Review Article

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The Pivotal Role of Forensic Medicine in Disaster Management and Mass Casualty Incidents: Lessons Learned from the Hat Yai Flood Disaster

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Abstract:

Disaster management is an intricate, multi-layered public health and security challenge that scales exponentially during mass casualty incidents (MCIs). While emergency medical services and clinical teams prioritize the immediate triage, stabilization, and treatment of survivors, forensic medicine is tasked with the systematic management, examination, documentation, and identification of the deceased. This article comprehensively examines the critical, multidisciplinary responsibilities of forensic practitioners in the wake of natural catastrophes and anthropogenic crises. It details the operational execution of Disaster Victim Identification (DVI) protocols, evaluates the role of forensic pathology in determining the cause and mechanism of death, and discusses the evolving paradigm of Humanitarian Forensic Action (HFA). Using the Hat Yai flood disaster in Southern Thailand as a primary case study, this paper critically analyzes the unique logistical adaptations, multidisciplinary coordination, and operational challenges encountered during real-world flooding responses. Furthermore, this paper addresses how contemporary scientific technologies intersect with international human rights law and legal frameworks to restore dignity to victims and provide closure to grieving communities.

Keywords: disaster victim identification (DVI), forensic medicine, Hat Yai Flood, humanitarian forensic action (HFA), mass casualty incidents (MCIs), post-mortem examination

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Introduction

Mass casualty incidents (MCIs) spontaneously overwhelm local administrative, medical, and logistical infrastructures[1,2].

In the immediate golden hours of a disaster response, global consensus mandates that active rescue operations and the preservation of living patients receive absolute priority. However, as the rescue phase inevitably transitions into a recovery operation, a secondary institutional crisis frequently emerges: the management and identification of human remains[3,4]. Historically treated as a secondary administrative burden, the handling of the deceased is now recognized as a vital component of disaster response[2]. Forensic medicine functions as the definitive nexus connecting medical science, humanitarian ethics, and the international judicial system[5]. The prompt deployment of specialized forensic teams is essential not only to preserve physical evidence for legal or criminal proceedings but also to fulfill a fundamental humanitarian obligation: upholding the absolute right of families to know the fate of their missing relatives[4,5]. To understand the practical integration of these principles, it is necessary to examine how standard international protocols withstand environmental and infrastructural limitations during localized emergencies. While theoretical frameworks offer rigid guidelines, sudden-onset natural disasters often disrupt the baseline utilities required to execute standard operations, forcing forensic teams to innovate on-site.

DVI framework and Hat Yai case study

Disaster victim identification (DVI) protocols and operational frameworks

The operational cornerstone of forensic medicine during a disaster is DVI. Modern forensic deployments strictly adhere to standard international guidelines, primarily established by the INTERPOL DVI Guidelines, which mandate a rigorous, four-phase workflow to prevent erroneous identification[6].

Phase 1: Scene recovery

Forensic personnel work methodically within designated geographic sectors to locate, document, and recover human remains and associated personal effects[4,6]. Every body, body part, and item of evidence is assigned a unique, sequential tracking number. High-resolution photography, 3D laser scanning, and Geographic Information System (GIS) mapping are deployed to log the exact coordinates of each find. Maintaining a meticulous chain of custody at this stage prevents the accidental mixing of personal belongings, which could compromise subsequent identification efforts[1].

Phase 2: Post-Mortem (PM) data collection

Recovered remains are transported to temporary or permanent field mortuaries equipped with adequate refrigeration infrastructure[3]. Forensic pathologists, odontologists, anthropologists, and fingerprint technicians perform highly detailed examinations[3,7,8]. PM data collection focuses on documenting three primary, globally accepted identifiers: Deoxyribonucleic acid (DNA) Profiling, Forensic Dental Charting, and Fingerprint Analysis[1,6].

Applying international protocol to Hat Yai flood disaster management

The severe flood disaster in Hat Yai, Songkhla Province, Southern Thailand, presents a critical operational model for executing the INTERPOL DVI Phase 2 framework under extreme environmental constraints. The disaster was characterized by a sudden, catastrophic deluge that completely inundated the urban infrastructure, rendering permanent municipal power grids and standard medical centers temporarily inoperable. This sudden-onset natural disaster resulted in multiple casualties, creating acute logistical challenges that required immediate, field-accessible solutions.

To manage the deceased under strict infection control and public health protocols, the forensic command structure established a closed-system field mortuary situated at a secure distance from the affected community[4]. Body receipt and registration were centralized under a single designated officer responsible for issuing sequential unique identification codes prefixed with "Hy", eliminating the risk of duplicate numbering or administrative confusion.

To optimize field mortuary logistics, a digitized spatial mapping system was implemented to log and track the exact shelf assignment of each body within the mobile refrigerated containers. Any refrigeration unit experiencing mechanical failure or temperature fluctuations outside the protocols was immediately flagged in the system as "out of service" to prevent the placement of remains in compromised storage zones. To uphold human dignity, comply with humanitarian principles, and prevent post-mortem structural deformation, remains were never stacked directly on top of one another[4,5]. Instead, adaptive multi-tiered rack systems, utilizing custom-fabricated bamboo and steel frame components, were engineered directly on-site. This structural modification successfully optimized the vertical volume inside standard shipping containers, creating individual separated tiers for each victim while safeguarding the physical integrity of the remains.

This unique identification number remained affixed to the body throughout the entire process, from initial registration until final release (Figure 1). The post-mortem storage units were used to preserve remains under specific, controlled temperature conditions[3,4]. Remains awaiting examination were strictly maintained at 2–6 °C; this targeted refrigeration range slows down putrefaction and prevents DNA degradation while crucially avoiding the tissue crystallization caused by freezing, which can generate artifacts and distort soft-tissue trauma markers during autopsy[3] (Figure 2). Conversely, bodies that had already undergone comprehensive post-mortem examinations were transferred to a long-term storage environment maintained at −20 °C. This deep-freezing approach was operationally imperative to halt further advanced decomposition during the extended timeline required for DNA reference matching, ante-mortem data reconciliation, and final legal release by authorities.

Workstations and reconciliation

PM data collection was organized as a sequential four-station workflow, reflecting a comprehensive multidisciplinary approach to forensic medicine.

Station 1 focused on external examination and property documentation[1]. Clothing characteristics, anthropometric measurements, and secondary identifiers, including tattoos and surgical scars, were meticulously recorded. All personal property was secured in individual labeled bags that remained physically attached to the corresponding remains throughout the entire examination process to preserve the chain of custody[4].

Station 2 was dedicated to friction ridge (fingerprint) recovery, performed by a specialist forensic team with a quality control review before progression[6]. For flood victims exhibiting skin maceration or epidermal slippage (a common complication in prolonged water submersion), specialized techniques were employed: controlled warm-water immersion was used to re-expand desiccated tissue, while detached epidermal gloves were mounted onto a technician's finger or a prosthetic digit to restore skin tension prior to impression capture. Carbon powder brushing was selected over conventional ink to allow correction without permanently staining the ridge detail of decomposed tissue. Completed impressions were transmitted to the Regional Fingerprint Bureau (Division 9, Thung Tamsao) for AFIS database comparison.

Station 3 comprised forensic autopsy, biological sampling for DNA analysis, and forensic anthropological assessment[3,8]. The integration of forensic anthropology was

vital; these specialists analyzed skeletal traits to estimate the biological profile—including age, biological sex, stature, and ancestry—which significantly narrowed down the missing persons database, particularly for fragmented or severely decomposed remains where soft tissues were lost[8]. Tissue selection for DNA followed a prioritized hierarchy based on specimen preservation: costal cartilage was collected first for ease of access, followed by femoral bone cortex for its higher cellular density, and finally dental specimens in cases of advanced decomposition, given the superior protection conferred by enamel on intrapulpal DNA[1]. Autopsy findings also aimed to distinguish true drowning (evidenced by airway mud and pulmonary hyperinflation) from death attributable to pre-existing cardiac pathology or pulmonary thromboembolism[3]. DNA reference samples from biological relatives were transported each evening to the Institute of Science Equipment, Prince of Songkla University, and to the Regional Forensic Science Laboratory (Division 10, Yala) for parallel processing.

Station 4 comprised forensic odontological examination, with the forensic pathology team pre-opening facial soft tissues to minimize time requirements for the dental team[7]. Portable digital dental radiographic units were used to obtain full post-mortem dental charts, which were recorded under the corresponding body identification code[7].

The final identification decision was vested in a formal Identification Board comprising senior forensic scientists, legal officers, and administrative directors[1,6]. A positive identity was confirmed only when a minimum of 13 concordant STR loci were established by DNA comparison, or when two or more independent primary identifiers—such as concordant fingerprint ridge detail combined with matching dental charting—were simultaneously confirmed[6]. This multi-modal threshold approach ensured that each release was scientifically robust and legally defensible, reflecting the core principles of the INTERPOL DVI reconciliation standard[6]. Prior to confirming release, the multidisciplinary expert team convened a formal matching meeting to review and verify all identification findings (Figure 3).

Phase 3: Ante-mortem (AM) data collection

Concurrently, dedicated missing persons units and interview teams engage with the relatives of missing individuals to gather historical records[4,6]. This process requires immense psychological sensitivity and cultural awareness[5]. Forensic teams collect comprehensive dental records, medical histories documenting prior fractures or orthopedic hardware, and direct or familial reference DNA samples[1,7].

Phase 4: Reconciliation

The final phase takes place within a formal Identification Board, chaired by senior forensic specialists and legal authorities[1,6]. Analysts systematically compare the post-mortem data against the accumulated ante-mortem datasets[6]. A positive, legally binding identity is only confirmed when an absolute, scientifically undeniable match is established between the primary identifiers[1]. If anomalies exist, the case is returned for further forensic investigation[6].

Technology critical appraisal and conclusion

Technological innovations overcoming modern operational challenges

As mass disasters grow increasingly complex due to high-impact travel mechanics, rapid urbanization, and shifting global climate hazards, traditional forensic methods face substantial hurdles. Severe body fragmentation, rapid advanced decomposition, and thermal destruction frequently render visual identification completely impossible. Furthermore, disasters involving displaced populations, undocumented migrants, or refugees present situations where baseline medical and dental records are entirely non-existent[5]. To combat these limitations, contemporary forensic science utilizes cutting-edge technologies; however, their deployment must be critically evaluated against real-world limitations[2].



Figure 1 Body identification labeling. A designated officer assigns each body a unique serial identification code at the time of registration; this code remains linked to the body until its final release.

Virtopsy (virtual autopsy), utilizing Post-Mortem Computed Tomography (PMCT), offers a non-invasive methodology to scan remains, allowing practitioners to document internal trauma patterns, gas embolisms, and hidden ballistic fragments without disrupting fragile anatomical structures[3]. Despite these advantages, its field implementation is severely restricted by high capital costs, the necessity for specialized radiation-shielded environments, and the lack of trained forensic radiologists in low-resource or disaster-struck areas.

Rapid DNA Sequencing via portable Next-Generation Sequencing (NGS) platforms enables real-time genetic profiling directly within temporary field mortuaries, significantly compressing the time required to cross-reference highly fragmented tissue samples[1]. Nevertheless, its operational feasibility is frequently compromised by environmental factors; field mortuaries often lack the stable, dust-free environments and continuous power supplies required to prevent instrument failure. Additionally, the high cost per sample chip presents a significant budgetary barrier for developing national emergency response frameworks.

Forensic Anthropological Software utilizes automated algorithms to analyze 3D skeletal measurements obtained from computed tomography (CT) scans, calculating ancestry, sex, and age with higher statistical precision than traditional manual osteological methods[8]. While highly efficient, these digital tools possess inherent systemic limitations: their algorithmic models are fundamentally built on specific

regional reference populations[8]. Applying software optimized for Western or European skeletal configurations to Asian or indigenous populations can induce significant demographic errors, emphasizing that technology cannot fully replace the contextual expertise of a forensic professional.

Conclusion

Forensic medicine is an irreplaceable structural pillar within the global architecture of comprehensive disaster management[2]. It transforms the chaotic aftermath of a disaster site into an objective, scientific, and highly organized operation[3]. By integrating advanced technology with rigorous international protocols, forensic teams ensure that truth is uncovered, justice is served, and legal frameworks remain intact[1]. As global population densities rise and climate shifts increase vulnerability to mass casualty events, national emergency response frameworks must fully integrate and fund forensic medical planning. Doing so is not merely a technical requirement: it is a profound humanitarian duty to safeguard human dignity in life and in death[5,4].



Figure 2 Post-mortem storage units. Refrigerated units were used to preserve the deceased; unexamined bodies were stored at 2–6 °C, while examined bodies were stored at −20 °C.



Figure 3 Expert team matching meeting. The multidisciplinary identification team convenes to review and confirm matching results prior to authorizing the release of a body.

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