Forensic Frontiers: Navigating Complex Challenges of a Large-scale Invasion by Armed Hamas Terrorists in Southern Israel

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On 7 October 2023, a large-scale invasion by armed Hamas terrorists occurred in southern Israel. Approximately 1500 militants breached the Gaza security barrier using tractors, RPGs, and explosives. Concurrently, the terrorists utilized various means including armed vehicles, motorized paragliders, sea incursions, and a massive rocket attack launched toward Israel. On entering Israeli territory, the militants dispersed and targeted several towns, kibbutzim (collective communities), and Israel Defense Forces (IDF) military bases near Gaza. This strategy resulted in a death toll exceeded 1300 civilians and soldiers. In addition, more than 240 individuals were abducted. This attack occurred in one day. In this article, we introduce the Israeli National Institute of Forensic Medicine, which specialized in forensic analysis during mass casualty incidents, and pivotal role it played on 7 October. We present a detailed discussion on methods, challenges, and adaptations the institute took in response to the event of 7 October.

THE NATIONAL INSTITUTE OF FORENSIC MEDICINE, ISRAEL

The National Institute of Forensic Medicine is the only official institution in Israel that provides medico-legal services. It provides services to government agencies including the Ministry of Justice, the Israeli police forces, the Ministry of Defense, and the IDF. The National Institute of Forensic Medicine, in terms of its status and position, is a professional governmental agency that provides service to determine suspicious and non-natural causes of death. In addition, the institute also assists in the identification of human remains.

EARLY RESPONSE TO A MASS CASUALTY INCIDENT AND THE USE OF ADDITIONAL FACILITIES

The Israeli Institute of Forensic Medicine faced a significant challenge on 7 October when an unforeseen mass casualty incident occurred. Initially, we estimated that there would be approximately 200 cases, a number deemed manageable within the institute's capacity. This early estimation set the stage for the institute's initial response and resource allocation. However, as the situation unfolded, it became clear that the scale of the event far exceeded these initial estimates. The institute, primarily perceived as a forensic medicine facility, found itself at the forefront of a national emergency, dealing with a scenario much larger than any previous situations it had managed.

After the realization that the number of bodies would be more than initially predicted, and would probably reach more than a thousand, decisions were made regarding how to manage the overwhelming body count. Due to the limited ability of the Institute of Forensic Medicine to accommodate this number of bodies, the institute made a strategic decision to operate the Shura camp. Originally a military camp, the camp was not intended for forensic treatment of mass fatalities. However, given the immediate demands of the situation, it was rapidly adapted for this purpose. The Shura camp, despite its primary military function, possessed certain infrastructural advantages that were instrumental in this context. It housed facilities that, while not designed for forensic examination, were adaptable for such use. Importantly, the camp included ample space, which was critical giv-

en the number of bodies to be processed. For this large-scale scenario, one of the most significant and essential logistical facilities this camp has was the refrigerated containers. The sheer number of casualties far exceeded the capacity of the existing refrigeration facilities at the Israeli Institute of Forensic Medicine. The containers at the Shura camp were crucial for the preservation of the remains and to ensure that the forensic process was not compromised by the rapid deterioration of the bodies.

PRIMARY IDENTIFICATION METHODS

All primary identification methodologies fundamentally rely on the juxtaposition of antemortem and postmortem data. These primary methods encompass DNA profile comparisons, fingerprint analysis, radiographic imaging, and dental record examination. In addition, identification can be supplemented through medical morphologic observations such as tattoos, scars, and dental implants.

For individuals who served in the IDF, their DNA is typically available in military databases. However, for those without military service, alternative sources were needed. In those cases, we requested personal items such as toothbrushes, which may contain DNA, or asked family members to provide DNA samples for comparison. In cases where an individual had undergone a medical procedure like a biopsy, hospitals were contacted to retrieve relevant information.

Antemortem imaging data is typically sourced from the healthcare records of hospitals, health maintenance organizations (HMOs), and dental clinics. Postmortem examinations employ radiographic techniques like X-ray imaging and computed tomography (CT) scans. For example, X-ray images or CT scans obtained postmortem can be directly compared to similar imaging studies conducted during the person's lifetime, thus facilitating accurate identification.

In the Shura camp, a systematic approach was adopted for the identification of human remains, where DNA samples and fingerprints were collected from each body in a concentrated manner, even prior to a detailed examination. This proactive strategy enabled the institute's laboratory to develop DNA profiles swiftly, thereby accelerating the identification process without awaiting the completion of the postmortem examination. However, despite these efforts, identification was not always successful. In cases in which these standard methods proved inconclusive, the corpses were transferred to the institute for further examination. At the institute additional identification techniques were employed, including the comparison of medical signs and antemortem imaging data.

NAVIGATING THE COMPLEXITIES OF IDENTIFICATION

Identification of bodies is the most daunting task at the Israeli Institute of Forensic Medicine. The success of the identification and the accuracy are particularly challenging during mass casualty incidents. This challenge is compounded in situations where bodies are severely damaged, making conventional identification methods less effective or even unfeasible.

A significant obstacle arises when dealing with bodies that have been burned at very high temperatures, often due to the addition of combustible materials, such as those used by Hamas. Extreme conditions can degrade DNA to the point where it is no longer viable for analysis. The degradation of DNA not only hampers the identification process but also complicates the determination of whether the DNA belongs to one individual or multiple individuals.

Recognizing that larger bone fragments are less likely to be severely affected by high temperatures, these fragments were prioritized for repeated DNA extraction attempts. This strategy enhanced the likelihood of retrieving viable DNA, thereby increasing the chances of successful identification in cases where initial extraction attempts were unsuccessful.

Our protocol is to allocate each body or body part to its own bag. However, in certain circumstances, the remains of individuals are scattered across multiple body bags. This situation occurred due to the inability to discriminate among the body parts in the field. This fragmentation presented a complex puzzle, requiring meticulous examination and pairing of body parts. The institute had to manage cases where parts of a single individual were distributed in different bags, necessitating a careful and systematic approach to reassociate these parts.

To circumvent these challenges, the institute employed alternative methods. In cases where DNA analysis proved inconclusive, larger bone fragments, which might be less affected by high temperatures, were examined.

Another layer of complexity included acquiring relevant antemortem data for comparison. Not all individuals have comprehensive medical or dental records readily available. In cases where an individual had served in the military, their DNA might be obtainable from military databases. However, for those who did not serve, the institute had to rely on examining personal belongings like toothbrushes for DNA extraction or contacting family members for genetic comparison.

An example of a specific case of failure of identification by the primary methods was an incident involving multiple casualties. All the remains were totally burnt and DNA from many could not be extracted. The institute managed to identify all but one individual. After the investigation of the case, the identification was possible due to knowledge of who was present at the crime scene. Among the number of adults in the same area, there were two children of whom one was missing and unidentified. That knowledge aided in identifying the missing child. We were able to use the age of the femur bone and its epiphysis. Although a full DNA profile could not be produced, the detection of the X and Y chromosomes gave a final determination because the two children were of different sexes. This case underscores the intricate nature of the identification process and the necessity for employing a range of forensic techniques.

X-ray imaging and CT scans offer a crucial tool in the forensic identification process. For example, if an individual had undergone X-ray imaging during their lifetime, these images could be compared to postmortem X-rays taken of the body. This comparative analysis is similarly applied in dental forensics. A dental X-ray from the individual's dental records can be compared with the X-ray taken postmortem at the forensic clinic. However, not all bodies come with such pre-existing medical information.

The EITAN system, an advanced health information exchange (HIE) platform developed by the Ministry of Health, played a pivotal role in facilitating access to electronic patient data. It operates in conjunction with OFEK, originally a Clalit Health Services initiative, to ensure interoperability across various medical institutions and service providers. These systems are instrumental in consolidating and securely sharing medical records, including X-ray images, across hospitals and HMOs. This networked approach, supported by the Association of Radiologists, significantly enhances the efficiency and accuracy of X-ray comparisons. Furthermore, dentists are integrated into this network, enabling streamlined access to crucial dental records, or antemortem data, which are essential for identification processes and various medical assessments.

PUBLIC EXPECTATIONS AT THE ISRAELI INSTITUTE OF FORENSIC MEDICINE

The Israeli Institute of Forensic Medicine adheres to a set of detailed and structured identification protocols, which are crucial in managing mass casualty incidents. These protocols, guided by international standards from organizations such as the Red Cross and Interpol, aim to ensure the accurate and dignified identification of the deceased. On body arrival, a swift documentation of personal effects, photographs, and fingerprints is performed for identification. Items are cataloged, and fingerprints are matched with databases. When needed, dental exams, a full medical exam noting unique physical markers, and DNA testing with antemortem or relative comparisons are used to confirm identities.

A critical aspect of the Israeli Institute of Forensic Medicine's response to mass casualty incidents is the inherently time-consuming nature of forensic examinations. On average, this meticulous procedure takes about an hour per body by experienced forensic pathologists, a duration that becomes exponentially significant with the increase in the number of casualties. This extensive time requirement for each examination, although necessary for accurate identification and investigation, often conflicts with the public's expectation for swift identification. In the aftermath of the 7 October terror attacks, as the number of cases escalated, there was mounting pressure from the public and from governmental bodies to complete the identification process. The public's impatience and distress were fueled by a lack of understanding of the complexities and requirements of forensic work, especially due to the large number of casualties. This urgency was further compounded by the emotional and psychological need for closure for the families of victims and the community at large.

The tension between the time-intensive nature of forensic processes and public pressure highlights a significant challenge in mass casualty management. It underscores the need for public education regarding forensic procedures and the development of more efficient methods that can handle large-scale incidents without sacrificing the thoroughness required for forensic investigations.

When the forensic pathologists could not cope with the overwhelming number of bodies, law enforcement agencies were enlisted to significantly contribute to the development of these protocols, mainly at the Shura camp. However, due to their lack of expertise and experience, numerus errors were made. For bodies that were burned, decomposed, or dismembered, the institute employed specialized methods. These procedures included reconstructive techniques and advanced DNA testing methods to handle the increased complexity. Each identification process, on average, took about an hour per body, underlining the meticulous and

sensitive nature of the work. The institute was acutely aware of the time-sensitive nature of their work, particularly considering public sentiment and the need for families to receive timely information.

In scenarios where multiple individuals have perished in the same incident, there are instances where all but one is identified, primarily due to severe disfigurement of the bodies. This extensive damage often results from high-temperature exposure, leading to challenges in determining the exact number of individuals involved and accurately categorizing the fragmented body parts, which are frequently severely burned. Such circumstances have even led to the burial of remains composed of body parts from more than one individual. In some of these cases, the truth about the identities of the individuals involved remained unknown, with some individuals documented as missing. It was only after exhumation and reanalysis of the buried remains that these errors came to light.

CONCLUSIONS

The situations we encountered highlight the complexities and limitations inherent in forensic science and emphasize the continuous need to advance identification techniques. They also reflect the critical impact of a shortage of forensic pathologists, underlining the importance of having sufficient expert personnel to handle such challenging forensic tasks effectively.

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Capsule

Clostridioides difficile ferrosome organelles combat nutritional immunity

Pi et al. reported that *C. difficile* undergoes an intracellular iron biomineralization process and stores iron in membrane-bound ferrosome organelles containing non-crystalline iron phosphate biominerals. The authors found that a membrane protein (FezA) and a P1B6-ATPase transporter (FezB), repressed by both iron and the ferric uptake regulator Fur, are required for ferrosome formation and play an important role in iron homeostasis during transition from iron deficiency to excess. In addition, ferrosomes are often localized adjacent to cellular membranes as shown by cryo-electron tomography. Furthermore, using two mouse models of *C. difficile* infection, the authors demonstrated that the ferrosome system is activated in the inflamed gut to combat calprotectin-mediated iron sequestration and is important for bacterial colonization and survival during *C. difficile* infection.

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Capsule

A spinal cord neuroprosthesis for locomotor deficits due to Parkinson's disease

People with late-stage Parkinson's disease (PD) often present with debilitating locomotor deficits that are resistant to currently available therapies. To alleviate these deficits, **Milekovic** and colleagues developed a neuroprosthesis operating in a closed loop that targets the dorsal root entry zones innervating lumbosacral segments to reproduce the natural spatiotemporal activation of the lumbosacral spinal cord during walking. The authors first developed this neuroprosthesis in a non-human primate model that replicated locomotor deficits due to PD. This neuroprosthesis not only alleviated locomotor deficits but also restored skilled walking in this model. The authors then implanted the neuroprosthesis in a 62-year-old male with a 30-year history of PD who presented with severe gait impairments and frequent falls that were medically refractory to currently available therapies. The authors found that the neuroprosthesis interacted synergistically with deep brain stimulation of the subthalamic nucleus and dopaminergic replacement therapies to alleviate asymmetry and promote longer steps, improved balance, and reduced freezing of gait. This neuroprosthesis opens new perspectives to reduce the severity of locomotor deficits in people with PD.

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