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Review Article

Forensic aspects of mass disasters: Strategic considerations for DNA-based human identification

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Abstract

Many mass disasters result in loss of lives. Law enforcement and/or public safety and health officials often have the responsibility for identifying the human remains found at the scene, so they can be returned to their families. The recovered human remains range from being relatively intact to highly degraded. DNA-based identity testing is a powerful tool for victim identification in that the data are not restricted to any particular one to one body landmark comparison and DNA profile comparisons can be used to associate separated remains or body parts. Even though DNA typing is straightforward, a disaster is a chaotic environment that can complicate effective identification of the remains. With some planning, or at least identification of the salient features to consider, stress can be reduced for those involved in the identification process. General guidelines are provided for developing an action plan for identification of human remains from a mass disaster by DNA analysis. These include: (1) sample collection, preservation, shipping and storage; (2) tracking and chain of custody issues; (3) laboratory facilities; (4) quality assurance and quality control practices; (5) parsing out work; (6) extraction and typing; (7) interpretation of results; (8) automation; (9) software for tracking and managing data; (10) the use of an advisory panel; (11) education and communication; and (12) privacy issues. In addition, key technologies that may facilitate the identification process are discussed, such as resin based DNA extraction, real-time PCR for quantitation of DNA, use of mini-STRs, SNP detection procedures, and software. Many of the features necessary for DNA typing of human remains from a mass disaster are the same as those for missing persons' cases. Therefore, developing a missing persons DNA identification program would also provide the basis for a mass disaster human remains DNA identification program.

Keywords: DNA; Mass disaster; Missing person; Human remains; Identification; Forensics

1. Introduction

On September 11, 2001, the USA experienced its worst intentional mass disaster in history. Two commercial passenger airplanes were hijacked and deliberately crashed into the twin towers of the NYC World Trade Center (WTC) [1,2]. A third such airplane was deliberately crashed into the Pentagon, and a fourth airplane was forced to crash in a field near Shanksville, PA. These terrorist attacks on the USA resulted in more than 3000 deaths. Mass disasters also can result from other intentional events, e.g. poisonous gas attacks such as that perpetrated in 1995 by the Aum Shinrikyo in a Tokyo subway [3], car bombs, or wars [4–7]; from natural events, such as the devastating tsunamis on December 26, 2004 that resulted from a 9.0 earthquake near Sumatra; and from accidents, such as fires [8–10] and airplane crashes, e.g. Swissair Flight 111 [11]. Many of these types of mass disasters result in loss of lives, and the recovered human remains range from being relatively intact to highly degraded. High impact disasters, such as airplane crashes, typically result in severe fragmentation and degradation of human remains [1,2,11–14].

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Situations involving individual missing persons also can be thought of as mass disasters that occur over a longer time period. Each year thousands of children and adults vanish without a trace or under suspicious circumstances. Spain was one of the first countries to initiate a national program to identify human remains of which there are at least 1000 unidentified remains [15]. In the USA alone there are 5000 unidentified recovered skeletonized remains registered on the National Crime Information Center (NCIC) [16]. Since only a small portion of unidentified remains currently are registered on the NCIC, the actual number may be five to ten times higher.

One aspect that falls under the responsibility of law enforcement and/or public safety and health officials after a mass disaster or a missing person investigation is the individualized identification of human remains found at the scene, so they can be returned to their families. Characteristics or traits used to assist in the identification of the human remains include, but are not limited to: skeletal features, dental comparisons, fingerprints, distinguishing marks (tattoos and scars), medical devices and implants, personal effects, and DNA profiles.

Not all human remains will be suitable for the more traditional identification approaches, especially if there is substantial fragmentation of the remains. Large numbers of mass casualties (such as occurred with the WTC) present a daunting task to rescue workers and government agencies in recovering and identifying the literally thousands of compromised human remains. Fingerprints or dentals record are often not useful in identification of such remains. In contrast to traditional comparisons, DNA-based identity testing is not restricted to any particular one to one body landmark comparison (e.g. friction ridge details in fingerprints). Furthermore, DNA profile comparisons can be used to associate separated remains or body parts. As long as the recovered human tissue contains a sufficient quantity of typeable DNA, important data can be obtained to assist in victim identification.

The DNA profiles from recovered mass disaster remains are compared with the DNA profiles from reference samples such as known personal effects of the victims or family member reference samples. Personal items (such as unlaundered clothing, a toothbrush, PKU cards from State mandated newborn genetic screening programs, or even archival pathology tissue) can serve as direct reference samples and may be available from which DNA can be extracted to attempt to identify the victims. In some situations, such direct DNA comparisons are not possible, and therefore family members must provide reference samples for indirect identification using kinship analysis [17].

While DNA-based human identity testing can sometimes be an uncomplicated process, mass disasters are almost always unexpected and therefore unpredictable. They place tremendous stress on the families of the victims, health care workers, government agencies and the community. In the immediate aftermath of a mass disaster, the chaotic environment can complicate effective identification of the remains. However, with some planning, such as in organization and surge capacity, a priori, instead of after the event, stress by those affected by the mass disaster can be reduced. Experiences from previous mass disasters, primarily from September 11, 2001, handling of missing persons cases, and identification of soldiers or military personnel from past wars can help better prepare the laboratory personnel responsible for the task of identification using DNA analysis, when the next mass disaster occurs [1–14, 18–22]. Herein we provide general guidelines to consider in developing an action plan for identification of human remains from a mass disaster by DNA analysis. We also discuss some of the key technologies that may facilitate the identification process.

2. External oversight committee/advisory board

When a mass disaster occurs, a number of agencies, institutions, and individuals, both public and private, readily offer humanitarian assistance to the laboratory tasked with the identification of the victims. The support and assistance offered covers every aspect of the operation from providing advice to services to offering new technologies for analysis. Any laboratory faced with the daunting task of mass disaster response can become overwhelmed with proposals and quick fix solutions. First and foremost, the laboratory director should consider assembling an appropriate external oversight committee (or advisory board) composed of recognized experts (both forensic and others). The board can meet regularly to help evaluate meaningful ideas, proposed processes, address specific scientific challenges and questions that will arise, and review and advise on the validity of novel technologies. Members of such an advisory board provide the laboratory with: a focused reality check on possible decisions; additional views; assistance in screening the approaches by those who offer assistance; ready access to recognized expertise; and greater confidence in the direction(s) taken by the laboratory. Typically, such advisory board members will agree to serve pro bono, but travel and accommodation costs need to be considered.

3. Value of non-DNA methods

Any information that supports a correct identification is invaluable and should be considered. Forensic scientists who are primarily trained in the field of DNA analysis often believe that DNA typing is the one and only reliable method for identification. DNA analysis