

Systematic Review

Cite this article: Saad C, Slaiby N, Chalhoub G, Mina C and Helou MC (2026). The Beirut Pager Explosions of 2024: A Systematic Review of an Unprecedented Mass Casualty Event. *Disaster Medicine and Public Health Preparedness*, 20, e87, 1–7
<https://doi.org/10.1017/dmp.2026.10357>

Received: 15 December 2025

Revised: 10 March 2026

Accepted: 17 March 2026

Keywords:

blast injuries; polytrauma; mass casualty incident; disaster medicine; pagers; hybrid warfare

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The Beirut Pager Explosions of 2024: A Systematic Review of an Unprecedented Mass Casualty Event

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Abstract

Objective: In September 2024, Lebanon experienced an unprecedented mass casualty incident involving the simultaneous detonation of thousands of weaponized pager devices. This systematic review characterizes the resulting injury patterns, surgical burden, and disaster-response lessons to help inform future preparedness and response strategies.

Methods: PubMed, Embase, Scopus, and Web of Science were searched for studies on casualties from the pager explosions. A random-effects meta-analysis estimated pooled prevalence of injuries by body region.

Results: Sixteen articles met inclusion criteria overall, comprising seven studies in the clinical synthesis and nine articles in the qualitative disaster-response synthesis. A consistent injury pattern predominantly affected the hands, face, and eyes. Specialty-specific cohorts demonstrated severe ocular destruction, frequent hand amputation, and a substantial operative burden. In the two comparable hospital-based cohorts eligible for meta-analysis, upper extremity injuries were most common (pooled prevalence 84%; 95% CI: 73–91%; $I^2 = 0\%$). The incident exposed critical weaknesses in triage, communication, and specialty surge capacity.

Conclusion: The 2024 pager explosions produced a novel injury signature distinct from conventional blast trauma. These findings, while based on limited case series, underscore the urgent need for health care systems to develop flexible, adaptive disaster plans that can respond to the unique threats of unconventional warfare.

Introduction

On September 17, 2024, Lebanon experienced a mass casualty incident (MCI) when thousands of weaponized pagers exploded simultaneously across the country. A second wave of detonations involving 2-way radios occurred the following day. According to the Lebanese Ministry of Public Health, these attacks resulted in over 2,900 injuries and 37 fatalities, overwhelming more than 150 hospitals nationwide.¹ This event has been framed within the context of hybrid warfare, posing unique challenges to a health care system already fractured by the 2020 Beirut Port Explosion and a prolonged economic crisis.^{2,3} Previous studies on the 2020 blast highlighted a reliance on non-governmental organizations due to weak state disaster management infrastructure.^{4,5}

The explosions produced a distinctive polytrauma profile.^{2,3,6,7} In the aftermath of the event, a series of valuable but fragmented reports emerged from the medical community, including hospital-based case series, operational reports from the field, and expert commentaries.^{1,8,9}

Prior studies have evaluated injury patterns, perioperative requirements, and trauma-system preparedness across other disaster and mass casualty settings, including major earthquakes and broader trauma-system responses to MCIs.^{10,11} However, they address different mechanisms of injury and response environments. We therefore aimed to synthesize the available evidence on the 2024 Lebanon pager explosions by characterizing the clinical injury patterns, estimating pooled prevalence of major anatomical injury patterns from comparable hospital-based cohorts, and identifying the principal operational challenges and preparedness lessons reported in the aftermath.

Methods

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.¹²

Search Strategy

A systematic search was conducted in September 2025 across four databases: PubMed, Embase, Scopus, and Web of Science, and was updated through March 2026 to capture newly published

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studies on the pager explosions in Lebanon. The search targeted literature published after the event, using a combination of keywords related to the explosion and resulting injuries: “pager explosion,” “Beirut,” “Lebanon,” “blast injury,” and “polytrauma.” The electronic search was supplemented by a manual review of the reference lists of included articles to identify additional eligible studies.

Eligibility Criteria

Studies were eligible for inclusion if they were retrospective cohort or case series reporting original clinical data on casualties from the pager explosions in Lebanon on September 17, 2024. The review focused on studies describing polytrauma patterns, surgical interventions, and patient demographics. All relevant peer-reviewed literature, including reports from the field, commentaries, and perspectives, that described the operational response, hospital preparedness, triage procedures, or lessons learned from the event were included as well.

Data Extraction and Quality Assessment

Data were extracted independently by 2 reviewers. Extracted variables included: study characteristics, patient demographics, polytrauma outcomes. Data related to disaster response was extracted and organized thematically into key domains: triage, surge capacity, communication, patient identification, and preparedness lessons.

The methodological quality of each included case series was assessed using the NIH Quality Assessment Tool for Case Series Studies. Quality assessment was performed independently by two reviewers, with disagreements resolved by consensus. Studies were rated as “Good”, “Fair”, or “Poor” based on the risk of bias identified in these domains.

Data Synthesis and Statistical Analysis

A thematic qualitative synthesis was conducted to identify and summarize the key operational challenges and preparedness lessons reported in the included literature. These findings were synthesized narratively rather than meta-analyzed because of heterogeneity in study design, reporting format, and outcome definitions. In this review, the term “polytrauma” was used descriptively to refer to injuries involving multiple anatomical regions as reported by the included studies, rather than as a standardized severity construct based on Injury Severity Score or other formal trauma scoring systems.

For quantitative synthesis, a meta-analysis of proportions was performed using data from the two studies that reported on comparable hospital-based polytrauma cohorts. A random-effects meta-analysis was conducted to estimate the pooled prevalence and 95% confidence intervals (CIs) for injuries to the upper extremities, cranium, abdomen, and lower extremities. The Freeman-Tukey double arcsine transformation was applied to stabilize variances.

Statistical heterogeneity was assessed using the I^2 statistic. A test for subgroup differences was performed to assess variation in injury prevalence across body regions. All analyses were conducted using R software (version 4.3.1). Results are presented visually using a forest plot.

Results

Search Results and Study Selection

The initial literature search yielded 36 records from 4 electronic databases. After the removal of 20 duplicates, the titles and abstracts

of the remaining 16 unique articles were screened. Following a full-text review for eligibility, seven studies were included in the clinical synthesis, of which 2 comparable hospital-based cohorts were eligible for quantitative meta-analysis.^{3,6,7,13–16} Nine articles were identified as relevant for the qualitative synthesis of the disaster response.^{1–3,7,9,17–19} The complete study selection process is illustrated in the PRISMA flow diagram (Figure 1).

Characteristics of Included Studies and Quality Assessment

The included studies and demographic characteristics are summarized in Table 1. These comprised Lebanese hospital-based case series, 2 transferred referral cohorts from Iran, large center ophthalmic series, a selected upper-limb trauma surgical series, and hospital-based operational reports. Taken together, the clinical synthesis included 282 patients, with one additional upper-limb trauma series contributing 100 reported surgeries. Two reports described the same patient cohort from the same institution and were therefore considered together for purposes of cohort interpretation and data presentation.^{3,7}

Methodological quality varied across the included studies. The Lebanese hospital-based case series provided the most complete data on acute injury patterns and operative burden. The ophthalmic and upper-limb surgical series contributed important specialty-specific data but represented selected cohorts, which limited generalizability. The operational and disaster-response reports contributed systems-level information but were not directly comparable to clinical case series for formal risk-of-bias assessment. Overall, the certainty of evidence remained limited because the available literature was dominated by retrospective single-center reports, selected cohorts, and heterogeneous outcome reporting.

Injury Patterns: A Consistent Polytrauma Profile

A consistent pattern of polytrauma was identified across all cohorts, with predominant involvement of the upper extremities, face, and eyes (Table 2). The meta-analysis of 2 comparable hospital cohorts ($N = 75$) provided pooled prevalence estimates for injuries by body region (Figure 2). Upper extremity injuries were the most common, with a pooled prevalence of 84% (95% CI: 75–92%) and no statistical heterogeneity between the studies ($I^2 = 0\%$). Cranial injuries were also prevalent but demonstrated significant heterogeneity, with a pooled prevalence of 35% (95% CI: 10–66%; $I^2 = 87\%$). Abdominal and lower extremity injuries occurred at lower rates, with pooled prevalences of 16% (95% CI: 2–39%; $I^2 = 79\%$) and 17% (95% CI: 9–27%; $I^2 = 0\%$), respectively. A test for subgroup differences was statistically significant ($p < 0.0001$), confirming substantial variation in injury prevalence across the different body regions.

The specialty-specific literature further refined the clinical profile of the event by demonstrating consistently severe ocular trauma, frequent bilateral involvement, and major associated upper-extremity and facial injury. Across these cohorts, open-globe injury, traumatic or auto-evisceration, and a high operative burden were common.^{6,13,15,16} For example, Antoine *et al.* reported open-globe injury in 57% of eyes, while Saade *et al.* reported severe globe trauma in 70.3% of eyes and traumatic evisceration in 45%.^{6,15} The pediatric referral series mirrored this pattern, with all 5 children sustaining ocular, facial, and upper-extremity injuries, including 3 auto-eviscerated eyes and four partial hand amputations.¹⁶ Because these were specialty-specific or selected referral cohorts rather than general hospital-based polytrauma cohorts, these data

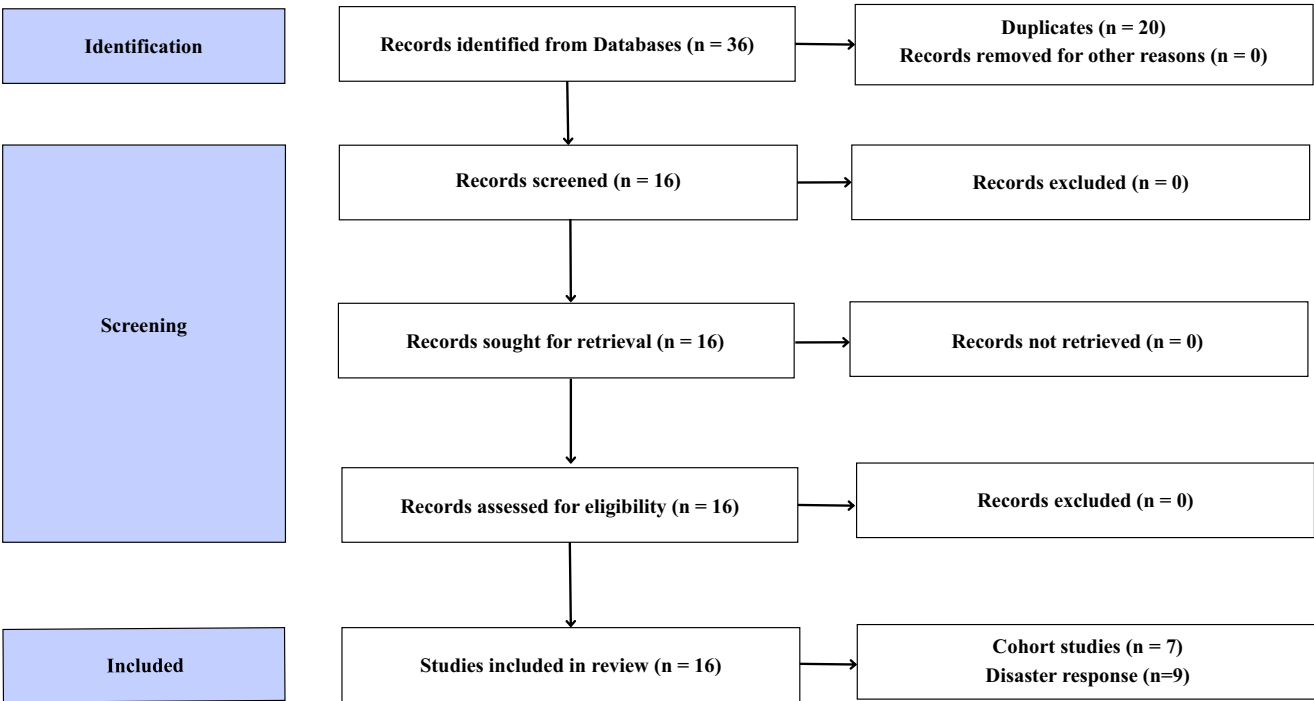


Figure 1. PRISMA 2020 flow diagram of study selection. This diagram illustrates the systematic search and selection process for the review of the 2024 Beirut pager explosions.

Table 1. Characteristics and baseline demographics of included studies

First Author, Year	Study Design	Country	Sample Size (N)	Mean Age (years)	Male (n, %)	Risk of Bias
Karam et al. (2025) & Sobh et al. (2025)	Case Series	Lebanon	37 patients	35.5	37 (100%)	Good
Antoine et al. (2025)	Case Series	Lebanon	38 patients (76 eyes)	32.8	36 (95%)	Fair
Daryabari et al. (2025)	Case Series	Iran (transferred from Lebanon)	123 patients	NR	NR	Poor
Hassanpour et al. (2026)	Case Series	Iran (transferred from Lebanon)	5 patients	9.2	4 (80%)	Fair
Saade et al. (2026)	Case Series	Lebanon	79 patients (158 eyes)	34.9 ± 9.6	76 (96%)	Fair
Hitti et al. (2026)	Qualitative operational study	Lebanon	182 casualties	NR	NR	NA
Nahle et al. (2026)	Case Series	Lebanon	100 surgeries	NR	NR	Fair

This table summarizes the design, setting, sample size, study quality, and available demographic characteristics of the studies reporting primary or aggregate data on casualties. Abbreviation: NR, not reported. Note: Risk of bias was assessed using the NIH Quality Assessment Tool for Case Series Studies. Studies were rated as Good (low risk), Fair (moderate risk), or Poor (high risk). Operational reports were not formally assessed for risk of bias using this tool.

were incorporated descriptively and were not included in the pooled prevalence meta-analysis.

Operative Burden and Specialty-Specific Interventions

The event imposed a substantial operative burden across multiple specialties (Table 3). A high proportion of patients required surgery, particularly orthopedic and hand procedures, wound repair, and ophthalmic salvage or ablative interventions. Evisceration or enucleation was frequently required in ocular cohorts, while amputations represented a major component of the hand surgery burden. Across the ophthalmic cohorts, the operative burden was substantial, with frequent evisceration or traumatic auto-evisceration, open-globe repair, vitrectomy, and adnexal reconstruction; in the

largest surgical series, 90 ophthalmic procedures were performed over 4 days.^{6,13,15} Similarly, the selected upper-limb trauma series described 100 surgeries and highlighted perioperative adaptation in a high-acuity, resource-constrained setting.¹⁴ In the 5 children transferred to Iran, the operative burden involved multiple ocular, facial, and orthopedic procedures required per patient with poor early visual and hand-function outcomes in most cases.¹⁶

Disaster Response: Operational Challenges and Lessons Learned

The qualitative literature identified several recurring operational themes.^{1–3,6,7,9,17–19} First, triage and prioritization were challenged by the unusually high proportion of patients requiring urgent

Table 2. Distribution of injuries by body region

Study	Head/Cranial Injury (n, %)	Facial Injury (n, %)	Ocular Injury (n, %)	Torso (Chest/Abdomen) Injury (n, %)	Upper Extremity (Hand) Injury (n, %)	Lower Extremity Injury (n, %)
Karam et al. (2025) & Sobh et al. (2025)	19 (52.7%) had brain injuries	22 (59.5%)	31 (83.8%)	10 (27.8%) had abdominal injuries	32 (86.5%) had left hand injuries	6 (16.7%) had right leg injuries
Antoine et al. (2025)	8 (21%) had cranial injuries	NR	38 (100%) ^a	3 (7.9%) had abdominal injuries	>81.6% had unilateral or bilateral injuries	7 (18.4%)
Daryabari et al. (2025)	NR	NR	123 (100%) ^a	NR	NR	NR
Hassanpour et al. (2026)	NR	5 (100%)	5 (100%)	NR	5 (100%)	NR
Saade et al. (2026)	NR	NR ^b	79 patients (158 eyes); severe globe trauma in 111 eyes (70.3%), open globe injury in 61 eyes (55%), traumatic evisceration in 50 eyes (45%); bilateral injuries in 36 patients (45.6%) ^a	NR	NR	NR

This table details the polytrauma pattern by showing the percentage of patients affected in multiple body systems.

Abbreviation: NR, not reported.

^aStudy population was selected on the basis of ocular trauma and therefore does not represent a general hospital-based polytrauma cohort.

^bAdnexal and periocular injuries were reported, but facial injury prevalence was not presented as a patient-level body-region outcome comparable to other cohorts.

evaluation.^{2,3,7,17} Multidisciplinary triage was essential to determine salvageability and prioritize specialist involvement.^{3,7,15}

Second, hospitals experienced a wave-like influx of casualties over several hours rather than a single short-lived surge, requiring sustained adaptation in staffing, operating room access, imaging use, and bed allocation.^{3,17} At some centers, whole-hospital mobilization and redistribution of selected patients to inpatient units helped decompress emergency department operations and maintain throughput.¹⁷

Third, communication and patient identification emerged as recurring challenges. Standard communication tools were disrupted or abandoned because of security concerns, forcing teams to rely on alternative messaging systems and improvised workarounds.^{1,3,17} In parallel, patient tracking was complicated by reluctance of some casualties to disclose their identities and by the severity of hand and facial injuries, which limited recognition and complicated use of standard wristband-based systems.^{1,19}

Overall, the disaster-response literature showed that the pager explosions created a highly specialized clinical and operational burden that extended beyond conventional trauma surge planning.^{1,2,9,17,18} Across reports, the response repeatedly involved rapid ophthalmic, orthopedic/hand, anesthetic, reconstructive, and neurosurgical coordination together with flexible hospital-wide mobilization.^{7,14,15,17}

Discussion

This systematic review and meta-analysis represents the first comprehensive synthesis of clinical and operational data following the 2024 Lebanon pager explosions. Across the included studies, the event was characterized by a recurrent pattern of injury involving the upper extremities, face, and eyes, together with a concentrated surgical burden and major operational challenges for receiving hospitals. Although the published literature remains limited and largely retrospective, the available evidence suggests that this event differed from conventional blast-related mass casualty incidents in both injury pattern and health-system demands.

The injury characteristics also exposed major limitations within existing disaster preparedness frameworks. Traditional all-hazards models were not designed to accommodate the sudden demand for ophthalmologic operating rooms, microsurgical instruments, specialized orthopedic teams, and expanded ICU capacity.⁷ The operative burden also extended to anesthetic and perioperative management, as resource-constrained conditions required flexible approaches to airway management, analgesia, and intraoperative stability.³ Communication systems were similarly disrupted, as hospitals abandoned pagers and walkie-talkies due to concerns about secondary detonations and shifted to encrypted messaging platforms on personal devices.^{1,3,17} Together, these challenges show how hybrid attacks can strain medical systems without directly damaging hospital infrastructure.

Placing this event in the broader context of other Lebanese mass casualty incidents further underscores its uniqueness. The 2020 Beirut Port explosion created one of the largest non-nuclear blast zones, yet its injury distribution was dominated by glass-related lacerations and lower extremity injuries linked to ground-level blast effects, with injury severity inversely correlated to the distance from the epicenter. In 2020, upper extremity injuries were present in 53.7% of admitted patients in an institution, often associated with defensive wounds from falling debris, rather than direct handling of explosives.⁵ Furthermore, ophthalmic injuries represented only 4.4% of presenting casualties at one institution, with many resulting from secondary blast effects like flying glass.²⁰ In contrast, the pager explosions produced a concentrated pattern of hand, facial, and ocular trauma because victims instinctively lifted the devices toward their faces at the moment of detonation. This behavioral component is rarely documented in blast medicine and likely contributed to the high rates of bilateral ocular damage and hand amputation.⁶

Comparing the operational dynamics of 2024 to 2020 reveals a stark evolution in disaster response challenges. In 2020, the primary challenge was the sheer volume of “walking wounded” who overwhelmed emergency departments in the first 2 hours, delaying care

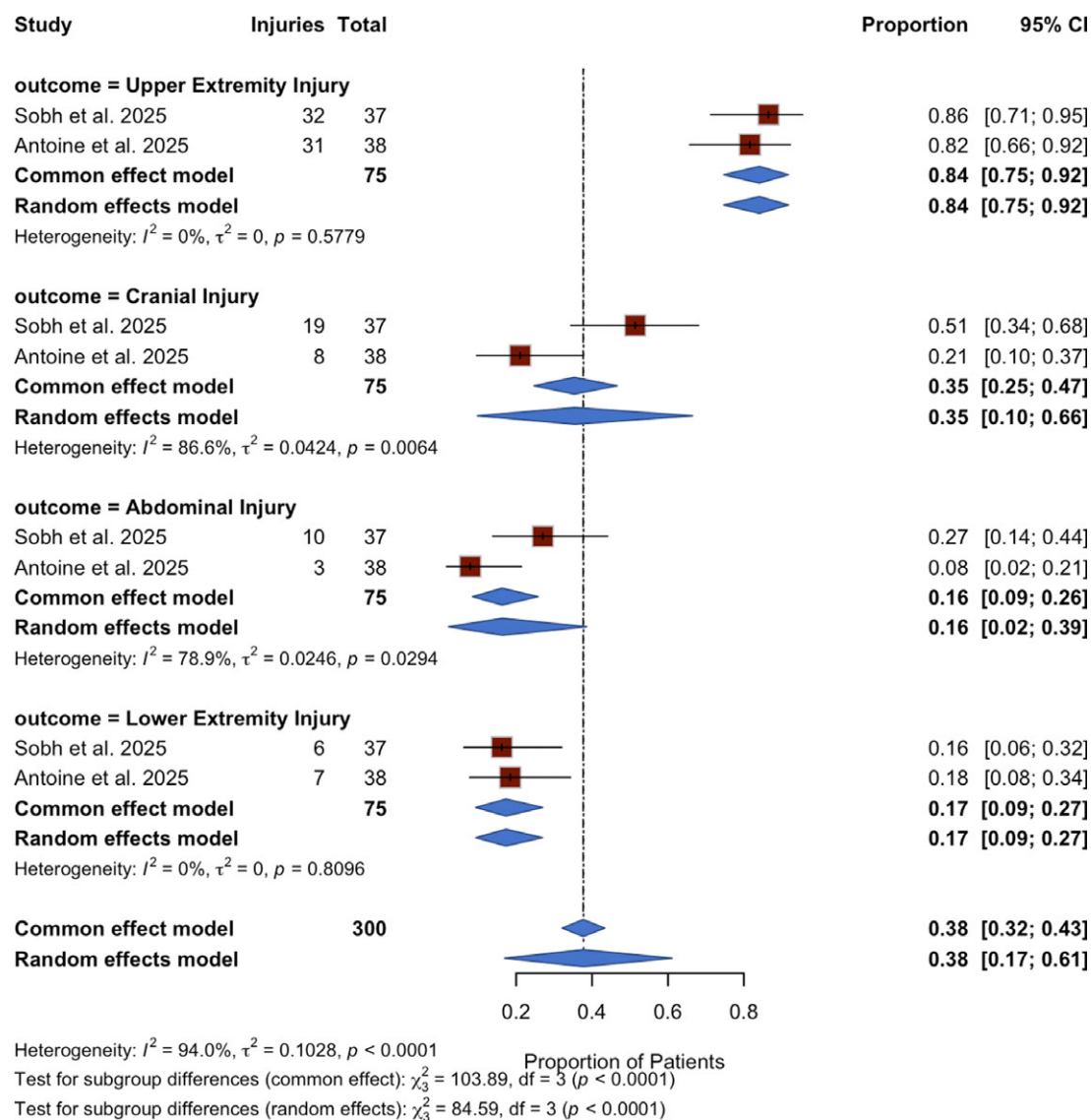


Figure 2. Forest plot of the pooled prevalence of injuries by body region. The forest plot displays the results of the random-effects meta-analysis of proportions for polytrauma injuries, stratified by body region. Each square represents the proportion of patients with a specific injury in an individual study, with its size proportional to the study's weight. The horizontal lines indicate the 95% confidence intervals (CIs). The diamond for each subgroup represents the pooled prevalence, with its width indicating the 95% CI.

for the severely injured.⁵ The response was further hampered by the physical destruction of hospitals and a reliance on non-governmental organizations (NGOs) due to weak state governance.^{4,5} However, international emergency medical teams (I-EMTs) were able to deploy, although they often arrived late or were ill-adapted to the specific needs of the crisis.²¹ Conversely, the 2024 pager explosions produced a much higher proportion of patients requiring urgent or immediate evaluation, while also concentrating demand in a narrower set of highly specialized services.^{2,7,17,19} The 2024 response also faced a unique technological blackout. While 2020 saw physical infrastructure collapse, communication networks remained functional; in 2024, the abandonment of standard communication devices due to security fears represents a new vulnerability in modern hybrid warfare.^{1,3,17}

Industrial explosions typically create multisystem trauma driven by environmental debris, wide blast radii, and collapsing infrastructure. The pager detonations differed by causing injury through handheld consumer electronics, resulting in localized

upper body destruction rather than widespread polytrauma.⁹ While sharing some resemblance to close-range suicide bombings, those events often involve metal fragment penetration from constructed shrapnel. In the pager explosions, heavy shrapnel was absent, but micro-shrapnel consisting of plastic, glass, and metal from the device casing caused significant local tissue destruction in both adults and children.^{6,16} The predominance of soft tissue destruction to the eyes and hands therefore reflects a mechanism that is rarely documented in the disaster medicine literature.

Operationally, the severity of incoming patients placed unprecedented strain on the health care system. This strain was exacerbated by historical gaps in disaster preparedness. Local coordination relied heavily on ad hoc cooperation between private entities rather than a centralized government command.^{4,21} The response was further complicated by a wave-like influx of casualties over several hours rather than a single short-lived surge, requiring sustained reallocation of staff, imaging resources, operating-room access, and inpatient capacity.^{3,17} One hospital reported that 97% of casualties

Table 3. Major surgical interventions by type

Study	Ocular Surgery (Evisceration/Repair)	Hand Surgery (Amputation)	Neurosurgery	Other Major Surgeries
Karam et al. (2025) & Sobh et al. (2025)	17 patients required evisceration/enucleation	31 patients required amputation	5 patients required foreign body removal from the brain	27 patients required wound repair
Antoine et al. (2025)	21 eyes were eviscerated; 18 eyes underwent open globe repair	NR	NR	36 eyes required eyelid laceration repair
Daryabari et al. (2025)	78 eyes were auto-eviscerated; 40 eyes required primary repair	NR	NR	20 eyes required primary vitrectomy
Hassanpour et al. (2026)	3 eyes auto-eviscerated; additional ocular procedures included primary repair, lensectomy, vitrectomy, IOFB removal, keratoprosthesis, and conformer placement	4 patients underwent partial hand amputations	NR	Multiple facial soft-tissue procedures, including staged debridement, layered repair/closure, and scar revision
Saade et al. (2026)	49 eyes underwent evisceration; 53 eyes underwent full-thickness globe repair	NR	NR	43 eyes required adnexal reconstruction; 90 ophthalmic surgeries were performed over 4 days
Hitti et al. (2026)	NR	NR	NR	35 patients required emergent surgery within the first 12 hours; whole-hospital operative surge described
Nahle et al. (2026)	NR	100 upper-limb trauma surgeries involving hand and finger amputations	NR	NR

This revised table highlights the significant surgical burden across multiple specialties, reflecting the complexity of the polytrauma. Abbreviation: IOFB, intraocular foreign body; NR, not reported.

were triaged as red, although this figure should be interpreted cautiously because triage systems were not uniformly described and high-priority designations may have reflected limb-threatening, vision-threatening, or other salvage-critical injuries in addition to immediately life-threatening physiology.² This drastically reduced the number of walking wounded, who often provide a natural buffer during MCIs and help preserve emergency department throughput. Their absence forced hospitals into immediate saturation and required rapid multidisciplinary mobilization rather than phased surge escalation.

Patient identification added another significant challenge. Extensive facial and hand trauma interfered with visual recognition and prevented the use of wristband-based systems. Many patients were also reluctant to provide their names due to security concerns, complicating documentation, continuity of care, and discharge planning.^{1,19} This issue was less pronounced during the Beirut Port explosion, where most casualties arrived with personal identification or family support, illustrating how sociopolitical context can shape clinical response as much as injury type.^{4,5}

The findings also have implications for preparedness in settings with limited disaster-response capacity. Effective planning for irregular or hybrid attacks should include stronger integration of multidisciplinary surgical teams, backup communication systems, flexible hospital command structures, and explicit surge planning for ophthalmology, orthopedic/hand surgery, plastic surgery, and anesthesia. In fragmented systems, NGOs and external disaster medical teams may be most useful when they reinforce local triage training, logistics, rehabilitation, psychosocial care, and specialty continuity without disrupting coordination. Relatedly, countries exposed to hybrid threats may benefit from stronger civilian-military medical coordination in communication redundancy,

transfer pathways, modular trauma teams, and role-flexible deployment of surgical personnel.^{9,18}

This review should be interpreted in light of several limitations. First, the published literature captures only a small and likely selected fraction of the thousands of casualties reported nationally. The findings are best interpreted as describing the published clinical and operational signature of the event rather than the complete epidemiology of the 2,900+ casualties reported nationally. Second, standardized severity measures were not consistently reported, limiting comparison with other blast-related cohorts and making it necessary to infer injury severity from operative burden, triage categories, and ICU use rather than from harmonized trauma metrics. Triage systems were also not uniformly described across reports. Finally, the specialty-specific cohorts, while highly informative, are not general hospital-based polytrauma samples and therefore cannot be assumed to reflect the frequency of those injuries in the total casualty population.

Future research should therefore move beyond acute descriptive reporting. There is a clear need for multicenter follow-up studies that examine long-term visual outcomes, upper-extremity function, reconstructive trajectories, return to work, rehabilitation needs, mental health sequelae, and underreported domains such as hearing loss, otologic injury, and neurocognitive outcomes. Prospective registries and better harmonization of injury-severity reporting would also improve comparison with other forms of blast and conflict-related trauma. Second, health systems must develop and validate disaster preparedness protocols that explicitly account for injury profiles atypical of conventional blast incidents. This includes integrating specialty-specific surge planning for ophthalmology, plastic and reconstructive surgery, and anesthesiology, and conducting simulation-based exercises tailored to scenarios

involving weaponized consumer electronics and high volumes of critically injured patients.

Conclusion

In conclusion, the Beirut pager explosions produced a highly distinctive hand-eye-face injury complex together with a concentrated specialty-specific surgical burden and major operational disruption. The available evidence suggests that this incident should be understood not simply as another blast event, but as an example of how weaponized consumer electronics and hybrid tactics can generate novel trauma patterns that challenge conventional disaster planning. Future preparedness for similar incidents will require flexible hospital-wide mobilization, stronger specialty surge planning, resilient communication and identification systems, and greater attention to long-term recovery in addition to acute survival.

Data availability statement. All data generated or analyzed during this study are included in this published article.

Author contribution. C.G.S. conceived the study design. C.G.S. and N.S. conducted the literature search and data extraction. C.G.S. performed the statistical analysis. C.G.S. and G.C. drafted the manuscript. All authors reviewed and approved the final version of the manuscript.

Financial support. The authors received no financial support for the research, authorship, and/or publication of this article.

Competing interests. The authors have no conflicts of interest to declare.

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