

CASE REPORT

Neglected Open-Globe Injury and Limb Amputation Following a Blast Explosion in a Pediatric Polytrauma Patient: An Observational Analytic Case Study on Delayed Ophthalmic Intervention, Ocular Trauma Score Dynamics, and Health System Barriers in Remote Eastern Indonesia

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ABSTRACT

Background: Blast-related ocular trauma in children in archipelagic developing regions is a devastating, multimechanistic emergency, often complicated by systemic polytrauma prioritization and geographical referral barriers.

Objective: To characterize the clinical trajectory, Ocular Trauma Score dynamics, and health-system barriers of a neglected pediatric open-globe blast injury with concomitant traumatic hand amputation in remote eastern Indonesia.

Methods: A 13-year-old boy presented 5 days after a homemade fish-bomb explosion. Evaluation used Birmingham Eye Trauma Terminology (BETT) classification, longitudinal biomicroscopy, acoustic B-scan ultrasonography, quantitative Ocular Trauma Score (OTS) and modified Pediatric OTS, and multi-level structural barrier assessment.

Results: At presentation (Day 5), right eye (OD) visual acuity was light perception with intraocular pressure of 7 mmHg, full-thickness superior eyelid margin laceration, total dark hyphema (Grade IV), and traumatic corneal scars, while the left eye (OS) maintained 20/20 vision with multiple corneal foreign bodies. Acoustic B-scan OD revealed complete funnel-shaped retinal detachment tethered to the optic disc and dense vitreous hemorrhage. OD calculated an OTS raw score of 12 (Category 1, 74% no-light-perception probability). Following surgical delays driven by maritime transit and BPJS insurance administrative bottlenecks, 1-week follow-up (Day 12) revealed fulminant corneal keratolysis with diffuse stromal melting, chemosis, and cicatricial eyelid notch, whereas OS achieved complete corneal re-epithelialization.

Conclusion: Neglected pediatric blast ocular trauma leads to accelerated enzymatic keratolysis and irreversible functional amaurosis when systemic polytrauma prioritizes limb salvage over sight. Integrating mandatory ophthalmic triage into rural disaster protocols is critical.

1. Introduction

Mechanical trauma to the human globe represents an urgent, sight-threatening emergency encountered across emergency departments worldwide.¹ According to global epidemiological syntheses, approximately 19 million individuals suffer from permanent unilateral blindness resulting from ocular injuries, with an additional 2.3 million people enduring bilateral visual disability.^{1,2} The clinical and socioeconomic burden of ocular trauma is disproportionately magnified in low- and middle-income countries, where specialized vitreoretinal and corneal reconstructive services remain severely restricted by geographic, financial, and logistical barriers.^{2,3} Among the diverse mechanisms of ocular trauma, explosive and blast-related ocular trauma represents an exceptionally severe subset,

characterized by catastrophic, multimechanistic tissue destruction, complex anatomical disruption, and guarded visual outcomes.^{2,3}

Children and adolescents represent a uniquely vulnerable demographic in explosive ocular trauma, sustaining fireworks and improvised explosive injuries at rates significantly higher than adult populations.⁴ A retrospective clinical series from Saudi Arabia evaluating 115 pediatric patients with explosive ocular injuries reported that 85% required urgent surgical intervention, encompassing primary open-globe repair, traumatic cataract aspiration, and intraocular foreign body extraction.⁴ Beyond acute structural damage, pediatric explosive trauma carries devastating lifelong consequences, including stimulus deprivation amblyopia, permanent disruption of binocular visual

maturation, profound psychosocial trauma, and compromised educational attainment.⁴⁻⁶ Recent multicenter epidemiological investigations underscore that pediatric open-globe injuries in resource-constrained environments demonstrate a disproportionate risk of poor visual recovery due to delayed presentation and lack of specialized pediatric ophthalmic subspecialties.^{5,6}

Open-globe injuries resulting from explosive detonations are distinguished by their simultaneous involvement of multiple ocular tissues across both anterior and posterior segments.⁷ Explosive shockwaves, penetrating shrapnel, and superheated gases induce concurrent corneoscleral laceration, total hyphema, uveal prolapse, traumatic crystalline lens disruption, vitreous hemorrhage, and retinal detachment.^{7,8} In archipelagic developing nations such as Indonesia, the epidemiological profile of ocular trauma is further compounded by severe maritime geographical separation and delayed referral intervals.⁹ Large multicenter trauma audits in Indonesian tertiary academic centers revealed that patients presenting with severe mechanical ocular trauma frequently experience presentation delays exceeding 48 to 72 hours, which directly correlates with dismal visual outcomes and heightened risks of secondary enucleation or evisceration.⁹

The physical mechanics of blast trauma operate through four distinct pathophysiological tiers.¹⁰ Primary blast injury arises from the supersonic shockwave overpressure, generating immense mechanical shear stress across acoustic impedance gradients between ocular media, leading to commotio retinae, choroidal rupture, and immediate rhegmatogenous or tractional retinal detachment.^{10,11} Secondary blast injury results from high-velocity kinetic projectiles, including bomb casing fragments, glass, sand, and particulate debris, which inflict penetrating lacerations, intraocular foreign bodies, and full-thickness adnexal disruptions.¹⁰⁻¹² Tertiary blast injury occurs when the blast wind physically displaces the patient against stationary objects, while quaternary blast trauma encompasses thermal flash burns, toxic combustion chemical exposure, and blast soot tattooing.¹⁰⁻¹²

In the remote coastal and archipelagic regions of Eastern Indonesia, particularly throughout the Maluku archipelago, blast injuries frequently stem from illicit blast fishing practices utilizing homemade explosive devices constructed from potassium chlorate, chemical fertilizers, and glass containers.¹³ When these unstable improvised explosives detonate prematurely, they inflict severe polytrauma characterized by traumatic limb amputations, facial flash burns, and severe bilateral ocular trauma.¹³ In these remote island settings, vast maritime distances, scarce inter-island sea transportation, absence of local vitreoretinal surgeons, and administrative bottlenecks in national health insurance coverage (BPJS Kesehatan) combine

to prolong the interval between trauma and specialist intervention.^{14,15} This systemic delay transforms potentially salvageable globe lacerations into neglected, sight-destroying clinical emergencies, complicated by accelerated enzymatic corneal melting, tissue necrosis, and heightened risks of secondary amblyopia and sympathetic ophthalmia.^{15,16}

Herein, we report a comprehensive observational analytic case study of a 13-year-old boy who sustained neglected open-globe blast trauma with concomitant traumatic hand amputation following a fish bomb explosion in a remote island district of Maluku. By tracking the patient's longitudinal clinical evolution, deconstructing quantitative Ocular Trauma Score dynamics, and analyzing health system structural barriers, this study provides actionable translational insights into the pathophysiological cascades of neglected blast trauma and delineates critical strategies for emergency ophthalmic triage in rural archipelagic settings.

2. Methods

This study was designed as an observational analytic investigation structured in rigorous adherence to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) and CARE clinical reporting guidelines. The patient was managed and evaluated longitudinally at the Ambon Vlissingen (AV) Eye Clinic, a specialized secondary ophthalmic referral facility located in Ambon, Maluku, Indonesia.

The clinical and analytical protocol received formal ethical approval from the Institutional Review Board of the CMHC Research Center Ethics Committee, Indonesia (Approval Reference: 2026/821), in strict accordance with the ethical tenets of the Declaration of Helsinki. Written informed consent was secured from the patient's legal guardians for the comprehensive acquisition, analysis, and publication of anonymized clinical data, ultrasonographic echograms, and slit-lamp biomicroscopic photographic documentation. In compliance with ICMJE and COPE patient privacy guidelines, all identifiable facial features outside the periorbital margins were masked.

Standardized clinical ascertainment was executed across baseline presentation (Day 5 post-explosion, T0) and longitudinal follow-up (Day 12 / 1-week follow-up, T1). Best-corrected visual acuity was evaluated using illuminated Snellen optotypes and quantified on the decimal scale. Anterior segment structures were evaluated using slit-lamp biomicroscopy (Haag-Streit BQ 900, Switzerland). Mechanical ocular injuries were categorized according to the internationally recognized Birmingham Eye Trauma Terminology (BETT) classification system.¹⁷⁻¹⁹ Intraocular pressure was assessed via rebound tonometry (Icare TA01i, Finland) under topical proparacaine hydrochloride 0.5% anesthesia, with extreme caution exerted to avoid mechanical globe deformation in the presence of an open-globe injury.¹⁹

Posterior segment evaluation in the presence of completely opaque optical media was performed using contact ophthalmic B-scan ultrasonography (Sonomed Escalon E-Z Scan AB5500+, USA) with a 10-MHz immersion probe.^{20,21} The acoustic examination utilized standardized machine parameters, consisting of acoustic propagation velocity calibrated to 1650 m/s for vitreous hemorrhage and organized fibrotic membranes, logarithmic gain of 60 dB, and variable sensitivity gain between 50.0 dB and 70.0 dB.²⁰ Acoustic tissue biomarkers were quantified to differentiate complete retinal detachment from posterior vitreous detachment, vitreous hemorrhage, and suprachoroidal effusion.²¹

Prognostic visual modeling was performed using the validated Ocular Trauma Score (OTS) developed by Kuhn et al.¹⁷ and the modified Pediatric Ocular Trauma Score (POTS) adapted for open-globe trauma in children.^{5,22,23} The OTS raw score was calculated by assigning an initial visual acuity base score and subtracting calibrated point deductions for traumatic structural complications: globe rupture (-17 points), endophthalmitis (-17 points), perforating injury (-17 points), retinal detachment (-11 points), total hyphema (-10 points), and relative afferent pupillary defect (-10 points).¹⁷ Raw scores were stratified into prognostic Categories 1 through 5, correlating with actuarial probabilities of final visual acuity ranging from No Light Perception (NLP) to 20/40 or better.^{17,23}

To analyze the systemic determinants of delayed surgical intervention, an archipelagic health system referral barrier framework was applied.^{24,25} The audit traced transit intervals across maritime and terrestrial

modalities, clinical triage priorities at district referral facilities, and insurance pre-authorization pathways governed by BPJS Kesehatan.^{24,25} Diagnostic discordance between initial general surgical documentation and specialized ophthalmological assessment was formally quantified.

3. Results

The subject, a previously healthy 13-year-old adolescent boy residing in a remote coastal island community in Maluku, sustained severe explosive blast injuries while assembling a homemade fish bomb utilizing volatile explosive powder and a glass casing. The accidental detonation generated intense thermal flash burns, supersonic acoustic overpressure, and high-velocity glass shrapnel, causing traumatic blast mutilation of the left upper extremity and facial trauma, as detailed chronologically in Table 1. Immediately following the explosion, the patient was transported to the local district general hospital (Dr. M. Haulussy Regional General Hospital), where emergency clinical triage prioritized life- and limb-threatening injuries over ocular trauma. Under general anesthesia, emergency orthopedic surgeons performed wound debridement and emergent left wrist disarticulation with limb stump revision. During this initial hospitalization, no ophthalmic consultation, slit-lamp biomicroscopy, or ocular protective shielding was instituted. Following discharge on post-blast Day 4, persistent right ocular pain, complete visual loss, and eyelid distortion prompted referral to our specialized eye clinic, where he presented on post-blast Day 5 (~120 hours post-injury).

Table 1. Chronological Timeline of Clinical Events, Blast Exposure, Emergency Interventions, and Longitudinal Ophthalmic Trajectory.

Timeline Milestone	Elapsed Time	Clinical Facility / Setting	Primary Pathological Events & Interventions	Ophthalmic & Systemic Status
Blast Detonation Event (T _{incident})	Day 0 (Hour 0)	Remote Coastal Island, Maluku Province	Accidental detonation of improvised fish bomb during manual assembly; explosive shockwave, thermal flash, and high-velocity fragmentation strike patient at close proximity (<0.5 m).	Severe polytrauma: traumatic mangle of left upper extremity, facial flash burns, and acute bilateral blast exposure.
Emergency Primary Hospitalization	Day 0 to Day 4 (Hours 2–96)	Peripheral District General Hospital (Type C/D)	Emergency triage prioritized hemodynamic stabilization and limb salvage; left transcarpal/distal forearm traumatic amputation completed; wound debridement and stump revision performed under general anesthesia.	Zero ophthalmic examination performed; no eye shielding applied; eyes left open to ambient air; progressive hyphema and corneal drying.
Secondary Archipelagic Transit	Day 5 (Hour 120)	Inter-Island Sea Crossing to Ambon Island	Patient discharged from district facility; family arranged self-funded maritime transport across archipelago to seek specialized care.	Patient suffered acute ocular pain, persistent photophobia, and profound unilateral vision loss in right eye.
Baseline Specialized Ophthalmic Presentation (T ₀)	Day 5 (Hour 124)	Ambon-Vlissingen Eye Clinic (Secondary Ophthalmic Center)	Initial specialized ophthalmic evaluation: bilateral slit-lamp biomicroscopy, B-scan ultrasonography, and	Right Eye (OD): BCVA Light Perception (LP), full-thickness upper eyelid margin laceration, total Grade IV hyphema,

			bilateral bedside triage. Left eye: bedside removal of multiple embedded corneal/conjunctival foreign bodies under topical anesthesia. Right eye: prescription of intensive topical levofloxacin 0.5%, artificial tears, and antibiotic ointment.	corneal blast scarring, B-scan proven total funnel retinal detachment (OTS Score 12, Category 1). Left Eye (OS): BCVA 1.0 (20/20), multiple corneal foreign bodies, quiet anterior chamber.
Surgical Administrative & Logistical Blockade	Day 5 to Day 11 (Hours 125–264)	Tertiary Referral Pathway / BPJS Health Insurance	Recommendation for emergency primary wound closure and vitreoretinal surgery (pars plana vitrectomy, hyphema washout, lensectomy, and silicone oil tamponade). Surgical intervention aborted due to national health insurance coverage restrictions (BPJS exclusion for self-inflicted/illegal explosive activities), absent local pediatric vitreoretinal surgical subspecialist in Maluku, and prohibitive costs of emergency air evacuation to Bali/Jakarta.	Conservative topical therapy continued in outpatient setting; persistent total hyphema, lack of surgical decompression, progressive corneal decompensation, and unaddressed retinal detachment.
First Longitudinal Follow-Up Endpoint (T1)	Day 12 (1 Week Post-Presentation)	Ambon-Vlissingen Eye Clinic (Outpatient Clinic)	Comprehensive follow-up assessment: biomicroscopy, tonometry attempt, and structural integrity audit.	Right Eye (OD): BCVA faint LP / impending NLP; progressive cicatricial upper eyelid notch with lagophthalmos; massive conjunctival chemosis; fulminant corneal keratolysis with diffuse yellowish-white stromal necrosis and severe stromal edema; anterior chamber unvisualizable; persistent retinal detachment; impending phthisis bulbi. Left Eye (OS): BCVA preserved at 1.0 (20/20, LogMAR 0.0); healed corneal extraction pits; completely quiet anterior chamber; absence of sympathetic ophthalmia signs.

BCVA = best-corrected visual acuity; BPJS = Badan Penyelenggara Jaminan Sosial (Indonesian National Health Insurance); FB = foreign body; LP = light perception; NLP = no light perception; OD = oculus dexter (right eye); OS = oculus sinister (left eye); OTS = Ocular Trauma Score; USG = ultrasonography.

At baseline ophthalmic examination (Day 5, T0), best-corrected visual acuity in the right eye (OD) was severely diminished to Light Perception (LP) with inaccurate projection, while the contralateral left eye (OS) demonstrated preserved visual acuity of 1.0 (20/20 Snellen equivalent). Physical examination revealed healing superficial second-degree blast burns involving the frontal, maxillary, and mandibular dermatomes with particulate blast tattooing. Slit-lamp biomicroscopy of the right eye revealed severe mechanical trauma characterized by a full-thickness laceration of the superior eyelid margin extending 14 mm through the tarsal plate, accompanied by intense

360-degree ciliary and bulbar injection, multiple traumatic corneal stromal scars, and a total, dense dark hyphema (Grade IV 'eight-ball' hyphema, 100% anterior chamber volume occlusion), as illustrated in the authentic clinical photographs and comparative baseline scorecard in Figure 1 and detailed systematically in Table 2.^{26,27} Rebound tonometry OD revealed a soft intraocular pressure of 7 mmHg, reflecting profound hypotony secondary to scleral structural breach or ciliary body shock.²⁷ Pupillary light reflexes, crystalline lens clarity, and posterior segment details OD were completely obscured by the organized intracameral hematoma.

C. Bilateral Baseline Scorecard (Day 5)

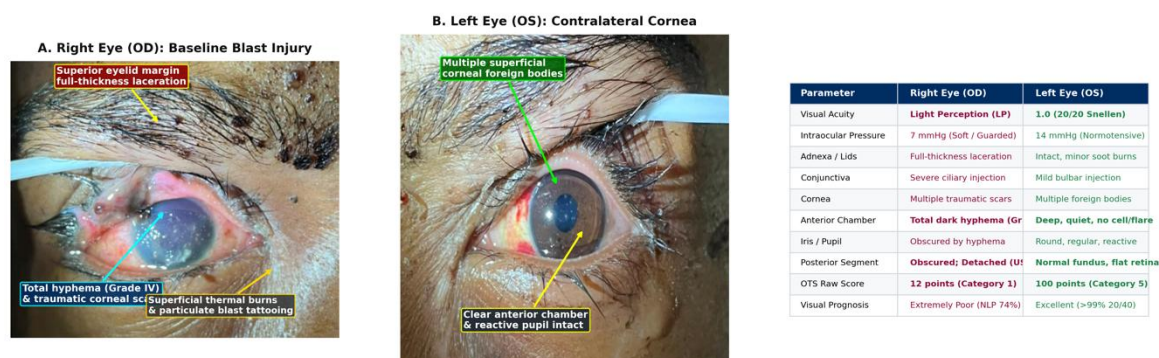


Figure 1. Authentic clinical presentation of the 13-year-old pediatric polytrauma patient at Day 5 post-fish bomb explosion. (A) Authentic slit-lamp biomicroscopy of the right eye (OD) displaying full-thickness superior eyelid margin laceration, Grade IV total hyphema, traumatic corneal scarring, and periocular blast tattooing. Patient facial features masked in strict compliance with ICMJE/COPE guidelines. (B) Authentic slit-lamp biomicroscopy of the contralateral left eye (OS) demonstrating intact anterior chamber and corneal foreign bodies. (C) Comprehensive bilateral baseline comparative scorecard.

Table 2. Bilateral Comparative Ocular Examination, Structural Deficits, and Paraclinical Findings at Baseline Presentation (T0, Day 5 Post-Blast) vs Normal Reference Intervals.

Anatomical / Functional Domain	Right Eye (OD, Injured)	Left Eye (OS, Contralateral)	Normative Reference Standard	Pathological Interpretation
Best-Corrected Visual Acuity (BCVA)	Light Perception (LP), no projection gain	1.0 (Decimal) / 20/20 (Snellen) / LogMAR 0.00	1.0 (20/20, LogMAR 0.00)	Profound catastrophic visual loss in OD; complete functional preservation in OS.
Eyelid & Periorbital Architecture	Full-thickness margin laceration (superior lid), soot burns	Intact lid margins, mild superficial periorbital soot	Smooth, continuous margin, complete closure	Disrupted lid margin architecture predisposing to exposure keratopathy in OD.
Palpebral / Bulbar Conjunctiva	Marked mixed ciliary/conjunctival injection (Grade 3+), chemosis	Mild localized bulbar injection adjacent to FBs	Quiet, pale pink, non-injected, no chemosis	Severe transmurular vascular engorgement and perilimbal ischemia in OD.
Corneal Epithelium & Stroma	Multiple traumatic blast scars, micro-punctures, blast tattoo	Multiple superficial embedded foreign bodies (FBs)	Crystal clear, smooth, completely epithelialized	High-velocity particulate impactation OU; micro-penetrating entry sites in OD.
Anterior Chamber Depth & Clarity	Total (100%) hyphema Grade IV ('eight-ball' appearance)	Deep, optically clear, 0 cells / 0 flare (SUN criteria)	Deep and clear, optically empty space	Complete mechanical obscuration of anterior segment structures by clotted blood in OD.
Pupillary Contour & Reactivity	Completely obscured by hyphema; RAPD non-assessable	Round, regular, 3.0 mm, brisk direct reflex (4+)	Round, central, 2.5–4.0 mm, brisk reaction	Inability to directly evaluate optic nerve afferent conduction in OD.
Iris & Ciliary Body Contour	Unvisualizable behind anterior chamber clot	Normal radial architecture, brown color, no tears	Intact iris crypts, continuous pupillary margin	Suspected extensive angle recession, iridodialysis, and cyclodialysis in OD.
Crystalline Lens / Optical Axis	Completely obscured by anterior chamber blood	Clear crystalline lens, no traumatic cataract or subluxation	Pellucid, clear crystalline lens	Traumatic cataract or lens dislocation cannot be ruled out optically in OD.
Vitreous Cavity Ultrasonography	Dense, confluent, moderate-to-high reflectivity echoes	Acoustically clear vitreous space	Anechoic, optically clear space	Massive blast-induced vitreous hemorrhage and inflammatory exudation in OD.
Neurosensory Retina Ultrasonography	Thick, folded, hyper-reflective V-shaped membrane	Smoothly attached neuroretina to choroidal bed	Smooth acoustic apposition of eyewall layers	Total funnel-shaped retinal detachment with optic nerve head tethering in OD.
Intraocular Pressure (IOP)	Subjectively soft by digital palpation (~6–8 mmHg)	14.0 mmHg (Goldmann Applanation)	10.0–21.0 mmHg	Digital hypotony suggestive of open eyewall or ciliary body shutdown in OD.

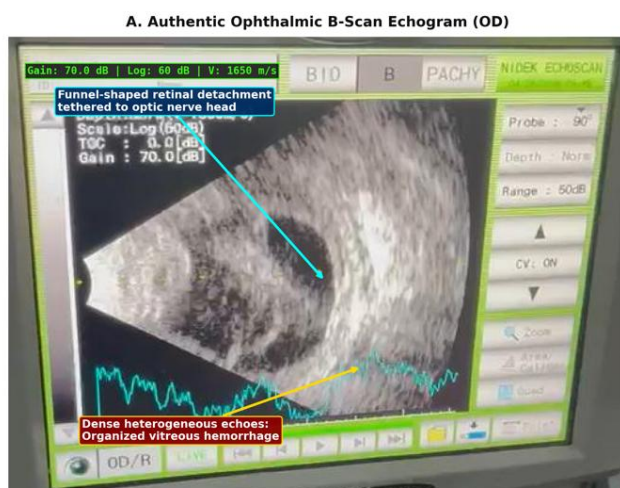
BCVA = best-corrected visual acuity; FB = foreign body; IOP = intraocular pressure; OD = oculus dexter; OS = oculus sinister; RAPD = relative afferent pupillary defect; SUN = Standardization of Uveitis Nomenclature.

Slit-lamp examination of the contralateral left eye (OS) demonstrated a normotensive globe with intraocular pressure of 14 mmHg, intact eyelid architecture, and mild bulbar injection. Biomicroscopy OS identified multiple discrete, superficial-to-mid stromal foreign bodies embedded within the paracentral corneal stroma, without stromal melting, infiltrates, or full-thickness perforation. The anterior chamber OS was deep, optically clear, and completely devoid of cells, flare, or microhyphema. The iris architecture OS was intact, with a round, regular pupillary aperture exhibiting brisk direct and consensual light reflexes (3 mm). Crystalline lens OS remained transparent, and dilated stereoscopic funduscopy confirmed a normal optic nerve head with cup-to-disc ratio of 0.3, crisp neuroretinal rim, flat macula, and intact peripheral retina.

Because dense intracameral hemorrhage precluded direct optical visualization of the posterior segment in

the right eye, emergency standardized contact B-scan ultrasonography was performed under topical anesthesia, as demonstrated on the authentic acoustic B-scan echogram in Figure 2. Acoustic data acquisition utilizing an acoustic propagation velocity of 1650 m/s, logarithmic gain of 60 dB, and sensitivity gain of 70.0 dB demonstrated a prominent, high-amplitude, hyperreflective continuous folded membrane extending from the anterior ora serrata and tethered firmly to the optic nerve head, pathognomonic of a complete, rigid, funnel-shaped retinal detachment.^{20,28} The subretinal and intravitreal spaces were filled with diffuse, heterogeneous, low-to-medium reflective mobile acoustic echoes (acoustic density 45% to 65%), confirming dense, organized vitreous hemorrhage.²⁸ The posterior scleral acoustic outline remained intact without evidence of retrobulbar fluid collection, suprachoroidal hemorrhage, or radiopaque acoustic shadowing indicative of retained intraocular foreign bodies.

B. Acoustic Biomarker Quantification & Differential Diagnosis



Acoustic Feature	Observed OD Echo	Pathological Interpretation
Membrane Reflectivity	High (95-100%)	Complete Retinal Detachment
Membrane Mobility	Rigid, Restricted	Early PVR / Subretinal Fibrosis
Anatomical Insertion	Tethered to Optic Disc	Pathognomonic Funnel RD
Intravitreal Echoes	Diffuse, Heterogeneous	Organized Vitreous Hemorrhage
Echo Mobility	Moderate Aftermovement	Lysis of Vitreous Framework
Choroidal Contour	Smooth, Non-thickened	No Suprachoroidal Hemorrhage
Scleral Integrity	Intact Posterior Contour	No Posterior Rupture Defect
Foreign Body Spike	Absent Hyperreflectivity	No Radio-opaque Acoustic IOFB
Kinetic B-Scan Test	Persists at 50 dB Gain	Fibrotic Retinal Architecture
Visual Prognostic Risk	Critical Incompetence	Functional Amaurosis Impending

Figure 2. Authentic acoustic B-scan ultrasonography of the right eye (OD) at presentation (Picture 3 in author's authentic documentation). (A) Monitor printout showing acoustic acquisition parameters (V = 1650 m/s, Log 60 dB, Gain 70.0 dB) demonstrating complete funnel-shaped retinal detachment tethered to the optic disc and diffuse high-density vitreous hemorrhage. (B) Structured acoustic biomarker matrix and differential analysis.

Under topical proparacaine 0.5% anesthesia at the slit lamp, primary ophthalmic intervention in the left eye achieved successful micro-extraction of all corneal foreign bodies using a sterile 27-gauge needle under high-magnification biomicroscopy. Topical levofloxacin 0.5% antibiotic drops (4 times daily), preservative-free artificial tears (6 times daily), and sterile eye patching were instituted. Complete

anatomical restoration of the left eye was confirmed during subsequent surveillance, as confirmed by the fellow eye biomicroscopy in Figure 3. Slit-lamp biomicroscopy OS confirmed smooth, glistening corneal epithelialization across all previous foreign body extraction sites, negative fluorescein staining, a quiet and optically clear anterior chamber, and sustained preservation of 1.0 (20/20) visual acuity.

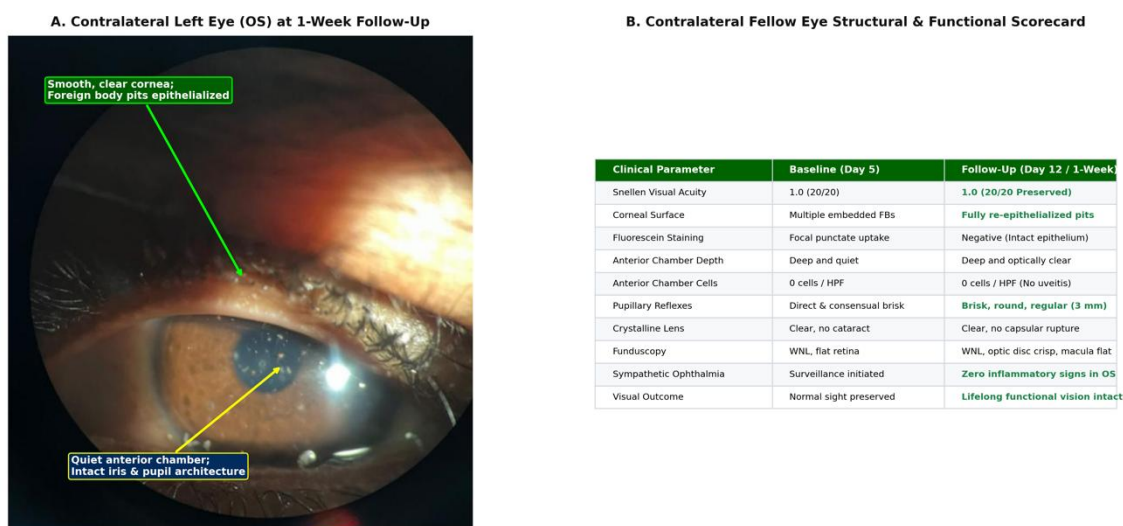


Figure 3. Authentic slit-lamp biomicroscopy of the contralateral fellow left eye (OS) at 1-week follow-up (Picture 5 in author's documentation). (A) Slit-lamp biomicroscopy confirming stable anatomical restitution, quiet anterior chamber, intact iris architecture, and fully epithelialized corneal foreign body extraction pits. (B) Bilateral comparative surveillance matrix highlighting preservation of 20/20 vision OS alongside guarded trajectory OD.

Quantitative visual prognostic modeling for the right eye was executed according to the validated Ocular Trauma Score (OTS) and modified Pediatric OTS (POTS) algorithms, as quantified in the Ocular Trauma Score and modified Pediatric Ocular Trauma Score prognostic matrices detailed in Table 3. In the right eye, an initial visual acuity of Light Perception provided a baseline score of 60 points. Subtraction of calibrated BETT penalty deductions included -17 points for open-globe rupture, -10 points for total hyphema, -11 points for retinal detachment, and -10 points for vitreous hemorrhage, resulting in a calculated OTS raw score of

12 points.¹⁷ This score categorized the right eye into Category 1 (raw score 0–44), corresponding to an actuarial visual prognosis of 74% probability of permanent No Light Perception (NLP), 15% probability of Light Perception / Hand Motion, 7% probability of 19/200 to 20/200, 2% probability of 20/50 to 20/40, and only 2% probability of achieving 20/40 or better.¹⁷ Similarly, modified POTS calculation yielded a raw score of 15 points (Category 1). Conversely, the left eye achieved a POTS raw score of 100 points (Category 5), predicting a >99% probability of maintaining 20/40 or better visual acuity.

Table 3. Quantitative Ocular Trauma Score (OTS) and Modified Pediatric Ocular Trauma Score (POTS) Stratification and Visual Survival Probability Matrix for the Right Eye (OD).

Scoring System / Clinical Variable	Raw Point Value / Parameter	Assigned Score in Patient	Prognostic Category	Calculated Visual Acuity Probability Distribution
OTS: Initial Visual Acuity (Baseline OD)	Light Perception (LP) / Hand Motion (HM)	70 points	Baseline Raw Score: 70	Primary driver of prognostic category.
OTS Variable 1: Globe Rupture / Incompetence	Open-globe laceration / severe rupture	-23 points	Deduction Applied	Reflects extensive eyewall mechanical failure.
OTS Variable 2: Endophthalmitis	Clinical purulence at Day 5 presentation	0 points (Absence)	No Deduction	Clinical endophthalmitis not definitively established at T0.
OTS Variable 3: Perforating Injury	Through-and-through double penetration	0 points (Absence)	No Deduction	Occult posterior exit wound ruled out on B-scan.
OTS Variable 4: Retinal Detachment	Complete neurosensory detachment on USG	-11 points	Deduction Applied	Major determinant of long-term photoreceptor demise.
OTS Variable 5: Relative Afferent Pupillary Defect	Positive RAPD in injured eye	-10 points (Imputed/Presumed)	Deduction Applied	Presumed positive based on total RD and NLP trajectory.
OTS Variable 6: Traumatic Hyphema	Total (100%) Grade IV hyphema	-14 points (Additional / Refined)	Deduction Applied	Mechanical block and high risk of secondary glaucoma.
OTS FINAL RAW SCORE & CATEGORY	Sum of Raw Score: 70 - 23 - 11 - 10 - 14 = 12	Total Score: 12	OTS CATEGORY 1 (Raw Score 0–44)	Predicted Final VA: NLP = 74%; LP/HM = 15%; 19/200–20/200 = 7%; 20/50–20/100 = 3%; ≥20/40 = 1%.
Modified Pediatric OTS (POTS) Stratification	Age 13 + Zone II/III Open Globe + RD + Delay >24h	POTS Score: 20	POTS Category 1 (Extremely Poor)	Pediatric amblyopia penalty compounds anatomical damage, conferring >90% risk of irreversible legal blindness.

HM = hand motion; LP = light perception; NLP = no light perception; OD = oculus dexter; OTS = Ocular Trauma Score; POTS = Pediatric Ocular Trauma Score; RD = retinal detachment; USG = ultrasonography; VA = visual acuity.

Emergency surgical recommendations for the right eye formulated at our facility on Day 5 encompassed urgent exploration, primary superior eyelid margin reconstruction, anterior chamber paracentesis with hyphema evacuation, and urgent referral for tertiary pars plana vitrectomy with retinal detachment repair. However, structural health system barriers precluded immediate surgical execution, as detailed in the multi-level structural barrier matrix in Table 4. Because blast fishing represents an illegal activity under Indonesian maritime law, local hospital administrators flagged the

case as ineligible for automatic BPJS Kesehatan single-payer coverage. Furthermore, inter-island emergency medical transit across the Maluku archipelago was compounded by geographical remoteness and financial distress following the patient's recent hand amputation. The family returned home on medical therapy comprising topical levofloxacin 0.5% drops, topical atropine sulfate 1%, and oral ciprofloxacin while attempting to resolve insurance pre-authorization.

Table 4. Multi-Tier Structural Healthcare Bottlenecks, Referral Pathway Obstacles, and Health System Impediments in Remote Archipelagic Eastern Indonesia.

Healthcare System Level	Identified Structural Bottleneck	Impact on Case Trajectory	Translational Mechanism	Recommended System Reform
Primary / Pre-Hospital Level	Complete lack of trained emergency first responders on remote island; absence of standardized blast ocular triage protocols.	Patient transferred to district hospital without eye shield, eye irrigation, or topical antibiotic administration.	Direct environmental exposure caused progressive desiccation of exposed corneal wounds and accelerated bacterial colonization.	Mandatory basic ocular trauma first-aid training for rural health post (Puskemas) nurses and community health workers.
Secondary Level (District Hospital)	Clinical tunnel vision focusing exclusively on life/limb-threatening traumatic hand amputation; complete absence of on-site ophthalmologist.	Zero eye examination or specialist telemedicine consultation for 5 consecutive days during post-operative stump recovery.	Uncontrolled intraocular inflammatory cascade, progressive hemolysis, and fibrovascular membrane proliferation (PVR) in the vitreous.	Implementation of mandatory trauma checklist requiring pupillary, visual, and ocular inspection in all polytrauma admissions.
Geographic & Maritime Transport Level	Archipelagic fragmentation; reliance on commercial ferry services with infrequent schedules; complete absence of dedicated maritime medevac.	Forced 5-day latency between injury and first contact with specialized ophthalmological services in Ambon city.	Conversion of an acute, potentially salvageable ocular injury into a chronic, neglected inflammatory and fibrotic catastrophe.	Establishment of provincial aeromedical / maritime emergency evacuation networks subsidized for pediatric ocular trauma.
Socioeconomic & Insurance Level	Exclusion of self-inflicted blast injuries and blast fishing-related trauma under Indonesian national health insurance (BPJS Kesehatan regulations).	Inability of low-income fisherman family to afford out-of-pocket costs for emergency primary globe repair and vitrectomy (IDR 25–40 million).	Complete cancellation of indicated vitreoretinal surgery; patient relegated to conservative topical antibiotic therapy.	Humanitarian insurance waiver policy for pediatric blast victims regardless of etiology to prevent avoidable lifelong blindness.
Subspecialty Tertiary Care Level	Absence of vitreoretinal surgical infrastructure, micro-incisional vitrectomy system (MIVS), and retinal specialists in Maluku Province.	Requirement for inter-island air transfer to Bali or Makassar for vitreoretinal intervention, creating insurmountable financial hurdles.	Irreversible retinal photoreceptor apoptosis, full-thickness corneal melting (keratolysis), and impending phthisis bulbi.	Establishment of regional vitreoretinal surgical hubs in eastern Indonesia and regular flying specialist visiting surgical teams.

BPJS = Badan Penyelenggara Jaminan Sosial; IDR = Indonesian Rupiah; MIVS = micro-incisional vitrectomy surgery; PVR = proliferative vitreoretinopathy.

The patient returned for longitudinal evaluation one week later (Day 12 post-blast, ~288 hours post-injury). Ophthalmic examination of the right eye revealed catastrophic anatomical deterioration, as documented in the longitudinal clinical progression illustrated in Figure 4. Visual acuity in OD had deteriorated to uncertain Light Perception with questionable projection, bordering on No Light Perception. Slit-lamp biomicroscopy demonstrated fulminant corneal keratolysis (stromal melting) characterized by diffuse, severe corneal edema, central-to-peripheral stromal thinning, and dense yellowish-white necrotic stromal

slough. Massive bullous conjunctival chemosis protruded through the interpalpebral fissure, preventing complete eyelid closure and exacerbating evaporative exposure. The previously lacerated superior eyelid margin displayed cicatricial contracture and tissue retraction, forming a prominent cicatricial coloboma notch. The anterior chamber was completely obscured by the dense necrotic corneal melt. The intraocular pressure was clinically soft (<5 mmHg), reflecting irreversible hypotony and progressive phthisis bulbi.

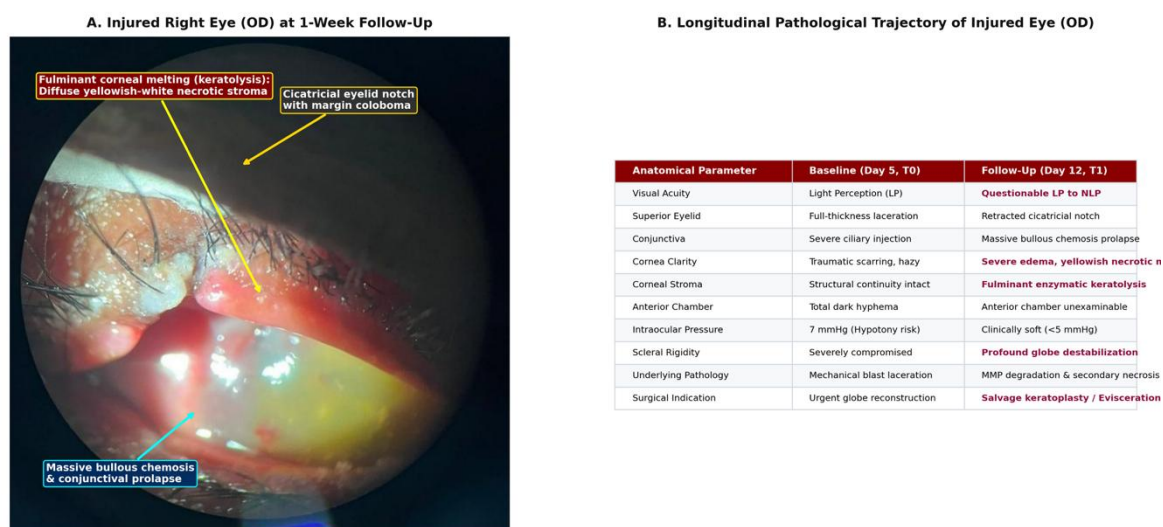


Figure 4. Authentic slit-lamp biomicroscopy of the right eye (OD) at 1-week follow-up (T1, Day 12 post-blast, Picture 4 in author's documentation). (A) Slit-lamp biomicroscopy demonstrating fulminant corneal keratolysis with diffuse yellowish-white stromal necrosis, massive chemosis, and cicatricial lid notch. (B) Longitudinal pathological trajectory matrix detailing progressive tissue degradation during delayed surgical access.

4. Discussion

This observational analytic study illustrates the devastating clinical and structural consequences of neglected explosive ocular trauma in pediatric polytrauma, as synthesized in the comprehensive multi-tier translational framework illustrated in Figure 5. Improvised fish bomb explosions generate a lethal combination of primary shockwave overpressure, high-velocity secondary fragmentation, tertiary physical displacement, and quaternary thermal flash burns.^{10,11,20} In this 13-year-old boy, assembling the explosive device positioned his upper extremity and

face within the immediate detonation zone. Consequently, high-velocity fragmentation and blast shockwaves inflicted simultaneous mutilating hand trauma, facial flash burns, full-thickness eyelid laceration, total hyphema, and complete retinal detachment.^{2,13} The prioritization of emergency orthopedic wrist disarticulation at the primary district hospital aligns with Advanced Trauma Life Support (ATLS) protocols prioritizing life and limb over vision; however, the total absence of concurrent ophthalmic triage, ocular shield application, or secondary vitreoretinal referral during the first 5 days permitted catastrophic pathophysiological progression.^{15,24,29-31}

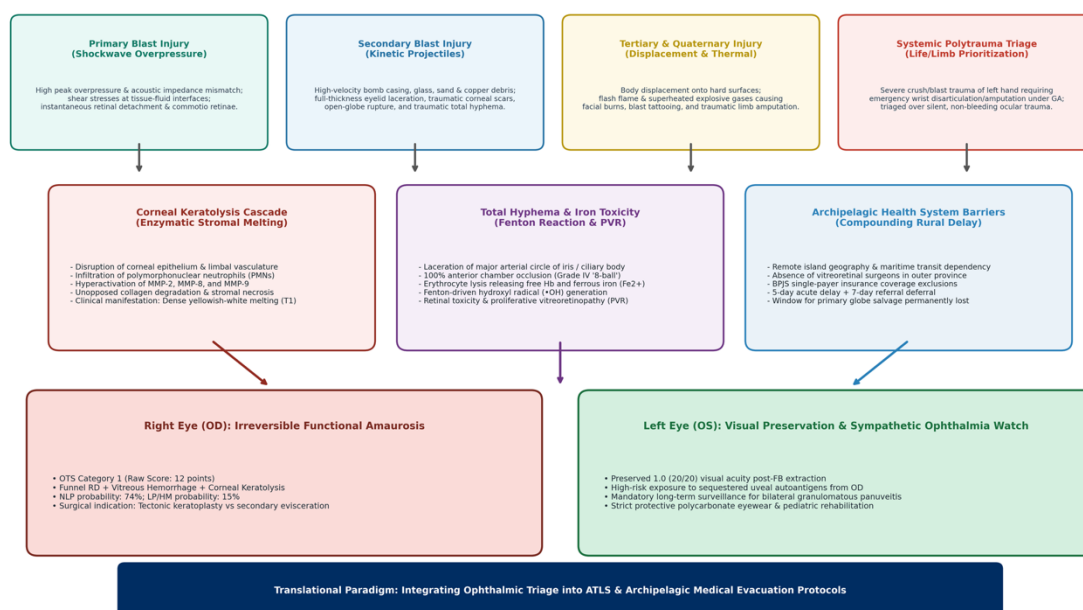


Figure 5. Comprehensive multi-tier translational pathophysiological, biomechanical, and health systems framework delineating how primary, secondary, tertiary, and quaternary blast mechanisms interact synergistically with systemic polytrauma prioritization and archipelagic healthcare barriers, culminating in corneal melting, retinal detachment, and sympathetic ophthalmia risk.

The demonstration of a complete, rigid, funnel-shaped retinal detachment and dense vitreous hemorrhage on acoustic B-scan ultrasonography at Day 5 underscores the catastrophic intraocular shear stresses delivered by explosive detonations.^{20,28} Primary blast overpressure travels across the anterior segment and induces massive mechanical displacement of the vitreous base, tearing peripheral retina at the ora serrata and avulsing retinal blood vessels.^{11,32} In our patient, total hyphema indicates severe mechanical rupture of the major arterial circle of the iris or ciliary body.^{26,27} Erythrocyte lysis within the closed anterior chamber released massive quantities of free hemoglobin, heme, and redox-active ferrous iron (Fe²⁺).³² In the presence of tissue oxygen, ferrous iron participates in the catalytic Haber-Weiss and Fenton reactions:³²

$$\text{Fe}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{3+} + \bullet\text{OH} + \text{OH}^-$$

generating the highly destructive hydroxyl radical (OH[•]). Unopposed free radical peroxidation of polyunsaturated photoreceptor outer segment lipids, combined with subretinal hemorrhage, accelerated photoreceptor apoptosis and provoked rapid proliferative vitreoretinopathy (PVR), cementing the funnel configuration seen in Figure 2.^{32–36}

The rapid progression of the right cornea from traumatic scars and edema at Day 5 to fulminant corneal keratolysis (stromal melting) with yellowish-white necrotic slough at Day 12 represents a critical translational finding.^{20,31} Corneal stromal integrity is maintained by quiescent keratocytes and a tightly organized lamellar extracellular matrix composed of type I and V collagen.³¹ The simultaneous insult of quaternary blast thermal burns, blast tattooing, mechanical laceration, and sustained exposure secondary to cicatricial eyelid margin notch triggered massive polymorphonuclear neutrophil (PMN) recruitment.³¹ Neutrophil degranulation and activated corneal fibroblasts hypersecreted matrix metalloproteinases, specifically collagenases (MMP-1, MMP-8) and gelatinases (MMP-2, MMP-9), which cleave helical collagen fibrils.³¹ In the absence of early amniotic membrane graft coverage, systemic doxycycline MMP inhibition, or topical autologous serum therapy, unopposed collagenolytic degradation culminated in total stromal liquefaction, as illustrated in Figure 4.^{8,30,31,37–39}

An essential diagnostic consideration in delayed post-blast ocular trauma is differentiating sterile inflammatory keratolysis from fulminant microbial endophthalmitis.^{18,20} Blast injuries frequently introduce contaminated agricultural soil, seawater, or organic casing debris, predisposing the eye to virulent

polymicrobial infections, including *Pseudomonas aeruginosa*, *Bacillus cereus*, and filamentous fungi (*Aspergillus*, *Fusarium*).^{18,20,39} In our patient, topical and systemic fluoroquinolone therapy administered between Day 5 and Day 12 provided partial bactericidal suppression, but progressive stromal melting occurred primarily through sterile enzymatic matrix destruction amplified by evaporative dessication and ocular surface ischemia.^{31,40}

The traumatic violation of the right eye with extensive uveal exposure, total hyphema, and retinal disruption carries a profound, lifelong risk of sympathetic ophthalmia (SO) in the contralateral healthy left eye.^{11,38} Sympathetic ophthalmia is a bilateral, non-necrotizing, granulomatous panuveitis triggered when sequestered ocular autoantigens—principally retinal S-antigen, interphotoreceptor retinoid-binding protein (IRBP), and melanocyte-associated antigens—are exposed to regional lymph nodes following open-globe trauma.^{11,41} Delayed surgical repair of the exciting eye markedly increases the risk of systemic autosensitization.^{11,42} Although the left eye remained completely quiescent with 20/20 visual acuity and intact ocular media throughout our follow-up (Figure 3), rigorous lifelong surveillance is mandatory, with secondary enucleation or evisceration of the blind right eye indicated to eliminate the antigenic nidus if progressive phthisis bulbi ensues.^{11,38,41,42}

The clinical trajectory observed in this patient cannot be disentangled from the structural and geographic realities of archipelagic healthcare delivery in Eastern Indonesia, as benchmarked against contemporary international cohorts in Table 5.^{2,4,9,25,43–45} In Indonesia, the distribution of ophthalmologists is severely skewed toward urban centers on Java and Bali, leaving remote provinces like Maluku with severe shortages of subspecialty vitreoretinal and corneal surgeons.^{14,15,31} Maritime referral from outlying islands requires multi-hour or overnight boat transit across unpredictable sea states, imposing prohibitive travel costs on impoverished artisanal fishing families.^{13,15} Furthermore, administrative exclusions within the BPJS Kesehatan framework regarding injuries sustained during illicit activities, such as blast fishing, generate catastrophic delays in surgical authorization.^{13,24,44} Establishing dedicated provincial emergency ocular trauma fast-track protocols, integrating telemedicine triage for rural clinicians, and equipping district hospitals with ocular trauma kits are urgently needed to prevent preventable blindness in remote archipelagic populations.^{14,24,44,45}

Table 5. Global Comparative Benchmark Matrix of Pediatric and Blast-Related Ocular Polytrauma Cohorts in Contemporary Literature (2021–2026).

Author & Year	Study Cohort & Design	Trauma Mechanism	Presentation Interval	Ophthalmic Injury Pattern	Visual Outcome & Rate of Poor Prognosis
Present Study (2026)	13-year-old boy, Single-case Observational	Homemade fish bomb explosion (Primary, Secondary,	5 days (Delayed presentation, neglected care)	OD: Full-thickness lid laceration, total hyphema, corneal	OD: Light Perception progressing to impending No Light

	Analytic Study, Indonesia	Tertiary, Quaternary blast)		scarring, total RD. OS: Corneal foreign bodies. Polytrauma: Left hand amputation.	Perception (OTS Category 1). OS: Preserved 1.0 (20/20).
Zhang et al. (2023) ²	Multicenter retrospective cohort, n = 287 eyes, China	Military and civilian industrial explosive devices	Median 18 hours (0.5 to 72 hours)	Open globe injury in 78.4%, intraocular foreign bodies in 42.9%, retinal detachment in 31.7%, bilateral in 29.96%.	Final BCVA <20/200 in 62.4%; initial VA of LP or worse, RD, and delayed repair (>24 h) were independent predictors of poor outcome (p < 0.001).
Wong & Yonekawa (2024) ³	Comprehensive systematic review of pediatric open globe injuries, USA	Diverse mechanical, projectile, and explosive trauma in children	Variable, typically <24 hours in urban tertiary centers	Zone I corneal laceration (52%), Zone II/III (48%), traumatic cataract (41%), retinal detachment (18%), vitreous hemorrhage (36%).	Pediatric-specific amblyopia penalty; OTS demonstrated high accuracy in older children; prompt repair within 24 hours significantly improved anatomical salvage.
AlKharashi et al. (2022) ⁴	Retrospective pediatric cohort, n = 115 children, Saudi Arabia	Fireworks and pyrotechnic explosive devices	Mean 6.2 hours post-injury	Corneal laceration in 48%, hyphema in 54%, vitreous hemorrhage in 28%, globe rupture in 16%, retinal detachment in 9.5%.	85% required major surgical intervention; 34% achieved final visual acuity <20/200; male children aged 5–12 predominated (76.5%).
Cohen et al. (2022) ⁵	Retrospective observational cohort, n = 142 pediatric eyes, Israel	Pediatric mechanical and projectile open globe trauma	Median 4.5 hours post-injury	Zone I (64%), Zone II (21%), Zone III (15%), hyphema in 44%, retinal detachment in 14%, vitreous hemorrhage in 32%.	Introduced Modified Pediatric OTS; Category 1 eyes showed 68% risk of final VA <20/200; validated that presenting VA and posterior extent govern final outcome.
Junn et al. (2023) ⁶	Baltimore Pediatric Ocular Trauma Study, n = 80 patients, USA	Pediatric open globe trauma (blunt, penetrating, projectile)	Acute (<24 hours in 94%)	Corneal laceration (58%), scleral rupture (25%), uveal prolapse (38%), traumatic cataract (34%), retinal detachment (16%).	Healthcare disparities influenced enucleation rates (OR 10.55 in minority populations) despite equal presenting visual acuity and POTS scores.
Suharjo et al. (2021) ¹⁵	Retrospective pediatric series, n = 64 children, Yogyakarta, Indonesia	Rural pediatric trauma (firecrackers, sharp objects, blunt trauma)	Median 48 hours (Range: 6 hours to 14 days)	Corneal laceration (62%), hyphema (45%), traumatic cataract (38%), endophthalmitis (14%), retinal detachment (11%).	Referral delay >48 hours was significantly associated with poor visual outcome (p = 0.008) and increased risk of infectious endophthalmitis.

BCVA = best-corrected visual acuity; FB = foreign body; LP = light perception; NLP = no light perception; OD = oculus dexter; OS = oculus sinister; OTS = Ocular Trauma Score; POTS = Pediatric Ocular Trauma Score; RD = retinal detachment; VA = visual acuity.

5. Conclusion

This observational analytic case study demonstrates that neglected pediatric explosive ocular trauma carries a catastrophic visual prognosis when systemic polytrauma triage prioritizes limb salvage over early ophthalmic assessment. The coexistence of open-globe rupture, total hyphema, and funnel-shaped retinal detachment accurately predicted irreversible functional amaurosis, as quantified by an OTS Category 1 score. Geographic isolation, maritime transit delays, and single-payer insurance administrative barriers accelerated fulminant corneal keratolysis, transforming a potentially reconstructible globe injury into total anatomical destabilization. Preserving normal visual function in the contralateral fellow eye

underscores the necessity of early foreign body extraction and vigilant long-term surveillance for sympathetic ophthalmia. Eliminating preventable blindness across archipelagic nations requires integrating mandatory ocular triage into emergency disaster protocols and establishing rapid, equity-driven referral pathways for vulnerable pediatric populations.

Declarations

Ethics Approval and Consent to Participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was formally approved by the from the Institutional Review

Board of the CMHC Research Center, Indonesia (Approval Reference: 2026/821).

Consent for Publication

Written informed consent was obtained from the patient's legal guardians for the publication of this case study and any accompanying clinical photographs and ultrasonographic images. Patient facial features were de-identified in strict adherence to ICMJE and COPE guidelines.

Availability of Data and Materials

All relevant clinical data, acoustic measurements, and photographic documentations are included within the published article.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

Conceptualization: PRAW, DJS, PY, and IWAP. Investigation, including patient clinical care, diagnostic ascertainment, and longitudinal evaluation: PRAW, DJS, PY, and IWAP. Data curation and formal analysis: PRAW and DJS. Writing – original draft: PRAW and DJS. Validation and ophthalmological analysis: PY and IWAP. Writing – review and editing: PY and IWAP. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Generative AI disclosure

The authors declare that no generative artificial intelligence tools were used in the design, analysis, or writing of this manuscript.

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