

Research article

Ophthalmic injuries from the beirut blast: Managing long-term consequences

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ABSTRACT

The 2020 Beirut Port explosion was one of the largest non-nuclear urban explosions in history, and resulted in a plethora of oculo-facial injuries. In this retrospective study, we present the two year follow up ophthalmic outcomes of the survivors of the blast. Only 16 out of 39 patients continued follow up at our center, with 13 having delayed complications and 7 requiring further surgery. The most common delayed complications related to the eyelid, lacrimal system, and orbit. Treatment of disfiguring facial and peri-ocular scarring with laser-assisted drug delivery of topical 5-fluorouracil showed great promise and significantly improved patients' functional and well as cosmetic outcomes.

1. Introduction

The Port explosion of August 4, 2020 was an event that left permanent scars on the facade of Beirut, one of oldest cities in the world, as well as its inhabitants. Around 2700 tons of ammonium nitrate were detonated after a fire erupted in one of the capital's port storage hangers, resulting in one of the largest non-nuclear explosions in modern history (Rigby et al., 2020; Landry et al., 2020). While the seismic waves of the explosion that rippled through Beirut have long dissipated, their ramifications are still felt two years later. 218 people were killed, 7000 were injured and around 300,000 were displaced (Majzoub, 2021).

Our center reported on the ophthalmic injuries caused by the blast in 39 survivors (Kheir et al., 2021; Mansour et al., 2022). The majority was constituted by ocular surface injuries (54.2%) and eyelid lacerations (41.6%), followed by orbital fractures (29.2%), brow lacerations (20.8%), and open globe injuries (20.8%). In this report, we will present the two-year follow up of the patients with ophthalmic injuries treated at the American University of Beirut Medical Center (AUBMC). We will highlight a few challenging cases, as well as innovative treatment modalities used to aid with oculo-facial scarring, mainly laser-assisted drug delivery (LADD) of 5-fluorouracil (5-FU).

2. Materials and methods

This is a single-center retrospective chart review of patients who presented to the Ophthalmology Outpatient Specialty Clinics at AUBMC from November 2020 till January 2023 for follow up on ocular or orbital injuries sustained from the August 4, 2020 Beirut Port explosion. All patients were identified from outpatient records retrieved from all ophthalmology clinics at AUBMC within 2 years of the explosion. Data review was conducted from January 15th, 2021, until January 15th, 2023. The review was done through the electronic medical record system (EPIC) by reviewing the charts of all 39 patients with ocular injuries related to the Beirut blast that were treated by the Ophthalmology team at AUBMC. The data collected from the chart review included patient demographics, eye examination (vision, intraocular pressure, anterior segment exam, fundus funduscopy), delayed complications, treatment strategies and need for surgical intervention.

3. Results

A total of 48 eyes of 39 patients with ocular injuries related to the Beirut blast were treated by the Ophthalmology team at AUBMC within the first 3 months of the blast. 20 eyes (41.7%) of 16 patients (33.3%) presented for further treatment over the following 2 years. Most follow

Abbreviations: 5-FU, 5-Fluorouracil; LADD, Laser-assisted drug deliver.

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up patients presented with delayed complications (13, 81.3%) and a total of 7 patients (43.8%) required further surgical intervention (Fig. 1).

Patients were followed up regularly depending on their condition, however, 23 patients were lost to follow up. Patients with severe or complicated injuries required more frequent visits whereas those with less severe injuries did not require further follow up. In the 2 year follow up period, the average number of follow up visits was 4 (Fig. 1). It is worth noting that several of the initial blast survivors have since left Lebanon, contributing to the loss of follow up.

The most common delayed complications were oculoplastic injuries related to the eyelid, lacrimal system and orbit (11, 65%) including cicatricial ectropion, cicatricial lagophthalmos, eyelid retraction, canalicular injury, nasolacrimal duct injury and madarosis. Other delayed complications included recurrent corneal erosions, residual corneal glass, corneal scars and LASIK flap retraction (Table 1). Overall, 6 patients required further oculoplastic procedures and 1 patient required further corneal surgery. Two patients (12.5%) with combined corneal and oculoplastic injuries required more than one secondary surgery (Fig. 1). One patient had corneal epithelial ingrowth under the LASIK flap of the left eye, in addition to right lower eyelid cicatricial retraction 4 months after initial injury (Case 1). Another patient underwent repair of multiple eyelid and brow lacerations that were complicated by cicatricial retraction and canalicular defects which required multiple surgical interventions including stent insertion (Case 3).

In the first 3 months of follow up, out of 48 injured eyes, 4 eyes had open globe injuries with primary no light perception vision (NLP) that required enucleation or evisceration. 3 eyes had a final best corrected visual acuity (BCVA) of less than 20/200 Snellen. Over the following 2 years, all 3 of these patients had further improvement with BCVA to better than 20/80. Two patients had scarring after corneal sutures were removed many months after initial injury. In addition, both patients had persistent correctopic pupils due to secondary iris injury. The third patient had orbital fractures and a retinal hemorrhage that resolved with improvement of final BCVA to 20/40 in the injured eye. Four patients had neuro-ophthalmic complications leading to permanent disability. Two patients had residual nerve palsy and one had a persistent visual

Table 1

Types of delayed ocular complications after the port of Beirut explosion.

Complications	No. Of injuries
Oculoplastic	11
Cicatricial ectropion	3
Cicatricial lagophthalmos	1
Eyelid retraction	4
Canalicular injury	1
Nasolacrimal duct injury	1
Madarosis	1
Corneal/Sclera	6
Lasik Flap retraction	1
Residual glass	2
Recurrent erosions	1
Corneal scarring	2
Total	17

field defect. Four patients had persistently dilated pupils and photophobia.

3.1. Case 1- blast wave injuries to ocular surface with subsequent epithelial ingrowth

A 27-year-old woman with a history of laser-assisted in situ keratomileusis (LASIK) 5 years prior to initial presentation presented with left eye hand motion vision due to a vitreous hemorrhage (VH) and corneal edema, and a right eye corneoscleral laceration, that was sutured the night of the explosion in the operating room. The right eye corneal sutures were removed 4 months later, and her vision returned to 20/20. Her right lower lid developed retraction that was released surgically with a plastic surgeon in December 2020. As for the left eye, the VH resolved, the corneal edema subsided, and her vision improved gradually to reach 20/20 over few months while taking topical steroids (prednisolone acetate, 1%) that was initially started at hourly intervals and slowly tapered over 6 weeks. However, an epithelial ingrowth under the LASIK flap was noted superotemporally, around 2.5 mm away from visual axis, with retracted flap edge superotemporally, and few retracted scarred edges nasally. A fistula tract connecting the epithelial ingrowth

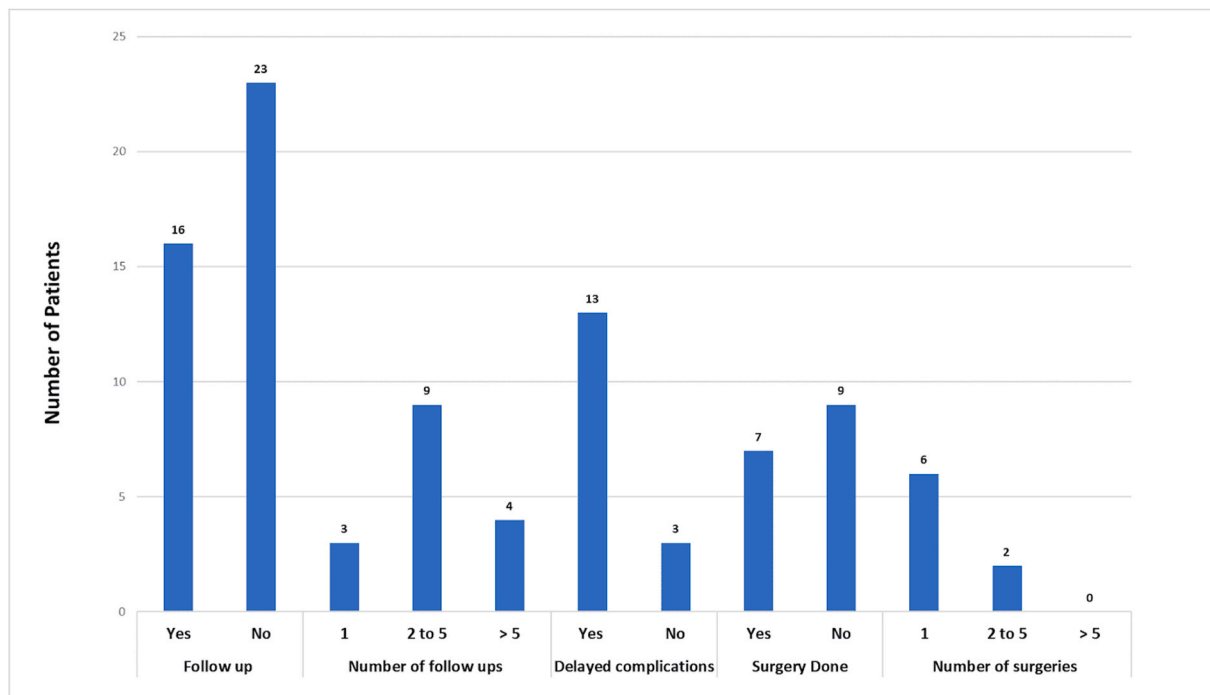


Fig. 1. Patient Distribution According to Number of Follow ups, Delayed Complications, and Need for Surgery After the Port of Beirut Explosion.

area to the intact flap edge was noticed superotemporally. It is presumed that the epithelial ingrowth resulted from the blast shockwave, causing transitory flap edge lifting, or folding, which may have been accentuated by the ensuing stromal edema (Kheir et al., 2022).

The epithelial ingrowth was monitored for over a year with sequential high-definition anterior segment optical coherence tomography (HD-OCT) cornea, while the vision remained 20/20. In February and March of 2022, two sessions of YAG laser disruption of the ingrowth were performed, which decreased the ingrowth but were not enough to eradicate it. In April 2022, the decision was made to lift the flap, scrape the epithelial ingrowth, and apply Mitomycin C for 10s before copiously irrigating it. On follow up, the LASIK flap was noted to be clear, with no epithelial ingrowth but residual retracted edges and scarring nasally (Fig. 2). Two months post-operatively, new epithelial ingrowth appeared around 4 o'clock, but quickly responded to topical steroids. Currently, the patient's vision is 20/20 in both eyes, and she is being closely monitored for any recurrence of ingrowth.

3.2. Case 2- typical glass shrapnel injury to periocular area

A 57-year-old woman, pseudophakic in both eyes, presented with complex lacerations to the right forehead, brow, and eyelid as well as right eye hyphema. The lacerations were deep, reaching the underlying bone, with disruption and prolapse of the retro-orbicularis oculi and preaponeurotic fat pads. Lacerations were primarily sutured, and the patient required a topical steroid as well as a dilating drop for around 3 weeks, after which the hyphema resolved with a persistent irregular tonic pupil. Best corrected vision reached was 20/20 in both eyes.

Her postoperative course was complicated with severe upper eyelid cicatricial retraction that caused lagophthalmos and exposure keratopathy, in addition to supraorbital neuralgia (Fig. 3). The keratopathy and dryness were treated with lubricating tears drops (hypromellose, 0.32%) applied 6 times daily, gel (carbomer) nightly, as well as eyelid taping before sleep.

The cicatricial retraction was managed with a total of four rounds of 5-FU subcutaneous injections and laser assisted drug delivery of 5-FU at post-op week 3, week 6, week 9, and week 12. A fractional ablative CO₂ laser was used with an energy of 100 mJ and a low density, followed by topical application and subcutaneous injections of 5-FU. Improvement in the scarring was noted after the second injection and marked improvement in lagophthalmos was seen after the 3rd injection. During

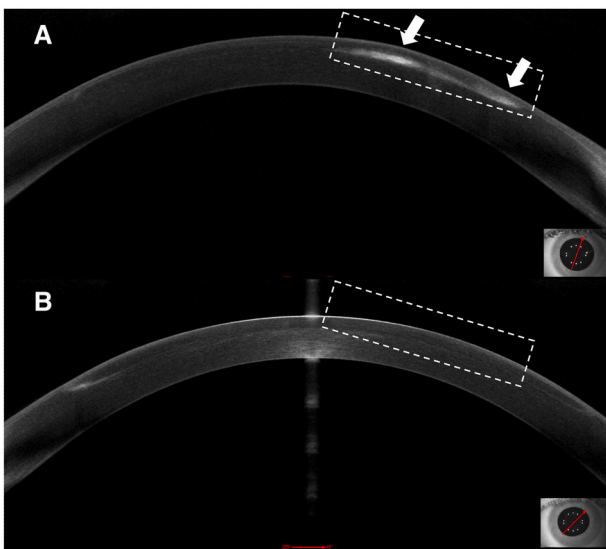


Fig. 2. A. Optical coherence tomography showing epithelial ingrowth at the flap interface superotemporally before flap lifting. B. shows resolution of the epithelial ingrowth after flap lifting.



Fig. 3. A. External photograph of 57-year-old female patient demonstrating right upper eyelid cicatricial retraction and lagophthalmos post blast trauma. B. Resolution of lagophthalmos after four sessions of laser assisted drug delivery and subcutaneous injections of 5-FU.

her final visit, a residual irregularity in the eyelid fold and crease were noted due to tissue loss and residual scarring, but complete resolution of lagophthalmos and exposure keratopathy were noted.

The supra-orbital neuralgia was most prominent by week 12 after the blast, and symptoms mostly resolved following a subdermal injection of triamcinolone acetate (40 mg/ml) in the supraorbital notch area in addition to a course of oral steroids (prednisone 60 mg) taken once daily and tapered over 4 weeks, pregabalin (75 mg) twice daily and vitamins B1 (100 mg), B6 (200 mg) and B12 (200mcg) once daily for 8 weeks.

3.3. Case 3 – glass shrapnel injury to cornea and eyelid

A 26-year-old female presented an hour after the blast with multiple complex facial lacerations including the eyelids, and a hyphema of the left eye filling 50% of the anterior chamber with a deep corneal laceration. Vision in the right eye was 20/20 but the left eye was counting fingers near face. There was a deep partial thickness corneal laceration of the left eye traversing the pupil obliquely from 4 o'clock to 10 o'clock but with no leak from the anterior chamber (Siedel negative).

Close monitoring of the corneal laceration was employed after initiating topical (moxifloxacin, 0.5%) 4 times daily and systemic antibiotics (moxifloxacin 400 mg) once daily for 7 days along with topical steroids (prednisolone acetate 1%) every 2 h and slowly tapered over 6 weeks. Although visual acuity was improving and the hyphema was resolving, the laceration was still uptaking fluorescein. A 10-0 nylon suture was placed at the deepest area of the corneal wound to approximate the edges and hasten the healing process. The corneal suture was then removed around 4 months later, with good results. Minimal corneal scarring remained, and a 20/25 BCVA was achieved.

As for the eyelid lacerations, sutures were placed previously by the plastic surgery team as a primary response in the emergency room, with the computed tomography scan showing multiple subcutaneous foreign bodies in the eyelid and cheek area. Scarring and cicatricial retraction were noted at the eyelid margins, with significant contracture reaching the cheeks. In addition, there was an eyelid margin defect 2 mm medial

to the punctum with canalicular defect, but the distal lacrimal system was not disrupted. The canalicular laceration was corrected by placing a monocanicular mini-monoka style lacrimal stent to reconstruct the canaliculus in December 2020 and was removed 3 months later. The naso-lacrimal system was patent during her last follow up visit in April 2022, with no residual epiphora. Finally, the patient's facial scars were treated with 2 sessions of carbon dioxide laser resurfacing with satisfactory final results.

3.4. Case 4 & 5 - extensive facial injuries

A 44-year-old female presented with extensive glass injury and complex lacerations mainly affecting the right side of her face, luckily, she did not sustain any globe injury. Patient had glass fragments embedded deep into facial tissues in the right lateral canthal area and cheeks that had to be surgically removed. She underwent a total of 6 sessions of fractional ablative CO₂ laser treatment combined with topical and subcutaneous 5-FU at monthly intervals, which led to dramatic improvement in her scar appearance as well as skin texture and pliability. No local or systemic complications or adverse events were noted after more than 2 years of follow up (Fig. 4).

A 49-year-old man presented with extensive facial and bodily injuries including glass injuries and chemical injuries. He had severe left eyelid and globe lacerations requiring left eye evisceration, implant placement, and left upper eyelid secondary reconstruction. Over the course of the 2 years follow up, he underwent 5 treatment sessions of LADD of topical 5-FU at monthly intervals. The final result was a dramatic improvement in facial scarring, eyelid function and overall facial appearance (Fig. 5).

4. Discussion

In the aftermath of this disaster, countless people were found with physical and psychological damage that permanently altered their lives. Victims of ophthalmic trauma and facial lacerations were left with facial scars that are not only aesthetically displeasing but also a daily reminder of their trauma. Hence, the process of scar rehabilitation was of paramount importance in the recovery process, and indeed the authors noted how much the physical improvement in scar appearance would help patients improve their psychological recovery.

The authors employed multiple therapeutic approaches in the management of scars including the use of topical corticosteroids, topical silicone-based ointments, silicone sheeting, reinforced acrylate strips (3M™ Steri-Strip™, Saint Paul, USA), topical sunscreen, and sometimes botulinum toxin injection. But the most effective method in scar



Fig. 4. A. External photograph of 44-year-old female patient demonstrating extensive facial scars post blast trauma. B. Significant cicatricial improvement after 6 sessions of laser assisted drug delivery of 5-FU.



Fig. 5. A. External photograph of 49-year-old male patient demonstrating extensive facial scars post blast trauma. B. Significant improvement after 5 sessions of laser assisted drug delivery of 5-FU.

modulation in our experience was the use of fractional ablative lasers and LADD of 5-FU in addition to subcutaneous 5-FU injections.

5-FU is a pyrimidine antimetabolite traditionally used as a chemotherapeutic agent; however, it has a wide therapeutic application, alone or in combination with other therapeutic agents and treatment modalities (Casale and Patel, 2022). 5-FU has been shown to reversibly inhibit fibroblast proliferation *in vitro* (Mallick et al., 1985) and *in vivo* (Blumenkranz et al., 1982) and modulate the wound-healing response resulting in reduced scar formation (Yoo et al., 2015). In ophthalmic practice, 5-FU has been safely and effectively used to prevent scarring in glaucoma filtration surgery (Five-year follow, 1996) proliferative vitreoretinopathy (Asaria et al., 2001) and anophthalmic socket reconstruction (Priel et al., 2012; Mina et al., 2018; Andreo et al., 1997).

Laser alone, as well as intralesional injections of 5-FU are effective treatment modalities for facial scars (Shah et al., 2016; Gold et al., 2014; Karmisholt et al., 2018). Laser assisted drug delivery is a more efficient transcutaneous delivery method of topical medications into the deeper skin layers which allows for a synergistic therapeutic response. Fractional ablative lasers such as carbon dioxide (CO₂) lasers or Erbium:YAG (Er:TAG) lasers create vertical ablation channels in the skin that can serve as entry points for topical medications. It has been tried using different lasers and drugs on various dermatologic conditions including skin dyschromia, dysplasia, neoplasms, inflammatory conditions, scars, and for rejuvenation (Waibel et al., 2019; Asilian et al., 2006; Gómez et al., 2008; Seago et al., 2020). For scar treatment, LADD has been shown to be equally effective using 5-FU or triamcinolone acetonide, with more side effects with the latter (Karmisholt et al., 2018; Gómez et al., 2008).

All our patients that have received this treatment reported a dramatic improvement in the appearance of their facial scars, especially with regards to hypertrophic scars, dyschromia, texture, pliability, thickness, and contracture that were significantly better.

Interestingly, one of our patients had severe upper eyelid cicatricial retraction that significantly improved with the combined intralesional and LADD of 5-FU in the eyelid (Case 2). Her lagophthalmos and exposure keratopathy resolved after 3 rounds of monthly combined laser and injection. Similar case reports have been reported in the literature, which adds to the importance of this tool in the armamentarium of surgeons (Lee et al., 2018).

Although laser treatment for scar modulation has been reported very early in the post trauma course during the inflammatory or proliferative phase of healing, all our patients were treated in the remodeling or maturation phase, mostly for the logistical reasons, as clinics were

mostly busy with patient that needed primary ophthalmic or oculo-plastic care (Karmisholt et al., 2018).

Mitomycin C was another anti-metabolite utilized in the treatment of one of our patients (Case 1). Management of epithelial ingrowth under the LASIK flap after trauma must be tailored to the visual acuity, status of the flap and the progression of the ingrowth. Since our patient did not respond to the non-invasive Nd:YAG laser therapy, we opted for the mainstay of treatment of aggressive epithelial ingrowth: flap re-lifting and scraping (Yeh et al., 2006; Yesilirmak et al., 2018). Mitomycin C to the stromal bed has been shown to help in recalcitrant cases (Yeh et al., 2006; Wilde et al., 2017), and we applied it during the procedure. Suturing the flap has been associated with decreased recurrence rates, as it may prevent the invasion of epithelial cells (Wilde et al., 2017). We may employ this method in the future if the ingrowth recurs.

5. Conclusion

A large number of our initial patient cohort was lost to follow up, however, the ones that remained served as difficult clinical challenges. The majority suffered delayed complications; around half required further interventions. Of these interventions, a relatively novel one was LADD of 5-FU. Previous studies confirm 5-FU's safety and efficacy in the treatment and prevention of hypertrophic scars and keloids, however, its use in combination with laser therapy in the periocular region has not yet been evaluated, especially in post-traumatic cases. Further studies are needed to evaluate the efficacy of topical or intralesional 5-FU combined with laser therapy for the modulation of oculo-facial scars.

Although not all scars are visible, those on the face and the periocular area can be especially damaging to a person's self-esteem and morale, especially if sustained in a traumatic incident. It is of utmost importance to employ all available techniques in our arsenal in order to give our patients the best possible outcome.

Author contribution

RA designed and directed the project. WK, AK were involved in data collection. RA, WK, AK, PI, ER, ZE, DE were involved in the analysis and interpretation of results. RA, WK, AK, PI, ER, ZE, DE, FK, SA and AB drafted the manuscript and designed the figures. All co-authors contributed to critically revising the manuscript and read and approved the final version.

Disclosures

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Declaration of competing interest

The authors have no conflict of interest to disclose.

Data availability

No data was used for the research described in the article.

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