1338.45 versus 958.57 mm) and basal area (176.85 versus 77.92 mm2) with a thinner average retinal thickness (248.4 versus 408.8 mm). Visual acuity was negatively correlated with the size of IMHs, but not with any tomographic parameters in TMH. This may be due to the associated damage to the RPE or photoreceptors by the trauma. They found that all cases of TMH showed no posterior vitreous detachment (PVD) and/or opercula by examination and OCT [3]. This is consistent with previous studies that found relatively low rates of PVD in TMH patients [5, 6], which is in opposition to the theory of Yokotsuka et al. that the sudden vitreous separation is the cause of TMH [4].

5. Spontaneous Closure

TMHs have been shown to close without any treatment. There are many case reports showing that the spontaneous closures usually took place between 2 weeks and 12 months after the trauma [12–27]. About two-thirds of the reported cases had the holes closure within up to three months of the trauma and nearly all holes closed within six months. Almost all holes are small in size and gain significant visual improvement after the spontaneous closure (Table 1). Karaca et al. reported an unusual horseshoe-shaped traumatic macular tear with spontaneous closure one month after the blunt trauma [26].

There are also some case series documenting the spontaneous closure of TMH, with different closure rate up to 67% [7, 28–33] (Table 2). Mizusawa et al. reported that one (10%) of ten eyes with TMH achieved spontaneous holes closure at a follow-up of 8 months or longer [28]. Li et al. reported that three (10.7%) out of twenty-eight TMHs closed spontaneously after a mean follow-up of 14 months, and the closure occurred within 4.5 months after the injury [30]. Yuan et al. observed that, during a 12-month follow-up, seven (33.3%) of twenty-one cases achieved spontaneous closure of the TMH with significant visual improvement [31]. Chen et al. recently reported twenty-seven eyes with TMH which were followed for at least 6 months and observed spontaneous closure in ten (37.0%) eyes [32]. In a retrospective study of twenty-eight TMH cases, Miller et al. also observed a fairly high spontaneous closure rate (39.3%), in median of 5.6 weeks, with a minimal 1.7 weeks [33]. The largest series by Yamashita et al. reported spontaneous closure in eight (44.4%) of eighteen consecutive cases after a mean follow-up of 8.4 months [7]. The highest closure rate was reported by Tomii et al. that four (67%) of six eyes had spontaneous hole closure during a follow-up of 3 months or longer [29].

Usually, patients with spontaneous closure of TMH shared some common characteristics. First, majority of the patients with spontaneous closure were children or young in age [16, 25]. In Yamashita's large series, all eight patients were young (average age: 14.6 years) and male [7]. Miller et al. also reported that the spontaneous closure rate was greater in children than in adults (50% versus 28.6%) [33]. Second, spontaneous closure mostly occurred in smaller holes [7, 16, 23, 25, 30, 32, 34]. This may implicate that the eye injury is relatively not very severe, or, the hole occurrence is short in course. Third, eyes with spontaneous closure experienced usually absence of PVD [7, 16, 25]. Miller et al. concluded that younger patients without involvement of the posterior hyaloids were likely to have a better prognosis for spontaneous resolution [35].

There were reports of two patients, separately, 55-year-old and 56-year-old, with TMH closed spontaneously [19, 27]. Nasr et al. also reported a case of spontaneous TMH closure in a 50-year-old woman. The authors concluded that the hemorrhagic clot in the TMH base may serve as platelet clumping or a scaffold for glial cell migration and proliferation, thus contributing to spontaneous hole closure [24].

Chen et al. recently explored whether the morphological characteristics on spectral domain OCT can be used to predict spontaneous closure of TMH. In this retrospective study, the authors found that holes with spontaneous closure had smaller minimum diameter (244.9 ± 114.4 versus $523.9 \pm 320.0\,\mu$m, $p = 0.007$) and less intraretinal cysts (10% versus 76.5%, $p = 0.001$) compared to the holes that did not close spontaneously. Multivariate logistic regression showed that the presence of intraretinal cysts was an independent predictive factor for closure of macular holes, which suggests that the absence of intraretinal cysts on OCT can predict spontaneous closure of TMH. The authors further reviewed that most previously reported cases with spontaneous closure were also not accompanied by intraretinal cysts on OCT [32].

Table 1: Literature review of case reports on spontaneous closure of TMH.

References	Patient's age (yrs)	Closure time after injury	Hole size	Initial VA	Final VA
Nunode et al., 1983 [12]	11	15 days	0.2 DD	CF	0.1
Kusaka et al., 1997 [13]	12	4 months	0.1 DD	0.5	1.0
	18	4 months	0.1 DD	0.5	1.0
	19	3 months	0.1 DD	0.2	1.0
Murakami et al., 1998 [14]	12	3 months	0.2 DD	0.03	0.5
	10	3 months	0.1 DD	0.3	0.6
Parmar et al., 1999 [15]	25	15 days	370 μm	CF	0.1
Mitamura et al., 2001 [16]	17	12 months	0.2 DD	0.29	1.0
	13	3 months	0.2 DD	0.2	1.0
	12	3.5 months	0.1 DD	0.28	1.0
	8	4 months	0.2 DD	0.1	1.0
	17	11 months	0.1 DD	0.1	0.8
	13	1 month	0.2 DD	0.2	0.4
	15	3 months	0.1 DD	0.67	1.0
Yamada et al., 2002 [17]	11	18 weeks	0.2 DD	0.2	1.5
	19	4 months	0.2 DD	0.1	0.67
	15	6 months	0.17 DD	0.1	0.67
Yeshurun et al., 2002 [18]	15	5 weeks	600 μm	0.08	0.1
Menchini et al., 2003 [19]	56	2 months	180 μm	0.2	0.67
Carpineto et al., 2005 [20]	10	18 weeks	200 μm	0.1	0.8
Lai et al., 2005 [21]	24	6 weeks	100 μm	0.17	1.0
Chen et al., 2008 [22]	25	2 weeks	n/a	0.01	0.7
		2 weeks	n/a	0.01	0.9
Valmaggia et al., 2009 [23]	9	3 weeks	178 μm	0.04	0.5
Nasr et al., 2011 [24]	50	17 days	n/a	0.03	0.16
de Filippi Sartori et al., 2012 [25]	15	2 months	n/a	0.2	0.8
Karaca et al., 2014 [26]	21	1 month	n/a	CF	CF
Faghihi et al., 2014 [27]	20	2 months	n/a	0.04	0.04
	15	6 months	n/a	0.1	0.4
	25	2 months	n/a	0.06	0.6
	55	1 month	n/a	0.3	0.4

Table 2: Literature review of case series reports on spontaneous closure rate of TMH.

References	Number of cases	Mean age (yrs)	Observation time (month)	Closure rate	Closure time after injury (month)
Mizusawa et al., 1996 [28]	10	n/a	8	10%	9
Tomii et al., 1999 [29]	6	n/a	3 or more	67%	2.9 (0.5–5)
Yamashita et al., 2002 [7]	18	n/a	8.4 (4–12)	44%	1.7 (0.27–4)
Li et al., 2008 [30]	28	30	14 (3–131)	10.70%	4.5
Yuan et al., 2015 [31]	21	26	12	33%	1.7
Chen et al., 2015 [32]	27	26	9 (6–37)	38%	n/a
Miller et al., 2015 [33]	28	21	26.4	39%	1.3 (0.4–15.7)

The proposed mechanism of spontaneous closure of TMH encompasses the proliferation of glial cells or retinal pigment epithelial (RPE) cells from bank of the hole's edge to fill the hole bottom and stimulation of astrocyte migration to heal the TMH [36]. Other proposed explanations include formation of a contractile epiretinal membrane resulting in shrinkage and closure of the hole or complete detachment of the posterior hyaloid from the foveal area resulting in the release of an anteroposterior traction [37].

Due to the relatively high rate of spontaneous closure of TMH, it has been suggested that adult patients may be observed for 3 to 6 months after the hole formation, especially in young patients with small holes, good visual acuity, and posterior vitreous adhesion to the hole edges. But surgery

Table 3: Literature review of reports on vitrectomy outcomes for TMH.

References	Number of cases	Mean age (yrs)	Adjuvants	Tamponades	Anatomic success*	Functional success#
Rubin et al., 1995 [40]	12	15	TGF-β2	C3F8	67%	67%
García-Arumí et al., 1997 [41]	14	22	Platelet concentrate	SF6	93%	93%
Barreau et al., 1997 [42]	4	17	Platelet concentrate	C3F8	75%	50%
Margherio et al., 1998 [43]	4	13	Autologous plasmin	C3F8	100%	100%
Amari et al., 1999 [44]	23	27	None	SF6	70%	87%
Chow et al., 1999 [45]	16	25	Autologous plasmin	C3F8	94%	69%
Johnson et al., 2001 [6]	25	23	Serum or none	C3F8	96%	84%
Kuhn et al., 2001 [46]	17	26	None	SF6	100%	94%
Wachtlin et al., 2003 [47]	4	13	Platelet concentrate	SF6	100%	100%
Wu et al., 2007 [48]	13	10	Plasmin	C3F8 or sio	92%	92%
Ghoraba et al., 2012 [49]	22	27	None	C3F8 or sio	82%	n/a
Azevedo et al., 2013 [36]	4	12	None	Gas	100%	75%
Hou and Jiang, 2013 [39]	54	27	Platelet concentrate	SF6/C2F6/C3F8	89%	52%
Miller et al., 2015 [33]	11	21	None	Gas or sio	45%	n/a
Yuan et al., 2015 [31]	26	32	None	C3F8	69%	27%
Abou Shousha, 2016 [50]	12	23	None	SF6	100%	n/a

*With one operation; #2 lines' visual acuity improvement; sio: silicone oil.

may be recommended earlier for pediatric patients to prevent amblyopia, depending on the age of the child [35].

6. Vitrectomy

Vitreous surgery for IMH was first reported by Kelly and Wendel in 1991 [38]. Unlike the surgical treatment for IMH, the role of vitrectomy in TMH was less clear, due to the varying contributions of vitreous traction to its pathogenesis and associated retinal damage. However, current surgical techniques are similar to that of the IMH, including removal of the posterior hyaloid, epiretinal membranes, with or without internal limiting membrane (ILM) peeling, and intraocular gas or silicone oil tamponade.

Vitrectomy for TMH has been shown with improved anatomic and visual outcomes in some eyes. A reviewed analysis of surgical outcomes in published reports of vitrectomy for TMH found a successful closure rate of 83% with an overall single operation [35]. Since eyes with TMH are usually associated with different preoperative retinal pathologies, visual outcomes in successfully closed eyes may be unsatisfying. Like most studies, Hou and Jiang reported that 48 (89%) of the 54 eyes with TMH were successfully closed with visual acuity significantly improved after vitrectomy [39], but Yuan et al. did not find significant improvement of visual function in the 18 (69.2%) of 26 cases of TMH that were successfully closed with vitrectomy and gas tamponade [31]. Literature reported outcomes of vitrectomy for cases series of TMH which are summarized in Table 3 [6, 31, 33, 36, 39–50]. This review shows that the anatomic success rate ranges from 45% to 100%, with a median of 92.5%; functional success (2 or more lines' improvement) rate ranges from 27% to 100%, with a median of 84%.

Changes of the hole configuration after vitrectomy were also reported. Rishi et al. reported two TMH cases of delayed and spontaneous conversion of type 2 closure ("flat/open" configuration) to type 1 closure ("flat/closed") with improved vision months after vitreous surgery [51, 52].

6.1. Use of Adjunctive Therapies. Mechanism of macular hole closure treated with vitrectomy involves the stimulation of glial cell proliferation in the hole [53]. To accelerate the healing of the hole, early reports on TMH treatment involved use of adjunctive therapies.

Rubin and colleagues used TGF-β2 during vitrectomy for 12 eyes and achieved a closure rate of 67% in eight eyes after the first procedure [40]. García-Arumí et al. obtained a closure rate of 86% in fourteen eyes with full-thickness TMH, with the use of platelet concentrate, after a single surgery [41]. Barreau et al. reported four TMH cases with a mean age of 17 years treated with platelet concentrate and achieved an anatomic successful rates of 75% [42]. Amari et al. and Chow et al. were the first to report successful closure of TMH without the use of adjunctive therapies of TGF-β2, platelets, or serum during vitrectomy. Amari et al. achieved a closure rate of 70% in 23 consecutive TMH patients after the first vitrectomy and a rate of 96% after the second intervention. The mean BCVA changed from 20/160 preoperatively to 20/60 postoperatively and 61% of the eyes achieved BCVA of 20/60 or better [44]. Chow et al. reported that fifteen (94%) of sixteen eyes achieved hole closure after vitrectomy and six (38%) had final visual acuity of 0.5 or better [45]. Johnson et al. further studied retrospectively 25 patients who underwent vitrectomy with perfluoropropane (C3F8); twelve of the patients received autologous serum. The macular hole closed in all the 12 (100%) eyes in which serum was used but in 10 (77%) of the 13 eyes in which serum was not used. They found no significant difference in visual acuity outcomes with or without the use of serum [6]. Later, Wachtlin et al. reported a case series of four pediatric patients with TMH treated with vitrectomy with platelet concentrate, ILM peeling, and gas tamponade. Primary closure was achieved by a single intervention in all patients, with visual improvement of three to seven lines after surgery. There were no complications reported [47]. Recently, Hou and Jiang reported their previous series of 54 eyes with TMH that were treated with vitrectomy, platelet concentrate, ILM peeling, and gas tamponade; they found that 48 (89%) of the eyes achieved successful closure with significant visual acuity improvement [39].

6.2. Timing of Vitrectomy. In a recent study, eleven eyes with TMH underwent vitrectomy with a median time to intervention of 35.1 weeks. Median time to surgery for the 5 eyes with successful hole closure was 11.0 weeks versus 56.3 weeks for the 6 eyes that failed to close. The authors found no relation between initial OCT dimensions and final hole closure status, and they concluded that surgical intervention was less successful for hole closure when elected after 3 months [33].

6.3. Pediatric Vitrectomy. Although TMHs in pediatric patients have a high chance of spontaneous closure, some authors implemented vitrectomy in this subgroup and achieved successful outcomes. Wachtlin et al. reported successful closure of TMH in four (100%) pediatric patients (10–15 years old) after a single vitrectomy with no surgical complications [47]. In another study, four pediatric patients aged under 15 years with TMH following blunt ocular trauma were successfully treated with early vitrectomy. The authors concluded that early vitrectomy seems to be a safe and effective choice in pediatric TMH management, and the risk/benefit ratio of surgery seems to be better than observation [36].

6.4. Enzymatic Vitreolysis. Complete removal of the posterior hyaloid is a crucial step for the success of vitrectomy surgery for macular hole [54]. However, it is difficult to mechanically induce complete PVDs in children due to the well-formed vitreous body with strong adhesion between the posterior hyaloid and ILM [55, 56]. Inappropriate maneuvers during PVD induction may result in iatrogenic retinal breaks, inner retina damage, visual field defects, and vitreous hemorrhage. Retinal breaks could trigger an intense proliferative vitreoretinopathy, which will lead to poor anatomic and visual outcomes [56]. For these reasons, enzymatic vitreous liquefaction has been studied to aid PVD induction in pediatric TMH.

Margherio et al. reported "simple and atraumatic" outcomes of 4 pediatric patients with TMH who underwent vitrectomy with 0.4 IU adjuvant of autologous plasmin and 16% C3F8 [43]. Chow et al. reported that, with the use of intraoperative autologous plasmin to facilitate formation of posterior vitreous detachment in ten eyes, fifteen (94%) of sixteen eyes achieved hole closure after vitrectomy and six (38%) had final visual acuity of 0.5 or better [45]. Wu et al. reported a subsequent study of 13 pediatric patients (1–15 years old); after 15 minutes of enzymatic cleavage with 2 IU of autologous plasmin, PVD was noted in 3 eyes and partial PVD in 2 eyes and easily created in the remaining 8 eyes. The macular hole closed in 12 (92%) patients. Among 12 of the 13 patients with VA measurement, 11 (92%) patients had VA improvement of 2 or more lines and six (50%) achieved vision of 20/50 or better; all patients achieved a vision better than 20/200 [48].

With the recent clinical introduction of ocriplasmin (microplasmin/Jetrea; ThromboGenics, Iselin, NJ) which is a recombinant truncated version of plasmin approved by the US Food and Drug Administration for the treatment of symptomatic vitreomacular traction, one would expect a better outcome of enzyme-assisted PVD in pediatric cases of TMH [57].

6.5. Intraocular Tamponade. Gas is widely used in repairing any kind of macular holes. It is the surface tension of gas that provides a seal at the site of the hole to prevent reaccumulation of the intraretinal fluid from the vitreous cavity as the hole closes with time. Although gas tamponade is usually recommended over silicone oil for macular hole surgery, silicone oil has also been tried for TMH closure in some cases.

Moura Brasil and Brasil reported a case of a 9-year-old boy with a TMH who was treated with ILM peeling and silicone oil tamponade and who gained vision from 20/300 to 20/70 after silicone oil removal [58]. Ghoraba et al. studied 22 patients with TMH who underwent vitrectomy with silicone oil or gas tamponade. Silicone oil was used in children, patients with large holes, and those with difficulty in strict positioning. With a single surgery, TMH closure was achieved in 67% of cases with silicone oil and 92% with C3F8 [49]. Besides larger size of the holes and unreliability in maintaining a strict postoperative face-down position in child, the lower surface tension of the silicone oil as compared with that of the gas may also be an unfavorable factor for a better surgical outcome in silicone oil tamponaded eyes [59].

6.6. Internal Limiting Membrane (ILM). ILM removal for TMH was studied by Kuhn et al. in a case series of 17 consecutive patients, in whom ILM was removed without any adjuvant therapies. The result showed a 100% closure rate, with vision improving by at least two Snellen lines in 16 (94%) eyes [46]. Ikeda et al. suggested that vitrectomy with ILM peeling is useful not only for TMH closure but also for the release of accompanied severe retinal folds [60]. Wachtlin et al. also performed ILM peeling in treating pediatric patients with success [47].

Recently, inverted ILM flap technique with favorite anatomic and functional outcome for large IMHs was introduced. The inverted ILM flap may act as a scaffold for cell proliferation to promote the closure of the macular hole [61].

Shousha assessed the role of inverted ILM flap as a treatment option for large TMHs. In a prospective noncomparative study of 12 eyes with large TMHs (basal diameter of 1300–2800 um), a 100% closure rate and improvement of best-corrected visual acuity were achieved 6 to 9 months after the surgery [50].

7. Conclusion

TMHs are well-known complications of ocular blunt injury. TMHs are relatively rare compared to their idiopathic counterpart, but their visual outcomes and associated injuries can be severe. Besides the mechanism of TMH formation, the decision of whether to operate or simply observe these TMHs is also controversial. Surgical intervention with modern vitrectomy can be very successful in some patients. However, since spontaneous closure of TMH is not very rare, it is reasonable to defer surgical intervention for the first 3 months in amenable patient [33]. No matter whether TMH is spontaneously closed or surgically sealed, the final VA depends less upon the size of the hole than upon the degree of photoreceptor and RPE cell disruption.

Some questions still need to be addressed. What is the key factor(s) for the incidental spontaneous closure of the macular hole? What is the functional consequence(s) of a long period of waiting before vitrectomy? Management guideline of TMH, especially in pediatric patients, needs further to be clarified.

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Review Article

Pediatric Posttraumatic Endophthalmitis in China for Twenty Years

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Pediatric posttraumatic endophthalmitis (PTE) is a rare but serious disease that frequently has a poor visual prognosis. To date, only a few English studies have focused on this disease. We perform a systematic review of the Chinese literature on pediatric PTE and describe the epidemiology, management, causative organisms, and visual acuity outcomes of reported cases in twenty years. We found that *Staphylococcus epidermidis* was the most common isolated organism and the use of a disposable syringe needle was the most common cause of ocular injuries in pediatric PTE in China. In the last ten years, the time from injury to first presentation for treatment has shortened, the proportion of cases resulting from a disposable syringe needle has decreased, the use of intravitreal antibiotics as the initial treatment has increased, and the use of palliative treatment has decreased. Although these favorable changes have occurred in the last ten years, the visual prognosis of pediatric PTE is still poor.

1. Introduction

Pediatric endophthalmitis is a rare but serious disease that frequently has a poor visual prognosis. The most common cause is ocular trauma [1–3]. To date, only a few English studies have focused on pediatric endophthalmitis after trauma [1–9], possibly because of its low incidence [1–3]. Other than one recent large sample from India [8], all other reported samples were small.

In China, the incidence of pediatric endophthalmitis after open globe injury ranges from 9.7% to 20.6% [10–14], which is higher than that in developed countries (2.5% [1] and 3.5% [3]). At the same time, China is the world's most populous country. As a result, more pediatric patients have been diagnosed with posttraumatic endophthalmitis (PTE) in China and articles related to such patients have been published in Chinese journals. However, only one study involving a small sample of Chinese pediatric PTE has recently been published in an English journal [9].

The purpose of the present study was to perform a systematic review of the Chinese literature on pediatric PTE and to describe the epidemiology, management, causative organisms, and visual acuity (VA) outcomes of reported cases. A second aim was to examine changes in etiology, treatment, and visual outcomes in patients with pediatric PTE in China over time.

2. Methods

A systematic literature search was conducted in April 2016 of the China National Knowledge Infrastructure (CNKI), Wanfang, Weipu, and PubMed databases, using the following search terms: "pediatric or child or children or adolescent or infant," "trauma or injury," "endophthalmitis," and "China." The search was limited to references published within the last 20 years in the English or Chinese languages. A total of 79 articles were retrieved. After a detailed examination of these articles, we included only those that focused on a clinical study of pediatric PTE with a follow-up of more than 3 months. Articles were excluded if the content included other types of pediatric endophthalmitis or the article was a review or nursing study. After these selections, 25 articles were retained for further systematic analysis. We collected published data that included the name of the first author, publication year, number of patients and eyes, age and gender of patients, etiology, type of ocular trauma, time from injury to first presentation, initial VA, therapeutic methods, VA outcome, and causative organisms. The information provided in each article is shown in Table 1 [9, 15–38]. Because there were no articles meeting the criteria for randomized controlled trials and the study design, inclusion criteria, and therapeutic methods in these articles varied widely, it was impossible to conduct a meta-analysis. Instead, we collected the published data from each article in a database (Excel) and calculated the median or proportions for age, gender, type of ocular trauma, treatment methods, causative organisms, and VA outcomes. In addition, we divided the 25 articles into two periods according to the year in which the case data were collected (1994–2003 and 2004–2013) and compared the characteristics of the cases between these two periods.

Statistical analyses were performed with SPSS software (SPSS 15.0). Pearson chi-square tests were used to determine the differences in the proportions of treatment methods, causative agents, initial VA, and final VA between 1994–2003 and 2004–2013. An independent sample t-test was used to compare the time from injury to presentation for treatment between the two periods. P values of <0.05 were considered statistically significant.

3. Results

The 25 [9, 15–38] selected articles included 820 children with PTE. All cases were unilateral. The proportion of male to female children was 2.2 : 1 (567 male to 253 female). The children ranged in age from 1 to 14 years. The mean age as reported in 21 articles was 7.0 years for 670 children.

3.1. Time from Injury to First Presentation for Treatment. Seventeen articles provided information on the time between injury and first presentation in 599 cases, the mean being 9.3 days (range 4 hours to 120 days).

3.2. Nature of Trauma. All cases of PTE resulted from an open globe injury. Twenty-one articles provided information on the mechanism of injury in 704 eyes. In accordance with the standardized classification of ocular trauma by Kuhn et al. [42], in 619 of these eyes (87.9%) the cause was laceration, including penetrating, perforating, and intraocular foreign body wounds, and in 85 eyes (12.1%) the cause was rupture. All 25 articles reported the cause of injury. The leading cause was a disposable syringe needle (43.8%, 250/571). Other common causes included metal objects (scissors, wire, and nail), wood (tree branch, bamboo stick, and pencil), and an explosion (14.3%, 82/571). The injury site was reported in 10 articles for 220 eyes. Of these eyes, 179 (81.4%) had corneal wounds, 17 (7.7%) had scleral wounds, and 24 (10.9%) had corneoscleral wounds.

At the time of diagnosis with endophthalmitis, of 655 eyes, 421 (64.3%) had a cataract, as reported in 19 articles, and of 595 eyes, 122 (20.5%) had a retinal detachment, as reported in 17 articles.

3.3. Presenting VA. Twenty-one articles reported the presenting VA of 577 PTE cases. It was <5/200 in 78.0% (450/577) of cases, with no light perception in 9.9% (57/577), light perception in 25.5% (147/577), hand movements in 25.6% (148/577), and counting fingers in 17.0% (98/577). A total of 111 cases (19.2%) had a presenting VA of ≥5/200. The residual 16 patients (2.8%) were too young to obtain a VA.

3.4. Causative Organisms. Of the 14 articles with information on cultures from intraocular samples, 8 reported performing bacterial and fungal cultures for 297 eyes, and 6 reported performing a bacterial culture alone for 197 eyes. Positive bacterial results were obtained in 36.2% of eyes. Of the 160 eyes with an identified bacterial isolate, 126 (78.8%) had Gram-positive bacteria and 34 (21.2%) had Gram-negative bacteria. More details about bacterial cultures are shown in Table 2.

3.5. Management and Treatment. Of the 25 articles, 15 (507 eyes) reported pars plana vitrectomy (PPV) as the single method of PTE treatment. In the other 10 articles (313 eyes), the reported treatment methods for PTE included intravitreal antibiotics, PPV, and palliative treatment (intravenous and topical antibiotics). In these 10 articles, 192 cases (61.3%) were initially treated with PPV. Intravitreal antibiotics were administered as the initial treatment in 82 cases (26.2%), and 69 of the 82 cases underwent further vitrectomy. In the remaining 39 cases (12.5%), only palliative treatment was given.

In 15 articles, a second PPV operation was performed in 44 of 449 cases (9.8%). Of these 44 cases, 40 (90.9%) were retinal detachment after the first PPV, 3 (6.8%) had uncontrolled inflammation that did not respond to the first PPV, and 1 (2.3%) was a serious vitreous hemorrhage after the first PPV.

3.6. VA Outcomes. The final VA was reported in 23 articles regarding 678 cases. After we excluded 14 cases in which the VA could not be tested, there remained 664 cases with a final recorded VA. Compared with initial vision, the final VA improved in 497 cases (74.9%), was unchanged in 123 cases (18.5%), and had decreased in 44 cases (6.6%). Of 664 eyes, 206 (31.0%) achieved a VA of 20/200 or better, which included 48 eyes that were better than 20/40; 333 eyes (50.1%) had a VA of counting fingers or worse, which included 78 eyes (11.7%) with no light perception vision.

In 20 articles, 45 of 607 patients developed phthisis bulbi at the last follow-up. Of these patients, 9 had been managed without intraocular injection and vitrectomy and 13 had developed postoperative retinal detachment but reoperation was refused. Another 16 of the 519 patients experienced persistent hypotony after vitrectomy.

3.7. Trend Changes between the Two Periods. We divided the 25 articles into two periods (1994–2003 and 2004–2013) according to the year in which the case data were collected and compared characteristics of the cases between these two periods.

The mean time from injury to first presentation for treatment shortened significantly from 13.4 days to 6.4 days ($P < 0.05$) between the two periods (Table 3). Use of a

Table 1: Data available for analysis in the 25 articles.

First author	Year of publication	Number of eyes	Age	Gender	Time from injury to visiting	Etiology	Type of ocular trauma	Site of injury	Initial visual acuity (VA)	Treatment method	Culture result	Final VA	Follow-up time
Dong et al. [15]	1998	33	+	+	+	+			+	+	+	+	+
Wang [16]	1999	19	+	+	+	+			+	+		+	+
Fang [17]	2000	18	+	+	+	+	+	+	+	+		+	+
Gong et al. [18]	2000	28	+	+	+	+	+		+	+		+	+
Zhu and Zhang [19]	2003	68	+	+	+	+	+		+	+		+	+
Meng et al. [20]	2003	18	+	+	+	+	+			+	+	+	+
Li and Song. [21]	2004	20	+	+	+	+	+			+		+	+
Chen et al. [22]	2005	17	+	+		+	+	+	+	+	+	+	+
Liu et al. [23]	2005	24	+	+	+	+	+	+	+	+		+	+
Wang et al. [24]	2005	50	+	+	+	+	+	+	+	+	+	+	+
Zhou and Qiao [25]	2005	13	+	+		+	+		+	+		+	+
Sun et al. [26]	2006	12	+	+	+	+	+	+	+	+	+	+	+
Sha [27]	2006	25	+	+		+		+	+	+	+	+	+
Zhou et al. [28]	2007	103	+	+		+	+			+	+		+
Meng et al. [29]	2007	26	+	+	+	+	+		+	+	+	+	+
Shi [30]	2007	23	+	+	+	+	+		+	+	+	+	+
Peng et al. [31]	2008	16	+	+		+	+	+	+	+		+	+
Ge [32]	2008	78	+	+	+	+	+		+	+		+	+
Jiang et al. [33]	2010	39	+	+	+	+			+	+	+		+
Wu and Xiao [34]	2011	102	+	+	+	+	+			+	+	+	+
Wei [35]	2012	17	+	+	+	+	+		+	+	+	+	+
Shuang-Hua et al. [36]	2012	13	+	+		+	+		+	+		+	+
Lei et al. [37]	2013	19	+	+		+	+	+	+	+		+	+
Gong and Jiang [38]	2015	24	+	+	+	+	+	+	+	+	+	+	+
Wu et al. [9]	2016	15	+	+		+	+	+	+	+	+	+	+
Total		820	25	25	17	25	21	10	21	25	14	23	25

Table 2: Results of bacterial cultures.

Bacteria	Eyes (n)	Percent (%)
Gram-positive coccus	99	61.9
Staphylococcus epidermidis	50	31.2
Staphylococcus aureus	36	22.5
Streptococcus spp.	10	6.3
Pneumococcus	3	1.9
Gram-positive bacillus	27	16.9
Bacillus spp.	13	8.1
Propionibacterium	4	2.5
Bacillus diphtheriae	5	3.1
Corynebacterium	3	1.9
Nocardia	1	0.6
Listeria	1	0.6
Gram-negative bacillus	30	18.7
Escherichia coli	10	6.2
Pseudomonas aeruginosa	6	3.8
Klebsiella spp.	6	3.8
Proteus mirabilis	3	1.9
Bacillus levans	3	1.9
Haemophilus	1	0.6
Acinetobacter spp.	1	0.6
Gram-negative coccus	4	2.5
Neisseria	4	2.5
Total	160	100

disposable syringe needle was responsible for 57.7% of cases in the first ten years (1994–2003), compared with 22.0% in the second ten years (2004–2013) ($P < 0.05$) (Table 3). Metal objects, such as scissors, wires, and nails, were the leading cause of injury in the second ten years (2004–2013).

Excluding articles in which all cases of PTE were treated with PPV, 10 articles reported other treatment methods. In these cases, the use of intravitreal antibiotics as the initial treatment increased from 12.0% in 1994–2003 to 38.0% in 2004–2013 ($P < 0.05$), and the use of palliative treatment decreased significantly, from 27.5% to 0% ($P < 0.05$) (Table 3). The proportion of PPV use as the initial treatment between the two periods was similar (60.5% to 61.9%, $P > 0.05$).

For the initial VA, there was no significant difference between the two periods ($P > 0.05$). The final VA was improved in the second ten years compared with the first ten years ($P < 0.05$), and the proportion of phthisis bulbi decreased from 10.4% in 1994–2003 to 7.8% in 2004–2013 ($P < 0.05$) (Table 3).

4. Discussion

In this study, the mean time from injury to presentation for treatment was 9.7 days. In most of these cases, no primary repair had been performed before presentation with PTE. Al-Rashaed and Abu El-Asrar [4] reported that the primary repair had been performed in 62.8% of eyes at the time of diagnosis of PTE. Another study [5] reported that the primary repair of ocular injury in 7 of 10 cases of pediatric PTE was performed less than 3 days following trauma and the mean time was 4 days. Compared with these reports, the mean time of primary repair in the present study was even longer. The most likely reason was that a disposable syringe needle was the main cause of injury (43.8%) of ocular trauma, which usually leads to a painless and self-sealing wound. In addition, because they are afraid of being scolded or they lack language expression, children typically do not inform the family of the trauma in time. Thus, most children with a penetrating needle injury in this study were not seen for medical care until inflammatory symptoms appeared, such as pain, redness, or vision loss. These factors can result in a delay in diagnosis and treatment.

Two characteristics were commonly related to the nature of trauma in the present study. One is that a disposable syringe needle was the most common cause of ocular injuries, being responsible for approximately half of the cases. In developed countries, PTE following a penetrating needle injury has rarely been reported. Two studies from the United States that reported the causative agents of PTE in children showed that only 1 of 19 cases was due to needle injury [2, 5]. A penetrating needle injury seems to be more common in developing countries. A report from Turkey found that 8.3% of 242 perforating ocular injuries in children were caused by injection needles [43]. Several studies from India also reported ocular injuries in children following penetration with hypodermic needles [39, 40]. In one of these reports, the author pointed out that endophthalmitis occurred more frequently in syringe needle cases, most having been used during medical care; the microorganisms that subsist on these needles were the most important reason for the development of endophthalmitis [39]. In the present study, most needles were medical waste that had been disposed of inadequately. Thus, inadequate disposal of syringe needles is an important ocular hazard for children in China.

The other common characteristic of injuries in the present study was that 14.3% of them resulted from an explosion that resulted in rupture or an intraocular foreign body. To our knowledge, previous reports on PTE in children have not reported cases following an explosion. The pediatric explosive injuries in our study were always caused by setting off firecrackers, which is a traditional Chinese custom that children enjoy and participate in. Therefore, explosion is a common cause of ocular injury in China. In two large-sample studies from China, 140 of 836 (16.7%) ocular injuries in children were due to explosion [44, 45]. At the same time, ocular explosion injuries were often associated with IOFB, which is a risk factor for PTE [41]. Severe ocular rupture with delayed primary repair may even result in PTE.

The culture results in the present study showed that Gram-positive organisms (77.2%) constituted the majority of pathogens. This result is consistent with previous reports of pediatric PTE in which the proportion of Gram-positive organisms ranged from 66.6% to 100% [1–5]. In the present study, *Staphylococcus epidermidis* was isolated most commonly, accounting for 31.2% of the 160 isolates. In the pooled data from developed countries [1–5], *Streptococcus* species were found to be the most common organism, accounting for 57.1% of cases (32/56), whereas *Staphylococcus epidermidis*

Table 3: Comparison of characteristics of posttraumatic endophthalmitis cases between 1994–2003 and 2004–2013.

	1994–2003	2004–2013	P
Time from injury to presentation			
Number of articles reporting	8 (260 cases)	6 (220 cases)	
Mean time	13.4 days	6.4 days	<0.001
Causative agents			
Number of articles	9 (234 cases)	7 (236 cases)	
Disposable syringe needle	135 (57.7%)	52 (22%)	<0.001
Initial visual acuity			0.369
Number of articles reporting	9 (268 cases)	9 (169 cases)	
NLP and LP	113 (42.2%)	62 (36.7%)	
HM and CF	116 (43.3%)	75 (44.4%)	
≥5/200	39 (14.5%)	32 (18.9%)	
Final visual acuity			0.042
Number of articles reporting	11 (306 cases)	8 (218 cases)	
≥20/200	98 (32.0%)	56 (25.7%)	
≥5/200 and <20/200	58 (18.9%)	59 (27.0%)	
<5/200	150 (49.0%)	93 (42.6%)	
Phthisis bulbi	32 (10.4%)	17 (7.8%)	0.036
Initial treatment★			<0.001
Number of articles reporting	5 (142 cases)	5 (171 cases)	
Palliative treatment☆	39 (27.5%)	0 (0%)	
Intravitreal antibiotics#	17 (12.0%)	65 (38.0%)	
Vitrectomy	86 (60.5%)	106 (61.9%)	

★Excluding those articles in which all cases of endophthalmitis were treated with PPV.
☆Treated with intravenous and topical antibiotics alone.
#Including those treated with vitrectomy after initial treatment with intravitreal antibiotics.
NLP: no light perception; LP: light perception; HM: hand movements; CF: counting fingers.

Table 4: Culture results of previous reports.

Author	Number of *Streptococcus* cases	Number of *Staphylococcus epidermidis* cases	Number of culture-positive eyes
Weinstein et al. [1]	2	0	7
Thordsen et al. [2]	2	2	4
Çakir et al. [3]	1	0	1
Al-Rashaed and Abu El-Asrar [4]	22	5	35
Alfaro et al. [5]	5	1	9
Total	32 (57.1%)	8 (14.3%)	56
Present study	10 (6.2%)	50 (31.2%)	160

accounted for only 14.3% (Table 4). Because *Staphylococcus epidermidis* is part of the skin's normal flora, an open wound permits its entry into the eye. Delayed primary repair may increase the risk of a *Staphylococcus epidermidis* infection. In the present study, the mean time from injury to first presentation in these cases was 9.7 days, which was significantly longer than in other studies [1–5]. This finding may explain the higher proportion of *Staphylococcus epidermidis* in the present study. In a recent study from India that reported 143 PTE cases in children, *Enterococcus faecalis* was the most common causative organism. The difference in common causative organisms in different countries may be related to the various characteristics of nature and of the environment in different countries.

PTE in children generally has a poor prognosis. Pooled data from seven previous studies of pediatric PTE shows that only 35 of 94 cases (37.5%) achieved a VA better than 20/200 (Table 5) [2–5, 39–41]. In the present study, only 31.7% of the cases (184/581) had VAs of 20/200 or better, which was similar to that of previous studies. Factors that influence

Table 5: Previous reports of final visual acuity.

Author	NLP	LP-CF	≥5/200 and <20/200	≥20/200	Total
Thordsen et al. [2]	1	1	2	3	7
Çakir et al. [3]	0	3	0	1	4
Al-Rashaed and Abu El-Asrar [4]	11	10	0	10	31
Alfaro et al. [5]	2	2	1	7	12
Rabiah [39]	6	3	0	4	13
Jalali et al. [40]	8	2	0	7	17
Shilpa et al. [41]	4	0	3	3	10
Total	32 (34%)	21 (22.4%)	6 (6.4%)	35 (37.2%)	94
Present study	78 (11.7%)	255 (38.4%)	125 (18.9%)	206 (31.0%)	664

NLP: no light perception; LP: light perception; CF: counting fingers.

the prognosis in adult PTE have been analyzed extensively; they include being affected by the virulence of the microbe-causing infection, the presence or absence of a retinal break or detachment, the time of treatment, the presence or absence of an IOFB, and the extent of the initial injury [46]. Recently, one large-sample study from India reported that corneal abscess and retinal detachment are associated with a poor outcome. As the current study is a review of the literature, we cannot identify which factors influenced the prognosis in pediatric PTE.

By comparing the data between two periods, we found that the proportion of disposable syringe needle injury decreased from 57.7% to 22.0% and the time from injury to first presentation shortened significantly from 13.4 days to 6.4 days. These changes may suggest that, in the past ten years, the inadequate disposal of syringe needles has gradually improved and the protection of children in society has increased in China. At the same time, the use of intravitreal antibiotics as the initial treatment increased from 12.0% to 38.0% and palliative treatment decreased from 27.5% to 0%. This wide variation in treatment protocols during the study period reflects an improvement in medical facilities and treatment strategies in China. During the first ten-year period (1994–2003), PPV was not performed in most primary hospitals and general treatment guidelines for pediatric PTE were lacking in China. In the second ten-year period (2004–2013), prompt intraocular injection and timely PPV surgery had been widely adopted for the treatment of PTE among Chinese doctors, promoting more reasonable and standardized management of the disease. Nonetheless, expert consensus or unified guidelines for the treatment of pediatric PTE in China remain to be developed.

Staphylococcus epidermidis was the most common isolated organism and the use of a disposable syringe needle was the most common cause of ocular injuries in pediatric PTE in China. Although some favorable changes in treatment methods, causes of injury, presentation for treatment, and final outcome of VA have occurred in the last ten years, the visual prognosis of pediatric PTE is still poor. This study is limited by the fact that it is a literature review. Well-designed, randomized, controlled studies are required to determine the most effective treatments and their prognostic differences for pediatric PTE.

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Clinical Study

Surgical Management of Traumatic Retinal Detachment with Primary Vitrectomy in Adult Patients

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Purpose. To evaluate functional and anatomical results of pars plana vitrectomy (PPV) in the retinal detachment (RD) followed by severe eye trauma. *Methods.* Retrospective analysis of medical records of forty-one consecutive patients treated with 23-gauge PPV due to traumatic RD. Age, gender, timing of PPV, visual acuity, and presence of intraocular foreign body (IOFB) and proliferative vitreoretinopathy (PVR) were included in the analysis. *Results.* Mean age of patients was 47 years; the majority of patients were men (88%). Closed globe injury was present in 21 eyes and open globe injury in 20 eyes (IOFB in 13 eyes, penetration injury in 4 eyes, and eye rupture in 3 eyes). Mean follow-up period was 14 months; mean timing of PPV was 67 days. Twenty-seven (66%) eyes had a functional success; 32 eyes (78%) had anatomical success. As a tamponade silicone oil was used in 33 cases and SF6 gas in 8 cases. *Conclusions.* Severe eye injuries are potentially devastating for vision, but vitreoretinal surgery can improve anatomical and functional outcomes. Among analysed pre- and intra- and postoperative factors, absence of PVR, postoperative retinal attachment, and silicone oil as a tamponade were related to significantly improved visual acuity.

1. Introduction

Ocular trauma is a major cause of monocular blindness and visual impairment throughout the world. There are data suggesting that at least half a million people are monocularly blind from ocular trauma worldwide [1]. Proper diagnosis and treatment of eye trauma are essential to obtain good anatomical and functional results.

Traumatic retinal detachment (RD) accounts for 10–40% of all detachments [2]. It is supposed that the rate of traumatic RD is at the level of 0.2/10.000 [3]. There is no generally accepted definition of traumatic RD; thus the diagnosis is based on the particular history [4]. RD is seen in up to 30% among all serious eye injuries and has a poor prognosis for successful outcome [5]. RD may accompany both open and close globe injuries [6, 7] but is more prevalent after closed globe injury (about 70–85%) [8]. RD has been reported to occur in up to 30% of open globe injuries and 6–36% of those with posterior segment IOFBs [9].

Pars plana vitrectomy (PPV) has increased the recovery rate in traumatized eyes which previously were deemed inoperable and frequently were enucleated [7]. PPV allows the reconstruction of the posterior segment, controls the healing response [10], and prevents phthisis [11].

The aim of this study was to report functional and anatomical results in patients with trauma related RD treated with PPV in a group of adult patients after open and close globe injuries.

2. Materials and Methods

The medical records of forty-one patients having surgery due to traumatic RD during the period from January 2013 to June 2016 in the Department of General Ophthalmology of the Medical University in Lublin, Poland, were retrospectively reviewed. This study followed the tenets of the Declaration of Helsinki. The treatment chosen in the study was a part of a standard care. The study was approved by the local Ethic Committee at the University in Lublin, Poland. The patients gave their written informed consent to participate in the study and publish the data.

The following data were taken into consideration: age, gender, the eye involved, ocular history, type of injury, and ocular findings like initial visual acuity (VA), presence of intraocular foreign body (IOFB), posttraumatic endophthalmitis, choroidal detachment, lens injury, vitreous hemorrhage, follow-up time, and final VA.

The results of imaging studies (B-scan USG, CT) were also obtained in each case. Only eyes with a minimum follow-up time of twelve months were included in this study.

Ocular trauma was classified according to the Ocular Trauma Classification [12, 13]. An open globe injury is defined as a full-thickness defect of the cornea and/or sclera, and open globes are divided into ruptures or lacerations depending on the mechanism of injury (ruptures are caused by blunt objects and lacerations are caused by sharp ones). Lacerations are further subdivided into penetrating injury, intraocular foreign body (IOFB) injury, and perforating injury. A penetrating injury has an entrance wound, an IOFB injury has an entrance wound and a retained IOFB, and a perforating injury has an entrance and an exit wound.

BCVA was assessed with a Snellen chart. BCVA was converted to the logarithm of the minimum angle of resolution (logMAR) units for statistical analysis. In our study, functional success was defined as BCVA equal to or greater than 5/200 [7]; anatomical success was defined as total retinal reattachment at the last follow-up visit.

Statistical computations were performed using STATISTICA 10.0 software (StatSoft, Poland). Qualitative variables were described by percentages and quantitative ones by median ± standard deviation (SD). Wilcoxon test was used for assessment of BCVA results. Differences between groups were assessed using Mann–Whitney U-test. Statistical significance was set at 0.05.

3. Surgical Procedure

Surgeries were performed in local or general anesthesia. Cataract surgery and iris reconstruction when needed were performed in eyes after closed globe injury, suturing of the corneal, or scleral laceration in case of open globe trauma. Complete 23 G PPV with assistance of triamcinolone and sclera l indentation was performed using constellation system (Alcon, Fort Worth, Texas, US). Indocyanine green was used to dye internal limiting membrane in the posterior pole. Perfluorocarbon liquids were used to attach the retina. Subretinal fluid was drained using extrusion cannula during fluid-air exchange. Laser or cryopexy around the retinal break(s) was done. 5000 cst silicone oil or 20% sulfur hexafluoride (SF6) gas or air was used as a tamponade. Sclerotomies were sutured when needed with vicryl 8.0 sutures.

Table 1: Preoperative data of patients (type of trauma, presence of haemorrhage, and proliferative vitreoretinopathy (PVR), and intraocular foreign body (IOFB)).

	n	%
No haemorrhage	32	78,05
Vitreous haemorrhage	7	17,07
Suprachoroidal haemorrhage	2	4,88
Closed globe trauma	21	51,22
IOFB	13	31,71
Open globe trauma	4	9,76
Rupture	3	7,31
No PVR	37	90,24
PVR	4	9,76

Table 2: Intraoperative findings during vitrectomy (type of tamponade silicone oil or sulfur hexafluoride (SF6) gas and status of the lens).

	n	%
Silicone oil	33	80,49
SF6 gas	8	19,51
Lensectomy	8	19,51
Phacoemulsification	20	48,78
Scleral fixation	1	2,44
Sundmacher lens	1	2,44
Pseudophakia	11	26,83

4. Results

There were 36 men (88%) and 5 female (12%) subjects included. The mean age of patients was 49 years (range 25–80 years). Right eye was managed surgically in 56% of patients and the left eye in the remaining 43% of patients. The mean follow-up time was 14 months (range 12–16 months); mean timing of PPV was 67 days (range 1–180 days). Time period from injury to PPV was 22 days in open globe injuries and 102 days in close globe injuries.

Closed globe injury was reported in 21 eyes (51%) and open globe injury in 49% including IOFB in 13 eyes (32%), penetration injury in 4 eyes (10%), and eye rupture in 3 eyes (7%). Vitreous haemorrhage was present in 7 eyes and suprachoroidal haemorrhage in two eyes. PVR was reported in 10% of patients (Table 1). There were 9 total RDs, 8 eyes with giant retinal tears, and 10 eyes with multiple breaks.

Silicone oil was used as a tamponade in 33 eyes (80%) and SF6 gas in 8 eyes (20%) (Table 2). Indications for silicone oil were as follows: presence of PVR, RD with suprachoroidal haemorrhage, multiple breaks, giant retinal tear, and total RD. Thirty-two (78%) of 41 eyes had anatomical success and 27 (66%) functional success. Recurrent RD was observed in 9 eyes (22%). Secondary glaucoma was observed in 14 cases and was managed with antiglaucomatous drops; hypotony was found in one case.

Overall, mean BCVA improved from 1.4 logMAR to 1.25 logMAR ($p = 0.07$). Taking into account particular groups, additional analysis showed that BCVS was significantly ($p = 0.03$) better in eyes without PVR (1.2 logMAR) than in eyes with PVR (1.7 logMAR). Visual acuity was significantly better ($p = 0.05$) after PPV in patients with retina attached postoperatively (from 1.5 to 1.3 logMAR). Visual acuity was significantly improved in eyes with IOFB (1.0 logMAR), rather than in eyes after rupture, closed globe injury, and penetration (1.4 logMAR). BCVA was also significantly improved in eyes with silicone oil as a tamponade ($p = 0.03$).

5. Discussion

In the present study we have collected the clinical data of patients treated with 23 G PPV after RD followed by both open and close eye globe injuries. There were many pre-, intra-, and postoperative variables involved; we have found that statistically significant factors were as follows: preoperative PVR, postoperative retinal attachment, and silicone oil as a tamponade.

Comparison of the results in traumatic RD is extremely difficult as the number of variable parameters is large, including extent and localisation of injury and time from injury. Thus, there is a large diversity of clinical pictures resulting from this [14].

Experimental studies have shown that penetrating ocular injuries of posterior segment initiate a sequence of events which can ultimately lead to tractional and/or rhegmatogenous retinal detachment, breakdown of the blood-retinal barrier, initiation of an inflammatory response, and posterior vitreous separation [15, 16]. Proliferative alterations in the region of the vitreous base lead to the annular contraction of the retina; it can be stimulated by the vitreous haemorrhage and incarceration of the vitreous or inadequate wound care. This process can be interrupted by vitrectomy carried out in time.

Studies performed on animal models of ocular blunt trauma indicated that the initiating factor in the pathogenesis of RD is the anteroposterior compression of the globe during impact that leads to compensatory lengthening of the horizontal diameter [17].

Ocular contusion may result in numerous types of retinal breaks, including horseshoe tears, operculated holes, giant retinal tears, macular holes, and retinal dialyses [8, 18]. Sometimes it is difficult to identify the specific cause during clinical examination.

Mechanisms responsible for retinal break formation in closed globe injury may be as follows: vitreous base avulsion, abnormal sites of vitreoretinal adhesion (e.g., lattice degeneration), coup injury, contrecoup injury at a location opposite to the site of impact, or sudden posterior vitreous detachment induction [15]. The sudden acceleration of the vitreous body in closed globe injury may lead to extensive tearing of the retina around the base of the vitreous far out in the periphery.

Surgical repair is indicated as soon as the patient's circumstances allow it. The choice of surgery mainly depends on location of breaks, amount of PVR, and the surgeon's preference.

We suggest performing PPV as it enables removing posttraumatic coaxial opacities as cataract and vitreous haemorrhage in order to obtain a better view into retina with special attention to IOFB and retinal tears; moreover vitreoretinal proliferations and fibrovascular membranes may be also removed with forceps [14]. The presence or absence of choroidal hemorrhage must be determined before surgery by ultrasonography. The infusion cannula (preferably longer 6 mm) should be put with care. Silicone oil injection is preferable if there is coexisting PVR or giant retinal tear, total RD, suprachoroidal haemorrhage, and multiple breaks [19]. Traumatic RD is often complicated with PVR, especially in case of subretinal or vitreous hemorrhage, giant retinal tear, or large wound, when RPE and fibroglial cells have access to vitreous cavity. In our study preoperative PVR was reported in 10% of patients, but silicone oil was used in 80% of patients due to giant retinal tear, total RD, RD with suprachoroidal haemorrhage, and multiple breaks.

Scleral buckling alone may be sufficient after closed globe injury; however there are indications for primary PPV in traumatic RD-vitreous hemorrhage, dislocated lens, PVR, giant retinal tear with everted flap, posterior tear, and subretinal hemorrhage [20].

Due to the complexity of most cases, PPV with tamponade agents as the primary surgical technique is preferred [21]. Almost 40% of the cases will need relaxing retinotomies to reattach the retina [21].

In our study most of the patients were males (88%). Young male individuals are more vulnerable to ocular trauma (80%) probably because of their physical outdoor activities.

In our study mean time from trauma to PPV was 67 days, but it included both open and close globe trauma. It was 22 days in open globe injuries and 102 days in close globe injuries. Relatively long period after closed globe injuries may be explained by the fact that the vitreous body in young individuals is well-formed and posterior hyaloid not detached from the retina. Thus, vitreous limits the progression of RD especially when it is caused by inferior breaks or dialysis. This may be explanation why RSs are not recognized for months after trauma.

Timing of PPV in ocular trauma is a matter of discussion. Ryan and Allen [7] stated that four to ten days after injury seems to be the optimal time for vitrectomy to avoid the hazards of immediate intervention, while removing damaged tissue before serious sequelae occur.

Kuhn presented four options of timing of PPV after severe ocular trauma: early (days 2–4); delayed (days 5–7); late (days 8–14); and very late (past 2 weeks). He concluded that the earlier the vitrectomy, the higher the risk of intraoperative complications, bleeding, wound leakage, and bad visualization. Conversely, the later the vitrectomy, the higher the incidence and severity of postoperative complications, mainly PVR- [22, 23]. However, other authors investigated longer time [24] (mean 49 days) and they concluded that a delayed approach is compatible with good visual prognosis in relatively young patients.

The current study is limited by its retrospective methodology and the variability in the included pathology. Trauma cases are inherently unique and thus require an individualized approach to surgical treatment.

Competing Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Clinical Study

25-Gauge Vitrectomy in Open Eye Injury with Retained Foreign Body

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Purpose. Ocular trauma with retained foreign body is an important cause of visual impairment in working-age population. Clinical status impacts on the timing and planning of surgery. In the last year small gauge vitrectomy has become safer and more efficient, extending the range of pathologies successfully treated. *Aims*. To evaluate the safety and outcomes in patients with open eye injury with retained foreign body that underwent early 25-gauge vitrectomy. *Methods*. In this retrospective, noncomparative, interventional case series, we performed 25-gauge vitrectomy on 10 patients affected by open globe injuries with retained foreign body, over 3 years. We analyzed age, wound site, foreign body characteristics, ocular lesions correlated, relative afferent pupillary defect, visual acuity, and intraocular pressure. Follow-up evaluations were performed at 1, 3, and 6 months. According to the clinical status we performed other procedures to manage ocular correlated lesions. *Results*. The median age of patients was 37 years. The foreign body median size was 3.5 mm (size range, 1 to 10 mm). 25-gauge vitrectomy was performed within 12 hours of trauma. Foreign body removal occurred via a clear corneal or scleral tunnel incision or linear pars plana scleral access. Visual acuity improved in all patients. Endophthalmitis was never reported. Only two cases reported postoperative ocular hypertension resolved within the follow-up. Retinal detachment recurred in one case only. *Conclusions*. 25-gauge vitrectomy could be considered as early approach to manage open globe injuries with a retained posterior segment foreign body in selected cases with good outcomes and low complication rate.

1. Introduction

Ocular trauma with intraocular foreign bodies (IOFBs) is an important cause of visual morbidity and blindness in working-age population [1–3]. The role of vitrectomy as early approach to ocular eye injuries with IOFBs was widely supported by the literature [4–6]. The advancement in microsurgical vitreoretinal surgery techniques and instrumentation has allowed managing successfully traumatized eyes with IOFBs [7, 8]. In very few reports 25-gauge vitrectomy surgery was successfully used for the removal of foreign bodies and to manage ocular lesions using different maneuvers [9–11]. In this case series we report our experience in treating open eye injuries with IOFBs by 25-gauge pars plana vitrectomy in order to evaluate the final visual acuity, globe survival, and complication rate and to describe the proceedings of IOFBs removal and the management of ocular lesions correlated.

2. Methods

The setting was the Department of Ophthalmology, University of Bari, Bari, Italy. Over 3 years (2013–2015) ten consecutive patients affected by ocular trauma with retained IOFBs were included in this retrospective, noncomparative, interventional case series. At presentation we analyzed relative afferent pupillary defect (RAPD), Snellen best corrected visual acuity (BCVA), anterior segment by slit lamp biomicroscopy, intraocular pressure (IOP), and posterior segment by funduscopy. Ancillary tests like B-mode ultrasonography and computed tomography (CT) were performed to analyze ocular and orbital status and to detect the localization of the IOFBs. All patients were treated by 25-gauge pars plana vitrectomy by a single physician. According to the clinical status we performed other procedures like lens extraction (lensectomy via pars plana or phacoemulsification and aspiration

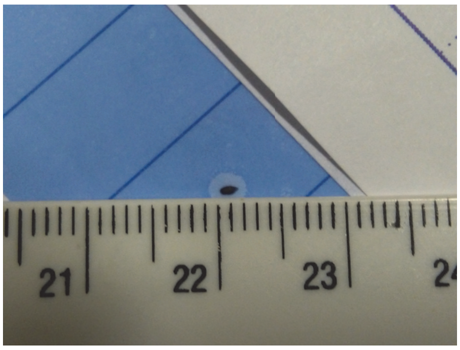


Figure 1: Small metallic IOFB.

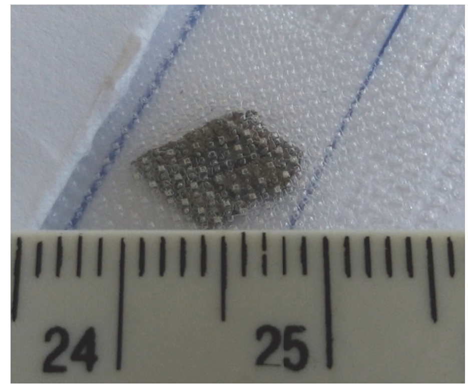


Figure 2: Large stone IOFB.

through a corneal incision), sulcus or capsular bag intraocular lens (IOL) implantation, and repair of retinal break or detachment. A long-term ocular endotamponade was used when necessary. Postoperatively all patients received antibiotics and steroid eye drops for four weeks with gradual tapering. Oral ciprofloxacin 500 mg twice daily was given in all cases with addition of systemic steroids when necessary.

We analyzed age, wound site, IOFB characteristics (chemical nature, size, and location), ocular lesions correlated, site and method for extraction of foreign bodies, and timing of surgery. Intraoperative and postoperative complications were recorded. Follow-up evaluations were performed at 1, 3, and 6 months.

3. Surgical Approach

At first the entrance wound was cleaned of any incarcerated tissues and incarcerated vitreous was cut as near to the wound as possible. The scleral, limbal, or corneal entrance wound was repaired before trocars were positioned.

Afterwards pars plana vitreous surgery was performed. When choroidal detachment occurred, use of a 6-mm length infusion cannula was considered.

According to the clinical status we performed other procedures to manage ocular lesions correlated. Four patients underwent small incision phacoemulsification for traumatic cataract at the same time of the vitrectomy. Four patients underwent lensectomy by 25-gauge vitrector handpiece. In a 40-year-old man we removed his relatively soft lens dislocated in the vitreous cavity by 25-gauge vitrector handpiece. In three patients we realized primary sulcus IOL implantation. Six eyes were left aphakic in order to place IOL after an improvement of ocular conditions and an accurate calculation of the IOL power. Core vitrectomy was performed before identifying retained foreign body. Active bleeding was controlled by elevating the infusion or perfluorocarbon liquid or endodiathermy.

In all patients meticulous removal of the vitreous was performed at vitreous base and around the impact site, and posterior vitreous detachment (PVD) was induced.

Clinic evaluation, ultrasonography, and CT helped us to plan the way of retained foreign body removal. In six patients removal of foreign bodies with small to medium size (range size, 1 to 4 mm) and a regular contour (Figure 1) occurred via a clear corneal or scleral tunnel incision.

In four patients we removed foreign bodies with small to large size (range size, 1,5 to 10 mm) (Figure 2) via linear pars plana scleral access with max length of 3 mm (surgeon decided on appropriate size to ensure safety space for the IOFB removal) realized at 12 hours (Figure 3). For large and more posteriorly located foreign body we used perfluorocarbon liquids to protect the macula against IOFB during its removal. All IOFBs were removed from the posterior segment using intraocular forceps and a retractable basket.

Retinal tears and rhegmatogenous retinal detachment were treated. The periphery was evaluated at the end of surgery meticulously.

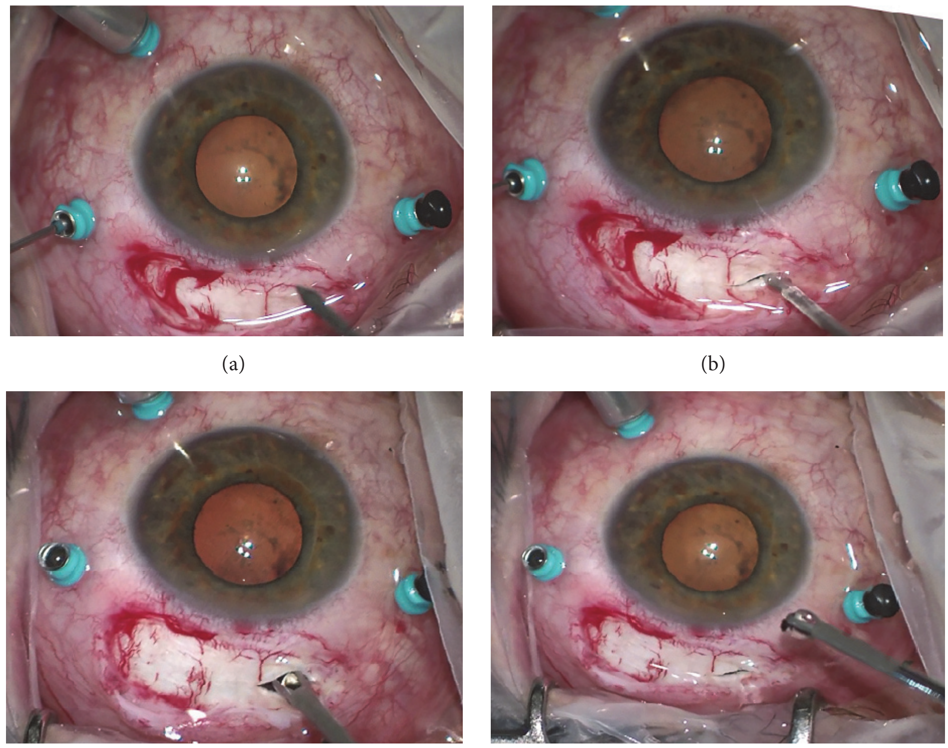
In six patients medium viscosity silicone oil (1000 centistokes) was injected with a mean time of 4 ± 2 months between injection and removal; the remaining patients underwent air tamponade. For endophthalmitis prophylaxis, intravitreal injection of vancomycin (1.0 mg/0.1 mL) and ceftazidime (2.25 mg/0.1 mL) was performed. In patients with penicillin allergies, intravitreal amikacin (0.4 mg/0.1 mL) or moxifloxacin (100 μg/0.1 mL) was used.

4. Results

We treated 10 patients affected by ocular trauma with retained foreign bodies. The median age was 37 years (range, 23 to 64 years). The entrance wound involved cornea in four cases, sclera in two cases, and limbus in four cases. At presentation six cases showed uveal prolapse, three of those with vitreous incarceration in the wound. Seven patients had traumatic cataract, one patient had lens subluxation, and another one had lens dislocation into the vitreous. In one patient there was no lens displacement.

B-scan ultrasonography revealed or confirmed, after funduscopy, vitreous hemorrhage in seven patients, retinal detachment in seven patients, and choroidal hemorrhage in five patients.

CT localized metallic IOFBs in six cases, a wooden IOFB in one case, a glass IOFB in one case, and a stone in one case but failure to detect intraocular plastic fragment resulted in



(a) (b) (c) (d)

Figure 3: Intraoperative photographs (inverted image as seen by the surgeon). (a-b) Linear pars plana scleral access with max length of 3 mm is realized at 12 hours preserving the sites of trocars. (c-d) A metallic foreign body is extracted through a pars plana sclerotomy by basket forceps to prevent slippage.

one case. The IOFBs median size was 3 mm (size range, 1 to 10 mm).

In two patients RAPD was reported while it was not evaluable owing to anterior segment status in three patients. The mean preoperative BCVA was 2 logMAR (Snellen Equivalent (SE) 20/2,000). The mean postoperative BCVA improved to 1.3 logMAR (SE 20/400), 0.95 logMAR (SE 20/178), and 0.85 logMAR (SE 20/142), at 1, 3, and 6 months, respectively. We did not consider the three patients with light perception to quantify mean visual acuity before surgery. In one of those patients visual acuity improved to 0.5 logMAR (SE 20/63) after 6 months from surgery.

At presentation the mean preoperative IOP was 9.4 ± 5.3 mmHg and four patients had hypotony (5 mmHg). Mean postoperative day 1 IOP was 13.6 ± 4.9 mmHg. Mean IOP was 14.8 ± 4.4 mmHg, $14{,}3 \pm 4.1$ mmHg, and 15 ± 5.6 mmHg at 1, 3, and 6 months after surgery, respectively. In one patient we recorded hypotony (7 mmHg) resolved spontaneously and in another one hypertony (30 mmHg) successfully managed by eye drops. 25-gauge vitrectomy was performed within a mean time of 12 hours from trauma (time range, 6 to 36 hours). At presentation and follow-up visits endophthalmitis was not reported. Retinal detachment recurred in one patient only and did not occur in the cases without retinal detachment at presentation.

5. Discussion

Pars plana vitrectomy is considered the most effective and safest approach for the removal of retained ocular foreign bodies and repair of retinal injuries correlated [12–15].

Advances in small-gauge (25-gauge or 27-gauge) vitrectomy instrumentation as well as surgical techniques have increased indications for complex cases.

First of all small-gauge vitrectomy should allow the best visualization of the intraocular lesions otherwise not detectable permitting the use of wide-angle binocular viewing system with chandelier xenon light source. Poor visualization may influence the efficacy of surgery increasing the risk of iatrogenic lesions, uncompleted removal of IOFB, and insufficient management of ocular injuries correlated, but the delay until the media clear up decreases the chances for vision recovery increasing the risk of complications as inflammatory reaction, proliferative vitreoretinopathy (PVR), endophthalmitis, and toxic reaction. However vitrectomy would be easier waiting for a reduction of corneal edema, traumatic hyphema or fibrinoid reaction, and the spontaneous separation of the posterior vitreous. Many other variables affect the algorithm for IOFB extraction like general medical status, the nature of the trauma, and the chemical nature of the IOFB [16].

If some retrospective analyses claim that the removal within 24 hours reduces incidence of endophthalmitis [17–19] and affects positively the final vision outcome [20, 21], other papers infer that the timing of IOFB removal is not a significant prognostic factor [6, 14]. However these studies have not sufficient power as prospective or randomized clinical trials.

If endophthalmitis is associated with ocular trauma, surgery is urgent. However we schedule a single time approach in order to reduce the risk of endophthalmitis and toxic reactions related to the chemical nature of the IOFB. Noninfectious toxicity is usually associated with metallic IOFBs. More frequently metal is reported in the cases of IOFBs (60% to 88% of IOFBs) [22, 23] as in our case series. Siderosis and chalcosis produce severe inflammation and sterile endophthalmitis hard to manage, so the timing of IOFB removal is an important risk factor for clinical outcome.

The severity of lesions correlated to trauma as scleral wound, vitreous hemorrhage, retinal detachment, also described in our case series, and the time delay of vitrectomy increase the risk of PVR [24]. This knowledge reinforces the belief that the timing of surgery should not be much delayed. After trauma it could be easier waiting at least 2 weeks for a posterior vitreous detachment before performing a vitrectomy but it is not always possible for the ocular lesions correlated and the young age of patients whose vitreous is tenaciously adherent to the retina. Vitrectomy removing the damaged vitreous decreases the risk of retinal detachment. So, using 25-gauge vitrectomy system equipped with a very high cut rates with a preserved duty cycle, surgeon was able to attach vitreous more safely performing a peripheral vitrectomy over detached retina and treating dense hemorrhage or vitreous debris, thanks also to a greater stability of the fluidics. Furthermore a chandelier light source allowed a bimanual technique to approach extreme anterior retina. In eyes with choroidal hemorrhage, confirmed by preoperative ultrasonography, surgeons choose a safer site with a relatively clearer periphery for the placement of trocars and selected a longer infusion cannula to avoid a slippage into the suprachoroidal space.

All the IOFBs were removed from the posterior segment by intraocular forceps with different design to resolve vitreous or fibrin adhesions around the foreign body and basket forceps to prevent slippage of the IOFB and protect scleral access borders. The use of 25-gauge vitrectomy to remove foreign body has also been reported, although an enlargement of the sclerotomy was required in all cases [11]. In this present study, in some cases for the removal of IOFBs we decided to perform scleral access at pars plana to preserve the sites of trocars in order to continue vitrectomy. We did not enlarge sclerotomy to avoid leakage during the later steps of vitrectomy. This technique was employed if the crystalline lens was intact, if the capsule was useful to IOL implant, and it worked for small to very large IOFB having a regular or irregular contour. If lensectomy was performed at the time of vitrectomy and sulcus implant was scheduled, IOFB was gently removed via a clear cornea or scleral tunnel incision. In some cases we combined microincision cataract surgery and 25-gauge vitrectomy without complications and without requiring suturing.

In all patients BCVA improved and also in two patients with RAPD at presentation. Sometimes RAPD evaluation was difficult or even impossible in cases with uveal (iris) prolapse through a corneal or corneoscleral wound.

25-gauge approach generally allows a less traumatic appearance, less conjunctival damage, less intraocular inflammation, and more rapid healing of sclerotomies when compared with 20-gauge PPV [25], although these advantages could seem irrelevant in patients with severe ocular trauma. Different studies have reported no significant difference in endophthalmitis rates between 20 and 25 gauges [26, 27] thanks to improvement in wound making and trocar/cannula entry systems used. Furthermore the design of small gauge and the higher cut rates can ensure a complete vitrectomy reducing the chances of iatrogenic retinal breaks. In our case series the absence of endophthalmitis and the low complication rate about postoperative retinal detachment and IOP alterations comfort us on the safety of our approach although this study included a relatively few patients and literature had reported a variable rate of endophthalmitis [18, 28–30] and postoperative retinal detachment [14, 31, 32] correlated to ocular trauma.

The major limitations of the present study include its noncomparative, retrospective nature. Nonetheless, this present series establishes that sutureless 25-gauge pars plana vitrectomy can be considered a safe and efficacious approach to manage posterior segment IOFBs.

Disclosure

The authors alone are responsible for the content and writing of the paper.

Competing Interests

The authors report no conflict of interests.

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Review Article

Posterior Segment Intraocular Foreign Body: Extraction Surgical Techniques, Timing, and Indications for Vitrectomy

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Ocular penetrating injury with Intraocular Foreign Body (IOFB) is a common form of ocular injury. Several techniques to remove IOFB have been reported by different authors. The aim of this publication is to review different timing and surgical techniques related to the extraction of IOFB. *Material and Methods*. A PubMed search on "Extraction of Intraocular Foreign Body," "Timing for Surgery Intraocular Foreign Body," and "Surgical Technique Intraocular Foreign Body" was made. *Results*. Potential advantages of immediate and delayed IOFB removal have been reported with different results. Several techniques to remove IOFB have been reported by different authors with good results. *Conclusion*. The most important factor at the time to perform IOFB extraction is the experience of the surgeon.

1. Introduction

Ocular penetrating injury with Intraocular Foreign Body (IOFB) is a common form of ocular injury [1]. It is encountered in 17–41% of open globe injuries. Sixty-six percent of trauma involving IOFB occurs between 21 and 40 years of age. Most common place for injury is work (54–72%), followed by home (30%). Trauma mechanism involves hammering (60–80%), use of power or machine tools (18–25%), and weapon-related injuries (19%) [1–3].

An ocular trauma review from the United States reported visual acuities of worse than 20/200 in 25% of patients who had IOFB injury [1, 2]. Multiple factors can predict poor visual prognosis, including worse initial visual acuity [1, 4, 5], hyphema [1], vitreous hemorrhage [1], uveal prolapse [1], afferent pupillary defect [1, 6, 7], and retinal detachment [1, 8]. The size of the IOFB is another prognostic factor related with the final Best Corrected Visual Acuity (BCVA). Larger IOFB are related with poor final BCVA [2, 4, 9] while smaller IOFB are related with better visual prognosis [4, 6].

Several techniques to remove IOFB have been reported by different authors. The aim of this publication is to review different timing and surgical techniques related to the extraction of IOFB.

2. Material and Methods

A PubMed search on "Intraocular Foreign Body," "Extraction of Intraocular Foreign Body," "Indications for Extraction of Intraocular Foreign Body," "Timing for Surgery Intraocular Foreign Body," "Surgical Technique Intraocular Foreign Body," and "Prognosis Intraocular Foreign Body" was made. Results were classified according to relevance according to the investigators. Smaller case series were not included. Priority was given to papers describing surgical techniques and their results.

3. Results

3.1. Timing and Indications for Vitrectomy. Potential advantages of immediate IOFB removal include a possible decrease in risk of endophthalmitis [1], a decrease in the rate of proliferative vitreoretinopathy (PVR), and a single procedure for the patient [1]. Early surgery was not significantly

Table 1: Different IOFB extraction techniques.

	Patients	BCVA baseline	BCVA at 3 months	Accident-surgery interval	IOFB size	Extraction technique
Yuksel et al.*	36 patients	20/550	20/120	14.2 ± 19.4 days	5.63 mm	"T" or "L" sclerotomy
Singh et al.*	14 patients	20/647	20/29	No mention	1 to 5 mm	Translimbal
Park et al.	10 patients	—	—	—	2.75 ± 1.04 mm	Viscoelastic capture
Rusnak et al.**	9 patients	20/25	20/20-	1 to 12 days	1.5 to 5 mm	Transscleral using magnet

*BCVA converted from LogMAR.
**BCVA converted from decimal.

associated with greater visual improvement [10] but had a significant impact on the development of posttraumatic endophthalmitis according to a report by Yeh [1]. On the other hand, delaying IOFB removal may result in improved control of inflammation caused by initial open globe injury, increase of the ability to assess intraocular structures, and the possible development of spontaneous posterior vitreous detachment (PVD) which might make excision of the posterior hyaloid easier [1]. Furthermore, in some cases, corneal edema associated to the site of entry may preclude visualization of the posterior segment and vitrectomy must be delayed until corneal edema disappears or endoscopic surgery may be indicated. Immediate surgical removal should be performed in all eyes with suspected endophthalmitis [4].

During Operation Iraqi Freedom, the time from injury to IOFB removal was 20.6 days (range 0–90) where the source of the IOFB was a propelled explosive (mortar, rocket-propelled grenade, or missile) in 36% patients and a nonpropelled explosive (grenade, mine, car bomb, or improvised explosive device) in 56% patients. There were no cases of endophthalmitis and they concluded that delayed removal may lead to good visual results and may not substantially increase the risk of endophthalmitis in such case of injuries [7]. However high-energy projectiles may heat-up but this heating may not always be enough to sterilize materials, so the probability of developing endophthalmitis is still present [11, 12].

3.2. Surgical Techniques. Table 1 shows surgical techniques of extraction of IOFB by different authors, size of IOFB, and interval accident-surgery.

Yuksel et al. performed 23 Gauge Pars Plana Vitrectomy for removal of retained foreign bodies and then enlarged the sclerotomy into a "T" or "L" shaped wound. There is no mention about the size of the enlarged sclerotomy. 36 patients were included in his report. Age was 43.2 ± 10.9 (15–60) years and they were followed up on for 9.4 ± 6.4 (2–27) months. Nine patients were female and 27 were male; right eye was affected in 54.1%. The interval between the injury and surgery was 14 ± 19.4 days (1–120). Seven cases had a primary wound repair in the same procedure. After vitrectomy, the IOFB was removed through the enlarged "T" or "L" shaped sclerotomy with 20 G forceps. Mean preoperative LogMAR BCVA was 1.44 ± 138 (Snellen equivalent 20/550, range 1.00 to 0.00) and mean postoperative LogMAR BCVA at the final visit was 0.78 ± 0.98 (Snellen equivalent 20/120, range 1.00 to 0.00, $p = 0.007$). In ten patients (27.8%) final visual acuity was better than preoperative values. Mean size of IOFB was 5.63 mm. Fibrin reaction was reported in eight (22.2%) patients. Intraocular pressure elevation was detected in 12 (33.3%) patients. All the patients with intraocular pressure elevation had silicone oil as intravitreal tamponade. Four (11.1%) patients with intraocular pressure elevation were controlled with medical therapy and one patient underwent diode laser cyclophotocoagulation. One of eight patients with silicone oil tamponade developed band keratopathy and phthisis bulbi. They concluded that 23-gauge PPV and sclerotomy enlargement for IOFB removal appear to be an effective and safe procedure in management of posterior segment IOFB [13].

Singh et al. reported an alternative approach for selected cases of IOFB in 14 patients with hammer and chisel injury. All the patients were men with mean age 27.62±8.2 range (17–46 years). The entrance wound was located in 4 patients at the limbus, in 7 patients in paracentral cornea, and in 3 patients in central cornea. Only 4 patients had primary repair. All eyes had posttraumatic cataract with capsular rupture. All the foreign bodies were metallic in nature. They underwent 23-gauge vitrectomy; then a self-sealing superior limbal incision was made. 20-gauge diamond coated IOFB forceps were inserted through the limbal wound and foreign body was grasped along its longest dimension and removed through the limbal port. Pars Plana Vitrectomy was completed after removing the posterior hyaloid. Mean preoperative logMAR visual acuity was 1.51 ± 0.93 (Snellen equivalent 20/647) and at 3 months was 0.17 ± 0.18 (Snellen equivalent 20/29). The improvement at 3 months was maintained at 6 and 12 months. Size of IOFB varied from 1 to 5 mm [14]. Postoperative complications included microscopic hyphema and loose blood in vitreous cavity seen in one eye, which resolved with conservative management within the next 7 days. No hypotony, choroidal detachment, or any other complication in the immediate postoperative period was reported. Late complications like IOP rise, epiretinal membranes, and retinal detachment were not seen in this series.

Park et al. described their technique in cases with full-thickness corneal laceration, traumatic cataract with anterior and posterior capsule rupture, and IOFB using a viscoelastic capture of IOFB with DisCoVisc® (Alcon Laboratories, Fort Worth, TX, USA) during 23-gauge MIVS [5]. The technique consists of primary suture of the wound; then they inserted a 23-gauge stiletto blade through the limbus. After this, they inserted a cannula; the anterior chamber was filled with DisCoVisc; phacoemulsification of the lens was performed, and residual cortical material was aspirated. A core vitrectomy and creation of a posterior vitreous detachment were performed; then IOFB was separated completely from

Table 2: The Ocular Trauma Score (OTS). Reproduced from Kuhn et al. [8].

Baseline visual acuity	Raw points	Diagnosis	Raw points	Sum of raw points	OTS
NPL	60	Globe rupture	−23	0–44	1
LP-HM	70	Endophthalmitis	−17	45–65	2
1/200–19/200	80	Perforating injury	−14	66–80	3
20/200–20/50	90	Retinal detachment	−11	81–91	4
>20/40	100	RAPD*	−10	92–100	5

*Relative afferent pupillary defect (RAPD).

Table 3: Conversion of raw points into OTS category and calculating the likelihood of the final visual acuity in five categories. The Ocular Trauma Score (OTS). Reproduced from Kuhn et al. [8].

Sum of raw points	OTS	No Light perception	Light perception/hand motion	1/200–19/200	20/200–20/50	>20/40
0–44	1	74%	15%	7%	3%	1%
45–65	2	27%	26%	18%	15%	15%
66–80	3	2%	11%	15%	31%	41%
81–91	4	1%	2%	3%	22%	73%
92–100	5	0%	1%	1%	5%	94%

all surrounding tissues, and photocoagulation was applied in the retinal tear. The anterior chamber was refilled with DisCoVisc. The IOFB was grasped using intraocular forceps and lifted to the level of the anterior capsule without changing hands. Once in the anterior chamber the IOFB was extracted through the main corneal incision site using the forceps. There were no changing hands, enlarging sclerotomy, or creating a new limbal wound.

Another method for extraction of magnetic IOFB is the external electromagnet that was developed in 1842 by Meyer [15] and their use was to prevent encapsulation [16]. PPV is still having better anatomical and functional prognoses and timely appears to markedly reduce the risk of endophthalmitis development compared with magnet extraction. Extraction of IOFB by electromagnet have 23% risk of developing vitreous hemorrhage by its strong pulling force [17, 18] and 10% risk of developing endophthalmitis [18].

Transscleral removal consisted in extracting an IOFB through sclerotomy without performing a PPV. Rusnak et al. reported 37 eyes with diagnosis of penetrating eye injury where 28 eyes were operated on by PPV and 9 cases by transscleral extraction without PPV. The extraction was performed on days from 1 to 12 (7.2 on average). They performed a conjunctival peritomy then a sclerotomy of 1.5 to 3.0 mm at 4.5 from the limbus. Using an indirect ophthalmoscope and a magnet, the IOFB was attracted. When the IOFB is removed, the sclera was sutured. In all the cases, cryopexy was performed. The initial BCVA was 0.8 (Snellen equivalent 20/25) with a final BCVA of 0.97 (Snellen equivalent 20/20-). There was no report about complications [19].

The Endoscopic Pars Plana Vitrectomy was first described by Thorpe in 1934 where the proposed indication was any media opacity [20]. The advantages of using an endoscopic system are bypassing anterior segment opacities, manipulation, and visualization of anterior structures [20, 21]. Regarding limitations of this technique, it currently does not permit bimanual instrumentation and the postoperative examination is still difficult by anterior segment opacity.

Shah et al. in their model eye study found that the use of perfluorocarbon fluids protects the macula in case of dropping the IOFB while attempting to remove it from the eye, especially when the IOFB has lower mass [22].

3.3. Prognostic Factors. Different prognostic factors have been related to a better final visual acuity such as better presenting visual acuity and hammering metal on metal as a mechanism of injury. Poor visual outcome is associated with poor presenting visual acuity [1, 4, 5], presence of afferent pupillary defect [1, 6, 7], vitreous hemorrhage [1], retinal detachment [1, 8], or prolapse of intraocular contents [1]. Greven et al. have not found relationship between size of the IOFB and the visual outcome [2], however, other authors have [4, 6, 9].

The Ocular Trauma Score (OTS) is a useful tool prior to surgical approach for predicting the visual prognosis. It was described by Kuhn et al. [8] in 2002 based on a review of databases of the United States of America and Hungary to identify the predictors of visual acuity after open globe injury (Table 2). To calculate the OTS a numerical value is assigned to the Best Corrected Visual Acuity (BCVA) of the patient. From this score "raw points" are subtracted according to a set of 5 variables. These variables are globe rupture (according to the raw points, this is the worst prognostic factor for final visual acuity even worse than endophthalmitis) [23], endophthalmitis (is not a frequent factor but can be present as soon as 24 hours after the event) [23], perforating injury, retinal detachment, and relative afferent pupillary defect (Table 2). The remaining value determines the Ocular Trauma Score which is stratified into five categories and they reflect the probability of obtaining a range of specific visual acuity at 6 months (Table 3). The use of OTS is an excellent prognostic tool to predict the visual acuity after ocular trauma [8, 23–25].

Agrawal et al. reported a series of 172 eyes with open globe injuries and its correlation to the Ocular Trauma Score. In his series IOFB had no impact on final BCVA. Good initial BCVA was associated with good final vision outcome. When RAPD or vitreous loss was present, more than 50% of patients had final BCVA less than hand motion [24].

4. Discussion

Several studies showed that the time to perform a PPV is not a prognostic factor to develop endophthalmitis. Extraction of an IOFB can delayed for long time with adequate vigilance of the patient as was seen in the report during Operation Iraqi Freedom, where the extraction of IOFB was delayed in some cases up to 90 days. We advise to perform immediate extraction of the IOFB in case of suspected endophthalmitis; otherwise it can be delayed for a few days until corneal edema resolves and allows a better visualization during vitrectomy, intraocular inflammation is controlled, and suprachoroidal hemorrhage liquefies and thus can be drained if necessary. These processes usually take between 3 and 14 days.

In this review we compared the results of different IOFB extraction techniques in previous reports. Yuksel et al. reported 36 patients with trauma related to IOFB using the "T" or "L" sclerotomy where the interval between accident and surgery was 14 days. The size of the IOFB was similar in all papers except in the viscoelastic capture but its technique requires a limbal port where IOFB can be extracted regardless of the size. The extraction of IOFB without PPV can be possible as shown by Rusnak et al. where they reported 9 patients with IOFB removed through a transscleral incision using a magnet achieving a good visual acuity and there were no report of complications; however other reports debate about the risk of using this technique. Park reported 10 patients in their paper, but there is no detail about BCVA or interval between accident and surgery since their publication is only a surgical technique description. We do not recommend extracting an IOFB in the vitrectomy era without performing vitrectomy, since there is a risk for vitreous incarceration in the wound and unnecessary traction can be applied to intraocular structures. Furthermore, if there is an intraretinal foreign body, some ocular trauma experts even recommend a retinochoroidectomy around the area of the posterior lesion to reduce postoperative cellular proliferation and consequent traction. The use of perfluorocarbon fluids before lifting the IOFB is highly recommended to try to avoid macular damage in case of dropping. Site and technique of extraction must be decided by the surgeon according to the injuries proper to each case and personal experience. We usually use a limbal approach if the crystalline lens is not present and a scleral enlargement when it is.

The OTS is an effective tool to predict the visual acuity. In the moment of the assessment of a patient with ocular trauma, it is important to perform a detailed examination of the affected area and try to identify any signs related to the OTS because it can give us a prognostic visual acuity in the moment of patient counseling.

5. Conclusions

In this review we observed that the IOFB can be removed by any technique regardless of the size of the IOFB. We conclude that PPV should be performed in all patients, and the exact mechanism of removal of IOFB should depend on the surgeon's preference given that all techniques described above were successful. The decision of which technique to use on a particular subject must be decided upon damage of particular eye structures (cornea, lens, and retina).

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Review Article

Timing and Outcomes of Vitreoretinal Surgery after Traumatic Retinal Detachment

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Traumatic retinal detachments are a significant cause of morbidity. There are currently no evidence-based guidelines on the appropriate time to perform vitreoretinal surgery to repair a traumatic retinal detachment. Early intervention, within seven days of the inciting trauma, may decrease proliferative vitreoretinopathy and postoperative endophthalmitis. Later intervention may yield a reduced risk of inflammation and hemorrhage, particularly in cases of concomitant open globe injuries. This article reviews the literature on the management of retinal detachments associated with ocular trauma from the years 2006 to 2016. Particular focus was placed on the timing of surgery, concomitant open globe injury, anatomical success rates, visual acuity, and complication rates. In this review, anatomical success was not significantly related to timing of intervention when compared between early and delayed intervention in eyes with and without concomitant open globe injuries. Visual acuities postoperatively varied widely despite timing of intervention due to the large variation in mechanism and extent of ocular injuries. Proliferative vitreoretinopathy was a common complication. Preliminary data indicate that endophthalmitis rates may be lower when early vitreoretinal surgery is performed. There is insufficient data to conclude whether early or delayed surgery leads to improved outcomes, highlighting the need for further research in this domain.

1. Introduction

Ocular trauma is the leading cause of decreased visual acuity in young adults [1]. 0.8% of retinal detachments (RDs) in the general population are secondary to trauma [2]. Most of these traumatic RDs are in young patients with work-related trauma [3, 4]. There is a general consensus that vitrectomy is the appropriate surgery for most traumatic RDs, but other interventions may include scleral buckle, laser, retinopexy, or a combination of these based on the individual patient. The timing to intervention, however, remains controversial [5, 6].

In addition to repairing the retinal detachment, the benefit of early intervention with vitrectomy is to remove the maximum amount of vitreous, thus eliminating the depot for inflammation to settle and epiretinal membranes to form. Some authors postulate that early intervention decreases postoperative proliferative vitreoretinopathy (PVR), a complication that can lead to redetachment and has been found to be more common in eyes that have suffered trauma than in nontraumatic RD [7]. Others contend for delayed intervention, allowing time for the eye to recover, a complete posterior vitreous detachment to develop, and the PVR process to settle, thus making the surgery less complicated. They also maintain that there is a decreased risk of severe hemorrhage when operating several days after the inciting trauma, particularly in eyes with prior open globe injuries. In delayed intervention, primary ocular repair, if needed, is often done within hours of the injury to stabilize the eye, while vitreoretinal surgery takes place up to one month later [6]. This review analyzes recent publications and research in the management and outcomes of traumatic RDs to suggest updated guidelines for the management of this condition, with particular attention as to whether vitreoretinal surgery should occur within the first 7 days after injury or later.

2. Methods

The following search terms were entered into http://www.pubmed.gov/ (US National Library of Medicine, National Institutes of Health): "(Retinal Detachment/statistics and numerical data" [Mesh] OR "Retinal Detachment/surgery" [Mesh] OR "Retinal Detachment/therapy" [Mesh]) AND "Craniocerebral Trauma" [Mesh]. Results were limited to the research studies conducted in humans within the past ten years (2006–2016) that are written in English. This search yielded 70 articles. Two independent reviewers analyzed all 70 articles and agreed that 24 of these articles were pertinent to this review. After extensive review of these 24 articles, it was mutually decided that 9 had data suitable to this review. Articles were excluded if they did not discuss traumatic retinal detachment, if they did not separate outcome measures based on whether patients had retinal detachment versus other types of retinal pathology, or if they did not involve surgical intervention for retinal detachment. For individual consideration of the impact of time to intervention, articles were only included if they reported outcome measures individually for each patient or stratified patients by timing to intervention.

Outcome measures studied included percentage of patients with improved visual acuity postoperatively and percentage of patients with attached retina at follow-up. Follow-up period was 3 months or greater for each study. A Pearson Chi-square test was used to determine whether timing to intervention resulted in a significantly different number of patients with attached retina at follow-up. The timing variable for each study was coded in two groups, one with patients receiving intervention within 7 days including those who had concomitant open globe repair and RD repair and the other with patients receiving intervention greater than 7 days after presentation. All studies fit into these two categories except Ehrlich and Polkinghorne [8], which reported a mean time to intervention of 22.4 days, which was coded in the timing category as greater than 7 days to intervention. P values of less than 0.05 were considered statistically significant, and hazard ratios were conducted with a 95% confidence interval by the Cox proportional-hazard analysis. Statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS) version 22.0 (IBM; Chicago, IL). Type of intervention and complications were reported for each study which included this data.

3. Results

3.1. Timing to Intervention. Most patients underwent primary closure promptly if necessary for open globe injury, but time to vitreoretinal intervention for retinal detachment varied. Of the 9 included articles, 5 provided information on timing to intervention (Table 1). Ehrlich and Polkinghorne reported a mean time to vitreoretinal intervention of 22.4 days (range 3–86 days) among a total of 19 adult patients and was therefore analyzed as greater than seven days before intervention [8]. Among the five articles, 171 patients in total underwent intervention within 7 days of diagnosis of trauma related RD, and 28 patients underwent intervention greater than 7 days after diagnosis of RD. Of those with intervention within 7 days, 88 of those had vitreoretinal surgery 48 hours or less after diagnosis of RD [9, 10]. Nashed et al. reported on 88 that underwent retinal detachment repair at the same time as open globe repair within 8 hours of initial presentation [5]. Some of the patients, including those reported by Wang et al., were pediatric patients (Table 1). These patients were all included in the analysis. Of note, none of these studies except Nashed et al. [5] identified and separated patients by the timing of open globe injury repair, whether it was prior to vitreoretinal surgery or concomitant with it.

3.2. Attached Retina at Follow-Up. A Chi-square test of independence determined that the relationship between the timing of intervention and the number of patients with an attached retina at follow-up was not significant; χ^2 (1, N = 199) = 0.216, p = 0.642. The effect size showed phi = 0.033. Results from each study individually can be found in Table 2. No other factors such as concomitant open globe or type of surgical intervention were found to be statistically significant in regard to subsequent anatomic success at follow-up.

3.3. Visual Acuity. A comparison of preintervention and postintervention best corrected visual acuity (BCVA) can be found in Table 3. Two of the studies included in our analysis provided visual acuities before and after surgery for each patient, and thus we compared the preoperative and postoperative visual acuities to determine if their vision improved, was stable, or deteriorated after intervention (Table 4) [8, 10]. The surgical interventions in these two studies included both vitrectomy and scleral buckle placement. In 54% of patients, visual acuity (VA) was improved after surgical intervention, whereas 36% of patients had a worsened VA after surgery. 10% of patients had a stable VA [8, 10]. Up to 32% of patients ultimately had no light perception, while up to 13% of patients achieved 20/20 VA [10] (Table 3). In Sheard et al.'s study, 65% of pediatric patients receiving scleral buckle had improved VA after intervention, 18% had worsened VA, and 18% were stable. Amongst the vitrectomy patients in the same study, 36% had improved VA after intervention, 36% had worsened VA, and 29% were stable [13].

3.4. Type of Intervention. Type of vitreoretinal intervention was reported for a total of 294 patients among the 9 included studies (Table 5). 159 patients underwent vitrectomy alone, 32 had scleral buckle placement alone, and 34 had both vitrectomy and placement of a scleral buckle. Of note, Rouberol et al. (50 patients) and Lesniak et al. (19 patients) stated that patients had vitrectomy with or without scleral buckle. The exact number of patients with adjuvant use of scleral buckle during vitrectomy was not reported in either of these articles; therefore these treatment counts are not included in the totals above. Silicone oil tamponade was used in a total of 131 patients. There is insufficient data to assess

Table 1: Time to and type of intervention.

Study	Time to intervention	Type of intervention	Number of patients
Nashed et al. [5]	<8 hours	Vitrectomy with silicone oil within 8 hours of presentation	88
Ehrlich and Polkinghorne [8]	>7 days	Small-gauge vitrectomy ± scleral buckle ± silicone oil tamponade	19
Rouberol et al. [9]	≤7 days	94% underwent cryotherapy 82% had a scleral buckle 76% underwent PPV	50
Wang et al. [10]	≤7 days	88% underwent PPV 70% had a scleral buckle placed	33
Sisk et al. [11]	>7 days	78% PPV and scleral buckle 11% PPV alone 11% scleral buckle alone	9

Table 2: Time to intervention versus percent attached at follow-up.

Study	Timing	Number not attached at F/U (%)	Number attached at F/U (%)	Total patients studied
Nashed et al. [5]	≤7 days	33 (37.5%)	55 (62.5%)	88
Ehrlich and Polkinghorne [8]	>7 days	6 (31.6%)	13 (68.4%)	19
Rouberol et al. [9]	≤7 days	12 (24%)	38 (76%)	50
Wang et al. [10]	≤7 days	24 (72%)	9 (27%)	33
Sisk et al. [11]	>7 days	4 (44%)	5 (55%)	9

whether the type of surgical intervention had an impact on either anatomical success or postoperative visual acuity.

3.5. Complications. Complication rates following vitreoretinal surgery for traumatic retinal detachment in these studies are detailed in Table 6. The vast majority of phakic eyes developed cataracts after surgical intervention [9, 11, 17]. Development of secondary glaucoma was also a significant complication and in some cases required surgical intervention [10, 15]. Multiple investigators found that patients developed phthisis bulbi, with up to 30% of patients experiencing this complication in certain studies [5, 8–10, 12]. PVR was a significant finding postoperatively, as it was found in up to 56% of patients [5, 8, 12, 15].

4. Discussion

This review analyzes the available articles over the last 10 years since the use of small gauge vitrectomy which included a diverse population of patients with traumatic retinal detachment, including both pediatric and adult patients. Notably, the mechanism of ocular injury, the extent of injuries, timing of RD development, and surgical management varied significantly between patients in the available studies.

4.1. Predictive Factors of Postoperative Retinal Attachment. In our review, reattaching the retina within 7 days after trauma did not significantly affect the likelihood that the retina would remain attached at follow-up, nor did waiting over 7 days before vitreoretinal surgery affect anatomical success rates. For all studies, this was assessed at more than three months after the surgery. This review highlights a lack of literature regarding this topic in regard to the appropriate intervention in these cases with or without the presence of open globe injury, suggesting the need of additional studies to help identify these factors. There is insufficient data to assess if the type of vitreoretinal intervention affects anatomical success or postoperative visual prognosis.

The available cases in the literature are limited and also represent a large mix of patients who had different mechanisms and extent of ocular trauma leading to many confounding factors in our analysis. Current recommendations are trending towards earlier intervention to reduce the risk of extension of the retinal detachment and increased proliferation of the epiretinal membranes. Further analysis of these cases should be performed in order to develop better guidelines as to the ideal time to repair these traumatic retinal detachments.

4.2. Predictive Factors of Postoperative Visual Acuity. There is insufficient data to conclude whether timing of intervention affects postoperative visual acuity. However, this is not the only factor affecting visual potential because regardless of what time vitreoretinal surgery is performed, postoperative VA varies widely. This makes it difficult to counsel patients about their expected visual outcome when they have traumatic retinal detachments.

This inability to accurately predict postoperative VA has led several investigators to study what factors influence final VA. Multiple studies support that a poorer VA at

Table 3: Visual Acuity after Traumatic Retinal Detachment.

Author	Number of patients	Initial (preintervention) BCVA	Postintervention BCVA	Comments
Nashed et al. [5]	88	2.3%: ≥20/50 16%: >20/800	8%: ≥20/50 50%: >20/800	36% of patients who received a retinectomy had a VA of >20/800 after intervention
Ehrlich and Polkinghorne [8]	19	5%: ≥20/50 22%: <20/50 & ≥20/200 5%: <20/200 & ≥20/400 69%: <20/400	21%: ≥20/50 5%: <20/50 & ≥20/200 11%: <20/200 & ≥20/400 63%: <20/400	63% had improved VA 21% had worsened VA 16% were stable
Rouberol et al. [9]	50	42%: ≥20/200	38%: ≥20/40 80%: ≥20/200	
Wang et al. [10]	31	3%: ≥20/50 9%: <20/50 & ≥20/200 87%: <20/400	28%: ≥20/50 9%: <20/50 & ≥20/200 3%: <20/200 & ≥20/400 58%: <20/400	These were all pediatric patients Only patients who have both a preintervention and postintervention BCVA are included in this chart 48% has improved VA 45% had worsened VA 6% were stable
Eliott et al. [12]	1	20/30	20/20	Pediatric patients
Sheard et al. [13]	47	Median for scleral buckle patients: 20/120 Median for vitrectomy patients: CF	Median for scleral buckle patients: 20/80 Median for vitrectomy patients: CF	These were all pediatric patients
Zhang et al. [14]	9	LP (average)	Between LP and HM	No statistical difference between preintervention and postintervention VA
Lesniak et al. [15]	28	LP (average)	20/4000 (average)	Pediatric patients with open globe injuries

Table 4: Time to intervention versus percent with improved or stable visual acuity.

Study	Timing	Percent with improved or stable VA	Number with improved/stable VA	Total patients studied
Ehrlich and Polkinghorne [8]	>7 days	79	15	19
Wang et al. [10]	≤7 days	54	18	33

presentation predicts a poorer final visual outcome [9, 12, 18]. Attachment of the macula at presentation was associated with an improved visual outcome [9, 10]. Developing endophthalmitis conferred an inferior visual outcome in one study [18] but was not shown to have the same effect in another [14]. Recurrent retinal detachment predicted a worse visual outcome [10], as did total RD on presentation, retention of silicone oil in the eye, and development of PVR [14]. The following factors were not shown to significantly influence visual outcome: an open globe injury, previous ocular surgery, lens injury, number and severity of retinal tears, presence of vitreous hemorrhage [9, 14, 16], need for multiple vitreoretinal procedures, and whether the patient received scleral buckling or PPV [9, 12, 14].

Most cases of redetachment after surgery were secondary to proliferative vitreoretinopathy [9, 14]. Wang et al. found that, in pediatric patients with traumatic RD, age, sex, location of injury, time between injury and RD, vitreous hemorrhage, and lens status did not predict anatomical success rate. However, poor preoperative VA (LP or worse),

Table 5: Type of intervention.

Study	Type of intervention	Number of patients
Nashed et al. [5]	Vitrectomy	88
Ehrlich and Polkinghorne [8]	Vitrectomy	16
	Vitrectomy + buckle	3
Rouberol et al.* [9]	Vitrectomy +/– buckle	50
Wang et al. [10]	Buckle	4
	Vitrectomy + buckle	19
	Vitrectomy	10
Sisk et al. [11]	Vitrectomy	1
	Vitrectomy + buckle	7
	Buckle	1
Eliott et al. [12]	Cryopexy + radial sponge	1
Sheard et al.** [13]	Vitrectomy	30
	Buckle	17
Lesniak et al.*** [15]	Vitrectomy +/– buckle	19
James et al. [16]	Vitrectomy	14
	Cryobuckle	9
	Vitrectomy + cryobuckle	5

Treatment breakdown for each study included:
*9 patients underwent no vitreoretinal intervention: 4 primary enucleation, 3 secondary enucleation, 1 no treatment due to phthisis, and 1 was lost to follow-up.
**This study also included another 14 patients who underwent vitrectomy for retinal pathology that was not an RD; these patients are not included above.
***Unclear how many patients underwent vitrectomy alone versus vitrectomy + buckle.

presence of PVR grade C or worse, detachment of the macula, total RD, and vitrectomy (as opposed to scleral buckle) are associated with a worse anatomical success rate [10].

An important point to consider is that RD does not always occur immediately after trauma. Other investigators have studied which patients are more likely to develop a retinal detachment after traumatic globe injury. Stryjewski et al. studied open globe injuries and found that a visual ability to count fingers (or worse), injury involving the sclera posterior to the limbus, and presence of vitreous hemorrhage all correlated with an increase rate of developing subsequent traumatic RD. They subsequently created a scoring system to predict the likelihood of a retinal detachment after open globe injury based on the presence of these characteristics [19]. However their analysis did not make any recommendations regarding the management of these cases once they develop retinal detachments. Pimolrat et al. also found that, in patients who require pars plana vitrectomy (PPV) after open globe injury, the presence of a rapid afferent pupillary defect was significantly associated with a worse visual acuity after vitrectomy. However, only 32% of the patients in this study had a RD, limiting its applicability to patients who have already developed a RD [20].

4.3. Complications of Surgical Intervention for Traumatic Retinal Detachment. While surgical intervention for traumatic retinal detachment can be vision-saving, it is not without its risks, as detailed in Table 5. PVR is a major concern after surgery for RD, with up to 56% of patients developing this complication [15]. As discussed previously, PVR is a significant risk factor for recurrent retinal detachment, so this complication is of particular importance. In a study of 28 patients treated with cryobuckle only for retinal detachment due to retinal dialysis, only 1 (3.6%) developed PVR [16]. This may indicate that cryobuckle alone is associated with a decreased risk of PVR development. However, this study had a small population and was limited to only patients with traumatic RD with retinal dialysis, which is often amenable to repair with buckle only. This is in contrast to most other traumatic RDs which have limited success with buckle-only repair. Further studies are necessary to explore this relationship. Endophthalmitis rates were as low as 3.4% when surgical intervention for RD repair was performed within 8 hours [5], whereas when timing of surgery is not taken into account, other authors report that ocular trauma resulted in endophthalmitis in up to 13% of cases [18]. These results suggest that other important outcome measures are also related to timing of vitreoretinal intervention, and further studies delineating the risks and benefits of early surgical intervention should be pursued. Traumatic retinal detachments are challenging and decisions should be individualized; however further analysis to help identify which surgical techniques improve outcome should be undertaken.

5. Conclusion

There is insufficient data to assess if early vitreoretinal surgery to repair traumatic RDs leads to significantly higher

Table 6: Complications after surgery for traumatic retinal detachment.

Author	Number of eyes	Type of intervention	Timing to intervention	Complications	Comments
Nashed et al. [5]	88	Vitrectomy with SO within 8 hours of presentation	Within 8 hours	49% retained SO 44%: PVR 8%: phthisis bulbi 3.4%: endophthalmitis	
Ehrlich and Polkinghorne [8]	19	Small-gauge vitrectomy ± SB ± SO tamponade	Mean: 22.4 d	21% had OHTN that responded to topical treatment 11% had hypotony (≤6 mm Hg) 5% developed PVR 5% developed phthisis bulbi	
Rouberol et al. [9]	50	94% underwent cryotherapy 82% had a SB 76% underwent PPV	Within 7 days	8% retained SO 6%: a secondary cataract 4%: an ERM 2% developed SO emulsification in the AC 2% developed phthisis bulbi	25 patients had open globe injuries, while 25 had closed globe injuries.
Wang et al. [10]	33	88% underwent PPV 70% had a SB placed	Within 7 days	30%: phthisis bulbi 18%: band keratopathy 15%: rubeosis 6%: VH 3%: secondary glaucoma 3%: siderosis	These were all pediatric patients.
Sisk et al. [11]	9	78% PPV and SB 11% PPV alone 11% SB alone	Varied 6/9 cases were chronic RD, likely delayed presentation	89% developed a cataract 56% developed secondary glaucoma after SO placement 56% developed PVR 56% developed complications from SO, such as emulsification blocking the visual axis 44% had recurrent RD	These patients all had repeated head trauma from self-injurious behavior. Some of these RDs were chronic.
Kolomeyer et al. [17]	41	PPV with 360° retinectomy	Varied	100% of phakic eyes developed a cataract 39%: PVR 32%: significant retinal hemorrhage intraoperatively 17%: corneal decompensation 17%: hypotony 17%: preretinal or retinectomy hemorrhage 15%: hyphema 15%: phthisis bulbi 5%: subretinal Perfluoron droplets	Only 63% of patients had traumatic RD.
James et al. [16]	28	100% had cryobuckle placement		46%: buckle removal 25%: buckle exposure 18%: strabismus 11%: infection related to the buckle	

SO: silicone oil, OHTN: ocular hypertension, ERM: epiretinal membrane, SB: scleral buckle, AC: anterior chamber, VH: vitreous hemorrhage, RD: retinal detachment, PVR: proliferative vitreoretinopathy.

reattachment rates at long-term follow-up and improved visual outcomes for patients. Common adverse outcomes after vitreoretinal surgery for traumatic RD include PVR, cataracts, secondary glaucoma, phthisis bulbi, and endophthalmitis. Preliminary studies indicate that endophthalmitis rates may be lower when early vitreoretinal surgery is performed. The information in this review suggests it is too soon to determine if vitreoretinal surgery for repair of traumatic retinal detachment should be performed within 7 days of the inciting event, and further studies should focus on prospectively determining the effect of timing to intervention particularly in cases of concomitant open globe injuries on clinical outcome variables and complication rates.

Competing Interests

All authors state that there is no conflict of interests regarding the publication of this paper.

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Research Article

Timing of Pars Plana Vitrectomy in Management of Gunshot Perforating Eye Injury: Observational Study

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The aim of this study is to report the difference in either anatomical or functional outcome of vitreoretinal intervention in cases of gunshot perforating eye injury if done 2–4 weeks or after the 4th week after the original trauma. Patients were treated with pars plana vitrectomy and silicon oil. Surgeries were performed in the period from February 2011 until the end of December 2014. 253 eyes of 237 patients were reviewed. 46 eyes were excluded. 207 eyes of 197 patients were analyzed. The included eyes were classified based on the timing of vitrectomy in relation to the initial trauma into two groups: 149 eyes (the first group) operated on between the 3rd and the 4th week and 58 eyes (the second group) operated on after the 4th week after the trauma. Following one surgical intervention, in the first group, attached retina was achieved in 93.28% of patients. In the second group, attached retina was achieved in 96.55% of patients. All RD cases could be attached by a second surgery. Visual acuity improved in 81.21% of patients, did not change in 15.43% of patients, and declined in 3.35% of patients. In the second group, visual acuity improved in 81.03% of patients, did not change in 12.06% of patients, and worsened in 6.89% of patients. There was no statistically significant difference between the two groups in either anatomical or functional results. We recommend interfering before the 5th week after the trauma as retinal detachment is encountered more in cases operated on after the 4th week. The visual outcome depends on the site of entry and exit (the route of gunshot).

1. Introduction

Mechanical injuries of the globe (open and closed) are classified according to Pieramic et al. [1] system that relies on four variables: type of injury, grade of injury, pupillary response, and zone of injury [1]. Open globe injuries are a common and often preventable cause of permanent visual impairment and visual loss [2]. Perforating ocular injuries are "through-and-through" globe defects with entry and exit sites. This is in contrast to penetrating injuries, which have a point of entry into the globe but no exit wound [3, 4].

Histopathological studies revealed that posterior vitreous detachment (PVD) usually occurred at 1 to 2 weeks after trauma [5]. The peripheral tractional retinal detachment then developed between 7 and 11 weeks, due to contractile fibrovascular ingrowth from the wound along the vitreous scaffold to the vitreous base and from preretinal membranes in the peripheral and equatorial retina. The end result at 4 months was tractional total retinal detachment and fibrous cyclitic, epiretinal, and subretinal membranes [6]. If not operated on it ends by phthisis bulbi [7].

Experimental and clinical studies suggest that, among all types of globe wounds, perforating injuries have the worst prognosis [8–10]. The factors limiting visual recovery include direct injury to the optic nerve or macula, intraocular scarring and fibrosis with secondary retinal detachment, and severe ocular disorganization [11, 12]. Several predictive factors affect the prognosis for final visual acuity [13].

Previous reports showed that vitreoretinal surgery in perforating injury prevents phthisis bulbi and achieves some functional result [7]. There is controversy to do vitreoretinal surgery early days or weeks after repair of the primary injury [14] or to use encircling scleral band or no [15].

The aim of this study was to compare the results of PPV during the 3rd to 4th or later than the 4th week after trauma in gunshot perforating eye injury.

2. Patients and Methods

This is a retrospective observational study of 207 eyes of 197 patients with perforating eye injuries caused by gunshots treated by pars plana vitrectomy and silicon oil with or without buckle.

Surgeries were performed in the period from February 2011 to the end of December 2014 during the period of political instability in Egypt. All surgeries were performed by a single surgeon (HG) at a single center.

All patients had preoperative evaluation included: best corrected visual acuity, intraocular pressure measurement, anterior segment examination using the slit lamp, and dilated fundus examination using indirect ophthalmoscope if the media were clear. The ocular trauma score (OTS) was retrospectively calculated.

Investigations done were B/scan ultrasonography and Computerized Tomography (CT) to locate the gunshot and for medicolegal aspect. Visual Evoked Potential (VEP) was requested for cases with no light perception to justify no surgical intervention.

Inclusion Criteria. Perforating gunshot ocular injury with at least light perception vision with minimum follow-up 6 months after the last surgical intervention was the inclusion criterion.

Exclusion Criteria

- Patients with visual acuity of no light perception
- Patients with retained intraocular foreign body (gunshot)
- Patients with endophthalmitis
- Patients with follow-up less than 6 months after the last surgical intervention.

2.1. Surgical Procedures. Primary repair was done elsewhere in all cases in the same day of trauma. Our plan for vitreoretinal intervention in such cases was to operate on at least 2 weeks after the primary repair to allow entry wound healing, suprachoroidal hemorrhage to liquefy if present and posterior vitreous detachment to occur. In this series, some factors made the time of intervention variable; for example, patients with scleral and limbal entry were operated on during the 3rd week after trauma. Patients with a central corneal wound or suprachoroidal hemorrhage were operated on in the 4th week from injury to allow more time for proper wound healing. Patients referred after the 4th week of trauma were operated on once they were presented to us.

The surgical technique was the same in all cases and was done by the same surgeon (HG). Three-port pars plana vitrectomy (PPV) was done using conventional 20 gauges or transconjunctival cannulated 20 or 23 gauges with or without scleral buckling.

Lensectomy using fragmentation or vitrectomy probe was done if there was cataract interfering with proper visualization or if lens touch occurred; otherwise the lens was spared.

A central vitrectomy was performed until central PVD was achieved if not already present. Perfluorocarbon (PFC) was injected to flatten the retina in cases with retinal detachment, to get a better view, to elevate the residual vitreous and to displace subretinal hemorrhage anteriorly.

Vitrectomy was completed as safe as possible anteriorly leaving an amalgam of tissue around the exit site to prevent PFC, air, and silicon from escaping into the orbit. No chorioretinectomy was done in those cases.

Vitrectomy under air was used frequently in the presence of bleeding. Laser was applied to any retinal break, 360 degrees and around the exit site if it was outside the macula. Air PFC exchange was done followed by silicon oil injection of 2,000 or 5,000 cSt. The bright illumination and wide field visualization systems allowed us to do all surgeries without the need of penetrating keratoplasty.

All patients were examined in the 1st postoperative day. Fundus examination and color fundus photography were done if possible. Postoperative follow-up was scheduled at 1 week, 3 weeks, 6 weeks, and then every 8 weeks.

In cases of development of retinal detachment after the primary surgery, the surgical procedure consisted of silicon oil removal, triamcinolone-assisted removal of any residual vitreous cortex, and removal of epiretinal membrane if involving the macula. Relaxing retinotomy was done in cases with excessive retinal proliferation preventing retinal attachment or subretinal S.O. PFC was injected. Laser was added to any break and to the edge of retinotomy followed by air PFC exchange. Silicon oil 5,000 cSt was injected at the end of surgery.

Statistical tests used are mean, standard deviation, chi-square test, and P value. P value was considered significant if <0.05. Statistical analysis was performed using a commercially available statistical software package (SPSS for windows, version 20).

3. Results (Tables 1–6, Figures 1–6)

253 eyes of 237 patients were reviewed. Excluded cases were 9 eyes due to no light perception at their presentation, 24 eyes with intraocular gunshot, and 13 eyes due to short follow-up (less than 6 months). 207 eyes of 197 patients were analyzed.

The included eyes were classified according to the duration between trauma and vitreoretinal intervention into two groups; the first group included 149 eyes in which

Table 1: Preoperative data of the patients.

		Group 1 2 w–4 w (149)		Group 2 >4 w (58)		X^2	P value
		N	%	N	%		
BCVA* preoperatively	LP**	47	31.54	29	50	6.34	0.175
	HM†	85	57.04	25	43.10		
	CF1m‡	10	6.71	2	3.44		
	20/100–20/200	4	2.68	1	1.72		
	20/40–20/100	3	2.01	1	1.72		
Anterior segment findings	Hyphema	21	14.09	3	5.17	4.746	0.577
	Lens subluxation	6	4.02	2	3.44		
	Aphakia	9	6.04	2	3.44		
	Cataract	25	16.77	10	17.24		
	Vitreous in anterior chamber	16	10.73	7	12.06		
	Anterior synechia	4	2.68	1	1.72		
Entry site	Corneal	58	38.92	26	44.82	1.186	0.553
	Scleral	61	40.94	19	32.75		
	Limbal	30	20.13	13	22.41		

*BCVA: best corrected visual acuity.
**LP: light perception.
†HM: hand motion.
‡CF: counting finger.
P is significant if <0.05.

Table 2: Intraoperative findings and exit site of the studied groups.

		Group 1 2–4 weeks (149)		Group 2 >4 weeks (58)		X^2	P value
		N	%	N	%		
Intraoperative findings*	Suprachoroidal hemorrhage	12	8.05	2	3.44	1.404	0.236
	Dense vitreous hemorrhage	45	30.20	15	25.86	0.382	0.537
	Retinal detachment	23	15.43	25	43.10	17.942	0.001
	Retinal incarceration	6	4.02	7	12.06	4.588	0.032
	Retinal fold	3	2.01	4	6.89	3.047	0.081
	Subretinal fibrosis	1	0.67	2	3.44	2.254	0.133
	Submacular hemorrhage	7	4.69	2	3.44	0.157	0.692
	Choroidal detachment	6	4.02	1	1.72	0.678	0.410
	Choroidal rupture	3	2.01	1	1.72	0.018	0.892
Exit site	Macular	49	32.88	10	17.24	5.125	0.077
	Disc	21	14.09	9	15.51		
	Others	79	53.02	39	67.24		

*For intraoperative findings comparison was made for each item separately as some cases have many findings.

vitreoretinal surgery was done between the 3rd and the 4th week after injury and the second group included 58 eyes in which vitreoretinal surgery was done after the 4th week after the injury.

In the first group, 129 patients (88.35%) were males and 17 patients (11.65%) were females. The age ranged from 4 to 48 years with mean ± standard deviation (25.58 ± 8.2 years). In the second group, 41 patients (80.39%) were males and 10 patients (19.61%) were females. The age ranged from 4 to 55 years with mean ± standard deviation (26.57 ± 11.23 years).

Preoperative visual acuity was distributed among the two groups as follows: in the first group, visual acuity was LP in 47 eyes (31.54%), HM in 85 eyes (57.04%), CF at 1 m in 10 eyes (6.71), 20/200 in 4 eyes (2.68%), and 20/100 in 3 eyes (2.01%). In the second group, visual acuity was LP in 29 eyes (50%),

Table 3: Postoperative complications.

	Group 1		Group 2		X^2	P value
	$n = 149$	%	$n = 58$	%		
Cataract	19	12.75	10	17.24	7.115	0.715
Hypotony	5	3.35	4	6.89		
Recurrent retinal detachment	7	4.69	2	3.44		
Retinal proliferation	10	6.71	6	10.34		
Macular pucker	18	12.08	5	8.62		
Corneal scar	21	14.09	6	10.34		
Band keratopathy	5	3.35	3	5.17		
Persistent high IOP* despite treatment	5	3.35	2	3.44		
Silicon oil in A/C**	2	1.34	2	3.44		
Subretinal fibrosis	8	5.37	5	8.62		

*IOP: intraocular pressure.
**A/C: anterior chamber.
P is significant if <0.05.

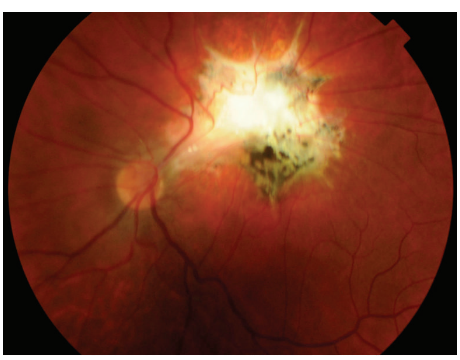

Figure 1: Color photo of left eye showing parafoveal exit with macular dragging.

Figure 2: Color photo of the right eye showing temporal exit with macular dragging.

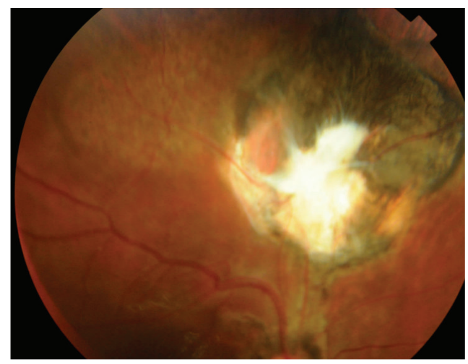

Figure 3: Color photo of the right eye showing superior exit.

HM in 25 eyes (43.10%), CF at 1 m in 2 eyes (3.44%), 20/200 in 1 eye (1.72%), and 20/100 in 1 eye (1.72%).

In the first group, 38.92% of entry sites were corneal, 40.94% were scleral, and 20.13% were limbal. In the second group, 44.82% of entry sites were corneal, 32.75% were scleral, and 22.41% were limbal.

Mean preoperative ocular trauma score (OTS) was 43.96± 12.64 in group 1 and 41.72 ± 12.94 in group 2. No statistically significant difference was found between both groups (P = 0.622).

The exit site was found at the macula in 49 eyes (32.88%) in the first group and 10 eyes (17.24%) in the second group. Optic nerve exit was observed in 21 eyes (14.09%) in the first group and 9 eyes (15.51%) in the second group. The exit site other than macula and optic nerve was present in 79 eyes (53.02%) in the first group and 39 eyes (67.24%) in the second group.

Retinal detachment and retinal incarceration were seen more frequent in group two with statistically significant difference (P values 0.001 and 0.032, resp.).

Most of the cases with retinal detachment in the two groups were accompanied with vitreous hemorrhage (78.26% in group 1 and 53.57% in group 2).

Operative findings are mentioned in Table 2.

By one operation anatomical results in the first group revealed attached retina in 139 eyes (93.28%) and 10 eyes (6.72%) developed RD. In the second group attached retina was achieved in 56 eyes (96.55%) and 2 eyes (3.45%) developed RD. All retinal detachment cases could be reattached by a second surgery. No eyes developed phthisis bulbi during the follow-up period.

There was no statistically significant difference between the two groups regarding anatomical results.

We did not notice any escape of either S.O. or PFCL into the orbit either during or after surgery. The reported postoperative complications were presented in Table 3.

In the first group, *postoperative VA* was LP in 12 eyes (8.05%), HM in 52 eyes (34.89%), CF at 1 m in 38 eyes (25.5%), 20/200 in 38 eyes (25.5%), and 20/100 in 9 eyes (6.04%). Visual acuity improved in 121 eyes (81.21%), unchanged in 23 eyes (15.43%), and declined in 5 eyes (3.35%).

In the second group, VA was LP in 4 eyes (6.89%), HM in 26 eyes (44.82%), CF at 1 m in 13 eyes (22.41%), 20/200 in

Table 4: Postoperative anatomical and functional results in both groups.

		Group 1 2–4 w (149)		Group 2 >4 w (58)		X^2	P value
		N	%	N	%		
Anatomical success	Attached retina by one operation	139	93.28	56	96.55	0.814	0.367
	Attached retina by 2nd operation	149	100	58	100		
Postoperative BCVA*	LP**	12	8.05	4	6.89	1.78	0.77
	HM†	52	34.89	26	44.82		
	CF1m‡	38	25.5	13	22.41		
	20/200	38	25.5	12	20.68		
	20/100	9	6.04	3	5.17		

*BCVA: best corrected visual acuity.
**LP: light perception.
†HM: hand motion.
‡CF: counting finger.
P is significant if <0.05.

Table 5: Comparison between pre- and postoperative BCVA in both groups.

BCVA*	Preoperative 207 eyes		Postoperative 207 eyes		X^2	P value
	Number	%	Number	%		
LP**	76	36.71	16	7.73	109.5	0.001
HM†	110	53.14	78	37.68		
CF 1 m‡	12	5.79	51	24.63		
20/100–20/200	5	2.41	50	24.15		
20/40–20/100	4	1.93	12	5.79		

*BCVA: best corrected visual acuity.
**LP: light perception.
†HM: hand motion.
‡CF: counting finger.
P is significant if <0.05.

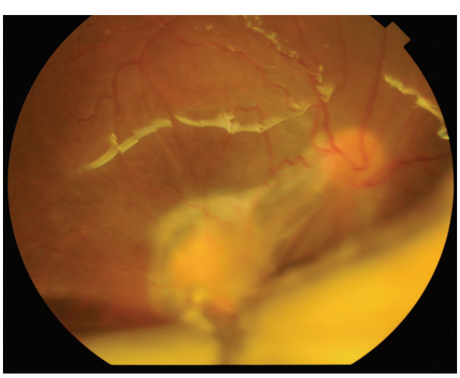

Figure 4: Color photo of right eye showing retinal incarceration at the exit site and lower RD under silicon oil.

12 eyes (20.68%), and 20/100 in 3 eyes (5.17%). Visual acuity improved in 47 eyes (81.03%), unchanged in 7 eyes (12.06%), and worsened in 4 eyes (6.89%).

There was no statistically significant difference between the two groups regarding functional results.

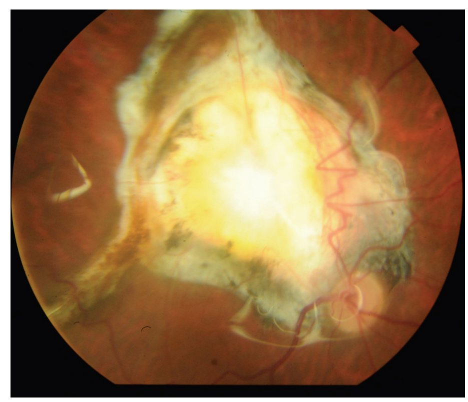

Figure 5: Color photo of right eye showing macular exit.

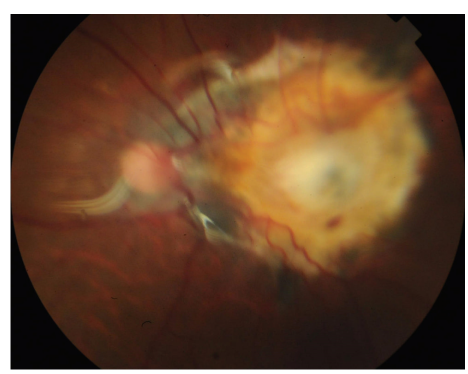

Figure 6: Color photo of left eye showing macular exit with retinal incarceration.

The postoperative anatomical and functional results were shown in Table 4.

The best corrected visual acuity improved in the two groups as compared to the preoperative VA (Table 5).

The main cause of low visual outcome was the central route of the gunshot, central corneal entry, and macular or

Table 6: (a) Relation of the gunshot and visual acuity in the 2 groups. (b) Postoperative visual acuity in patients with corneal entry. (c) Postoperative visual acuity in patients with macula exit. (d) Postoperative visual acuity in patients with optic disc exit.

(a)

BCVA* postoperatively	Corneal entry		Macular exit		Disc exit		X^2	P value
	Number	%	Number	%	Number	%		
LP**	9	10.71	8	13.55	11	36.66	17.295	0.002
HM†	47	55.95	34	57.62	18	60		
CF 1 m‡	28	33.33	17	28.81	1	3.33		

*BCVA: best corrected visual acuity.
**LP: light perception.
†HM: hand motion.
‡CF: counting finger.
P is significant if <0.05.

(b)

BCVA* postoperatively	Group 1 = 58		Group 2 = 26		X^2	P value
	Number	%	Number	%		
LP**=	8	13.79	1	3.84	2.597	0.273
HM†	33	56.89	14	53.84		
CF 1 m‡	17	29.31	11	42.30		

*BCVA: best corrected visual acuity.
**LP: light perception.
†HM: hand motion.
‡CF: counting finger.
P is significant if <0.05.

(c)

BCVA* postoperatively	Group 1 = 49		Group 2 = 10		X^2	P value
	Number	%	Number	%		
LP**=	7	14.3	1	10	0.757	0.685
HM†	27	55.1	7	70		
CF 1 m‡	15	30.6	2	20		

*BCVA: best corrected visual acuity.
**LP: light perception.
†HM: hand motion.
‡CF: counting finger.
P is significant if <0.05.

(d)

BCVA* postoperatively	Group 1 = 21		Group 2 = 9		X^2	P value
	Number	%	Number	%		
LP**	10	47.6	1	11.1	4.507	0.105
HM†	10	47.6	8	88.9		
CF 1 m‡	1	4.8	0	0		

*BCVA: best corrected visual acuity.
**LP: light perception.
†HM: hand motion.
‡CF: counting finger.
P is significant if <0.05.

optic nerve exit. This was shown in Tables 6(a), 6(b), 6(c), and 6(d). *There was no statistically significant difference between the two groups.*

4. Discussion

Perforating injuries of the globe account for a small portion of open globe injuries [2]. The incidence increased in Egypt since January 2011 due to political instability. The standard approach to treating perforating injuries is primary repair to restore the structural integrity of the globe at the earliest opportunity [2]. Previous reports showed the benefit of vitreoretinal surgery in such cases in preventing phthisis bulbi and achieving some visual result [7].

Controversy remains about the best timing of secondary intervention [14]. There are 3 opinions regarding the timing of

PPV in such cases: early vitrectomy within 1 to 3 days [16] and delayed vitrectomy between 7 and 14 days [3, 17] and more than 14 days [18, 19].

The argument for early vitrectomy within 1 to 3 days is to remove all proinflammatory factors before the beginning of fibrosis. The counterargument is that operating on an acutely traumatized eye can have unpredictable findings with a higher likelihood of continued hemorrhage. Suprachoroidal hemorrhage usually is not liquefied, making drainage difficult. Vitrectomy is also more challenging because a spontaneous PVD usually does not develop during this period, especially in young patients [20].

Waiting for 7–14 days after the primary repair allows spontaneous PVD to occur and a more thorough examination with ultrasonography to determine whether the eye is salvageable based on the intraocular anatomic status [20].

In our report, 253 eyes of 237 patients were reviewed. We excluded 9 eyes with no light perception at their presentation, 24 eyes with an intraocular foreign body, and 13 eyes due to short follow-up (less than 6 months from the last surgical intervention). 207 eyes of 197 patients are analyzed.

Patients with scleral and limbal entry were operated on during the 3rd week after trauma. Patients with a central corneal wound or suprachoroidal hemorrhage were operated on in the 4th week from injury to allow more time for proper wound healing. Patients referred after the 4th week of trauma were operated on once they were presented to us. Mean preoperative ocular trauma score (OTS) was 43.96 ± 12.64 in group 1 and 41.72 ± 12.94 in group 2. No statistically significant difference was reported between both groups ($P = 0.622$).

However the OTS in perforating trauma might not be accurate due to the presence of hyphema, dense vitreous hemorrhage, and/or RD which affected the evaluation of afferent pupillary defect (APD) necessary for scoring of the trauma [21]. Also there might be a bias in case selection by the referring physician. It could be that patients with severe injury were never referred from the ophthalmologist. The higher frequency of retinal detachment (RD) and retinal incarceration and lower frequency of macular exit sites in the second cohort are consistent with the possibility that the cohorts are not balanced.

Anatomical results in the first group revealed attached retina in 139 eyes (93.28%) and 10 eyes (6.72%) developed RD. In the second group attached retina was achieved in 56 eyes (96.55%) and 2 eyes (3.45%) developed RD. All retinal detachment cases could be reattached by a second surgery. No eyes developed phthisis bulbi during the follow-up period.

During primary PPV we found RD more in cases operated after the 4th week. It was related to the exit site. Most of cases with retinal detachment in both groups were accompanied with vitreous hemorrhage. This agrees with previous reports [5].

There was no statistically significant difference between the two groups regarding the anatomical results.

Pieramic et al. [1] recommended early vitrectomy within 72 hours after injury. While Vatne and Syrdalen [18] could not identify a beneficial effect of early vitrectomy after injury. They reported that the cases operated on more than 2 weeks gained anatomical success (18 eyes of 27 eyes) better than cases operated on earlier than 2 weeks (7 eyes of 14 eyes).

In their report, Abrams et al. [8] recommended vitrectomy 2 weeks after primary repair but no details about the definite time in their series. Abd EL Alim [22] reported different times of vitreoretinal intervention after the primary repair (less than 1 week in 5%, 2-3 weeks in 73%, and 3–6 weeks in 22% of patients). He excluded cases with corneal entry and macular and optic nerve exit and did not compare the anatomical and functional results between them.

The advances in visualization (wide field system, brighter light) and better cutting technique may be the causes of better results in our series as compared with previous results.

In this series, the best corrected visual acuity improved in the two groups as compared preoperatively. Analysis of the two groups shows the following.

In the first group visual acuity improved in 121 eyes (81.21%), unchanged in 23 eyes (15.43%), and declined in 5 eyes (3.35%).

In the second group visual acuity improved in 47 eyes (81.03%), unchanged in 7 eyes (12.06%), and worsened in 4 eyes (6.89%).

There was no statistically significant difference between the two groups regarding the visual acuity.

The final visual acuity in our study depends mainly on the location of the entry site and the exit site (macular or optic nerve). The cases with a central corneal wound and macular and optic nerve exit had bad visual prognosis in our series.

Hermsen [19] reported that final visual acuity in his series is similar in patients who had early vitrectomy (1–14 days) and those who underwent vitrectomy after 14 days. The best results were achieved when vitrectomy was performed between 15 and 30 days following injury.

Vatne and Syrdalen [18] reported that final result depends mainly on the severity of the primary injury.

Ramsay et al. [10] reported that the surgical success was related to initial visual acuity and the extent of vitreous hemorrhage. These factors in our opinion reflect the severity of trauma.

The drawbacks of our report are the retrospective nature and the patients with late intervention after the 4th week after trauma were analyzed as one group (group 2) without dividing it into different times of referral, for example (4–6 weeks, 6–8 weeks, 8–10 weeks, etc.).

Although statistical analysis showed no difference between the two groups, we think that pars plana vitrectomy is better to be done 2 weeks after injury to allow the entry site to heal and PVD to develop and suprachoroidal hemorrhage to liquefy. It is better not to be done more than 4 weeks after the primary injury to avoid fibrous ingrowth from the entry site to the exit site with possible retinal detachment and incarceration into the entry or exit site. Intervention should be taken case by case.

5. Conclusion

In gunshot perforating eye injury, there was no statistical difference between cases operated on during the 3rd or the 4th versus after the 4th week after primary repair in either the anatomical or functional results. However, we recommend interfering before the 5th week after the trauma as retinal detachment is encountered more in cases operated on after the 4th week. The visual outcome depends on the site of entry and exit (the route of gunshot).

Disclosure

The study was performed in Magrabi Eye Hospital, Tanta, Egypt. This work was self-funded by the authors.

Competing Interests

The authors declare that they have no competing interests.

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