- Archaeological methods bring control, order, and systematic search to scenes.
- Combined archaeological and anthropological search methods recover and account for the missing.
- Anthropological examinations are useful for resolving commingling and can help refine sample selection for DNA testing.
- Archaeology and anthropology combine successfully within multidisciplinary response processes.

1 | INTRODUCTION

1.1 | Discipline support

Archaeology and anthropology have, in their forensic applications, and by necessity and design, contributed greatly in recent decades to responses to disasters, where a disaster is primarily defined by the nature, scale, intensity, or time scale of an event that overwhelms the usual dedicated and available response resources.

These disciplines have often provided expertise outside the normal range of skills within processes of emergency response and medicolegal examination. Forensic archaeology, as a discipline that focuses on defining evidence and recovering within spatial distributions, often in buried contexts. Forensic anthropology as a discipline that focuses on defining and recovering human remains, often after taphonomic change, and involving fragmentary, partial, and commingled anatomical cases. How these disciplines are organized varies nationally. In North America, archaeology sits as a subdiscipline of anthropology. Elsewhere they sit as separate disciplines. Mass fatality incidents frequently involve dispersal of remains into the landscape making it appropriate to utilize both disciplines to assist in recovery and examination. They have evolved as mutually supportive technical applications in multidisciplinary investigation, coordinating closely with, and contributing to, crime scene examination, criminal evidence recognition, pathology and autopsy processes, DNA matching, and victim identification.

1.2 | Developing precedent

Broad examples of the development of these applications over the last decades have been summarized [1] and include the publication of disaster victim identification (DVI) guidance in the 1970s [2]. The dedication of physical anthropologists to recovering the missing from conflict in Latin America in the 1980s [3]. The recovery and analysis of cremated and commingled remains at the Branch Davidian compound, Waco, Texas [4]. The development of temporary mortuaries in Bosnia and Herzegovina by The International Tribunal for the Former Yugoslavia (ICTY) and International Commission on Missing Persons (ICMP), to rapidly process and sample thousands of cases from mass graves from the 1990s [5]. Utilizing osteological assessment and DNA matching of commingled and fragmentary remains within a triage system developed through the 2000s, most notably demonstrated in the response to 9/11 [6]. Refining the process of skeletal assessment and DNA sampling continued in the 2010s [7], seen in the consistent work applied in the laboratories of the ICMP to identifying victims from around the globe [8]. The increasing efficiency of response and international cooperation in the Malaysia Airlines Flight 17 disaster investigation saw the combining forensic and DVI processes to identify nearly all victims as well as gather evidence for criminal trials [9]. The collating of spatial data from the World Trade Center (WTC) scenes with anthropological and DNA matching data demonstrated the need to reevaluate death scenes where necessary, to maximize recovery through assessment of both intrasite and intersite spatial relationships of remains [10]. The organization of workflow and disciplinary interactions to accommodate the review of cases and process have developed consistently in recent years [11, 12].

In some jurisdictions, these discipline applications have become mainstream elements in DVI, especially when retrieving and documenting all human remains is a formal or legal necessity. Sharing of resources and knowledge has also increased through recent endeavors such as the American Academy of Forensic Science's Humanitarian and Human Rights Resource Center (HHRRC) [13]. However, in global terms, it can be argued that applications remain limited in use in some regions, partly due to a lack of formal discipline resource availability and allocation, but also because the potential benefits of implementing archaeology and anthropology processes to augment investigation may not be appreciated. The expanding scope of forensic anthropology and archaeology applications to DVI continues to be demonstrated and highlighted [14, 15].

2 | DEFINITIONS AND CONSIDERATIONS

2.1 | Disasters fast and slow

Many disasters are high-kinetic energy events, meaning the momentum of moving objects impacting bodies causes severe injury. Whether by natural causes such as earthquakes collapsing buildings or Tsunami waves, or by accidents such as airplane or train crashes, or by the deliberate violence of bombings or arson. But there is also longer term "slow disasters": the overwhelming of national or available response by increments over time, often as a result of conflict and violence, disease, or environmental extremes.

Fatalities in slow disasters are often left in the environment or hastily buried in mass graves. Human rights violations and war crimes can fall into this category and frequently lead to the dispersal of victims as a result of ethnic cleaning and mass murder across a forensic landscape: defined as the surviving topography, alterations, deposits, artifacts, and materials left in the natural and/or cultural landscape within a given time frame, concerned with and related to a specific sequence of events of legal interest [16, 17].

An example is the accumulated disappearance of victims into mass graves, for example, the Srebrenica massacre events of July to October 1995. Investigations over 28 years have identified over 7000 individuals (as 17,000 sets of human remains) from over 95 dispersed graves, more than 349 surface sites, as well as associated execution and holding areas [18]. These represent related atrocity crime scenes defined as "one or more locations that are relevant to the investigation of an atrocity, including buildings or locations (including bodies of water) where physical evidence may be collected relating to the perpetrators, victims, and events of the atrocity, such as mass graves and other sites containing deceased individuals" [19], this includes mass murder terrorist scenes. Recent legislation has developed capacity to support recognition and identification of such atrocities [20].

Whatever the cause, the end result – that of mass fatalities that require finding, identifying, and repatriating – is aided by the same processes, utilizing archaeological and anthropological methods: those that assist in locating, recovering, examining, sampling, reporting upon, and identifying victims.

2.2 | Organizing chaos

A defining feature of mass fatality incidents is the initial chaos at the scene or scenes. Understanding the extent of a scene and the postevent changes to the landscape are essential to be able to design, plan, and implement forensic and DVI responses after first response is completed. After the work of saving life at a scene ends, forensic work should take on a less frenetic pace. Liaising with first responders to understand how they have impacted a scene and what they have recorded is an important step.

There are some assumptions to be made concerning mass fatality scenes. There may be a dispersal and complexity of scenes as perimeters expand, or additional related crime scenes are defined. The multifaceted nature of a scene is exposed after response is initiated. It should be presumed there will be the potential for a great volume and variation of evidence as well as multiple cases of remains, often fragmented and commingled. Planning for scale at scenes ensures that resource needs and requirements are considered.

Mass fatality scenes can seem overwhelming. Bringing practical control to a scene and during examination phases is aided by breaking down the response in defined processes that are divided into manageable steps, formerly organized, and described. Whether this is undertaking steps in setting scene cordons or organizing examination workflow, it provides teams with clear work aims and intent, allows management coordination and control, provides a basis for systematic location and recovery, and demonstrates legal, evidential, and safety requirements are being addressed.

2.3 | The habitual nature of response

While the initial energy, location, and properties of a mass fatality scene means every disaster is different (though not unprecedented), responses can often be framed within standard procedures for responders. These are based on available experience and what is "normal," providing a semblance of control when faced with overwhelming and unprecedented scenes. Rather than impose normality to control chaos and deal with uncertainty, each scene should be assessed to determine how search and recovery processes can be deployed that successfully convert a contingency plan to a practical reality. This will control and maximize efficiency and certainty of evidence and victim recovery.

Specialist methods utilises by Archaeologists and anthropologists may not be part of normal response procedures in some jurisdictions, with their potential unappreciated. This places a responsibility for archaeologists and anthropologists – especially those in management and directing roles – to promote the appropriate discipline processes during planning. This includes guidance on the impacts of implementation on resources, time, and contributions to evidence recovery and analysis [21]. It is not necessarily easy to demonstrate how specialist processes can complement existing protocols when working in formalized management and control structures, especially under the pressure of response. There are however increasing number of case studies and publications on the potential and scope for coordinating archaeology and anthropology methods within multidisciplinary responses [17, 22].

2.4 | More haste, less speed

There are numerous pressure upon an investigation to provide rapid accounting for the causes of disasters, determine culpability, and accounting for the missing. This can result in the undertaking of recovery and examination at pace to provide rapid, reportable results that relieve pressure from managers, politicians, the media, as well as communities and families.

Haste can lead to variable results, and a lack of control. Procedures need to be appropriate and repeatable, providing demonstrably consistent results. Recording needs to be standardized and thorough, so that there is assurance of systematic search, examination, and analysis. Such deliberate work provides confidence that the processes implemented are accurate and effective.

It should also be noted that employing blanket procedures on search or excavation can in fact be more time-consuming and resource use intensive (due to arbitrary requirements to examine ground or remove material) than a more designed and nuanced approach that focuses on the specific landscape impacted by an event (see Excavation and sequences of stratigraphy next). Speed of excavation also impacts evidence recovery [23].

2.5 | One process, multiple outcomes

There are, in any DVI response, a number of desired outcomes including finding and identifying the dead, gathering evidence of the cause of events, gathering criminal evidence, gathering evidence for other legal matters (insurance, inheritance), gathering and processing personal effects, making scenes safe, demonstrating completion of search, undertaking scene closure, and restoration.

These questions are best answered if one planned process is designed that allows all evidence to be utilized for multiple purposes. This is logical, as there is no class of evidence that does not have multiple uses (see table 1 in [24]). For example, there may be limited potential for evidence to be used for criminal prosecutions, or support legal identification, if rapid body recovery does not provide the necessary breadth of detailed forensic recording. It should be presumed that all potential legal and investigative outcomes will utilize evidence. Indeed, it is impossible to know what legal purposes evidence may serve at the outset of a particular mass fatality recovery operation. This should lead to a more detailed and deliberate response design for the steps of search, recovery, and examination. A design that can only be completed when initial assessment of the fatality environment is made and should be able to successfully accommodate all potential requirements.

The rest of this article will provide examples and further discuss how archaeological and anthropological processes have been and can be considered for incorporation into DVI and mass fatality investigation. It is hoped this will assist in appropriate design, planning, and implementation of response.

3 | INVESTIGATIVE PROCESSES

3.1 | Innovations in search

The process of response is one of the continuous search, from macro to micro utilizing a battery of techniques to resolve investigative questions: How big is the scene? What is the potential evidence? Where is the evidence? Where are the victims? How have victims been impacted by events? To provide effective answers, there has been over time an expansion of techniques contributing to search.

3.1.1 | Aerial imagery

There has been an increased appreciation for the potential to use imagery in preparation and response to disasters, mass fatalities, and related landscape assessment. This has included research and evaluation of potential benefits, resource needs, and data processing capacities [25, 26]. Imagery and remote sensing have been successfully used to define the extent and nature of crime scenes and mass graves, as well as excluding areas from search [27, 28]. The availability of commercial high-resolution aerial imagery means that any landscape can now be rapidly visualized cost-effectively, and any changes before and after events noted. Dispersed and difficult-to-access sites across a landscape can be pinpointed. The rapid growth in access to drones means an aerial view of located sites can provide immediate intelligence to allow assessment of scene extent and properties, contributing to the design of search strategies [29]. Imagery can be rapidly printed or distributed and flagged to guide physical search on the ground.

3.1.2 | Thermal imaging

Aerial platforms providing multispectral analyses for archaeological assessment of landscape have developed in the last 20 years. Human remains and ground disturbance can be recognized due to specific taphonomic phenomena. Chemical variation due to decomposition and disturbance to soil can be detected hyperspectrally [30]. Thermal imaging cameras detect variation in heat signature. Disturbance caused by debris impact or burial aerates soil, which warms and cools at varying rates to surroundings. Heat is generated by decomposition in bodies and burials. While the potential to utilize thermal imaging to detect surface bodies is known, the useful time window is considered to be limited by rapid cooling of bodies to ambient temperatures (usually 24 h postmortem). However, they are further potential opportunities to detect heat signatures of remains, helping to locate cases that may be obscured, dispersed, difficult to locate, or moved. Dependent on season and environment, heat generated by thanatomicrobiome decomposition can be detected, mainly due to maggot activity. Controlled experiments have observed that maggot mass feeding entities within animal cadavers create internal temperatures of up to 20° above ambient temperatures, for up to 38 days postmortem, detectable using IR cameras [31, 32]. Detectable throughout the active decay period, there is potential for IR to locate bodies long past the time it might be presumed they would reach ambient temperatures.

Recent advances in drone and ground robot capabilities make repeated site overflights a cost-effective and practical method option for mass fatality landscape search. Platforms can carry IR cameras, GPRS, LiDAR, and multispectral cameras. Standard operating procedures (SOPs) for forensic use have been developed [33, 34].

The same decomposition processes assist in accounting for bodies that have been removed (e.g., by scavenging, concealment, or unauthorized collection). Evidence can be found at original deposition locations, even in the absence of a body. Fluids from decomposition can rapidly cause distinct dieback of vegetation. The action of maggot masses can cause movement of small objects, hair, and small bones into the humic soil zones in a matter of days in conducive environments [35]. Decomposition can cause chemical changes to soil that are clear markers of initial body deposition, and also burial [36]. The development of DNA testing techniques to retrieve viable profiles from soil, hair, and bone provides potential to produce a DNA match for a victim when the body remains absent [37, 38].

Bones and personal effects have the potential to remain intact for long periods if they descend to these soil horizon interfaces. For example, the remains of two missing persons killed in a mined area in Bosnia and Herzegovina (BiH) in 1993 were located in a woodland location during a search in 2015. The demining of a 100-m^2 area by stripping the leaf litter and humic zone revealed clusters of bones and clothing lying on the compact subsoil interface, dispersed in multiple locations. Multiple bone samples provided DNA profiles that were successfully matched, identifying the missing after 22 years.

In the same way, significant blood loss from a body can lead to rapid staining in underlying soil. Blood residues can descend to a depth of 5–10 cm, with limited lateral movement. Even if a body is moved shortly after death, such blood staining can remain stable, detectable through excavation at least 6 years after deposition [39, 40]. In a conducive environment, there is potential to retrieve samples from the soil over a considerable time frame.

3.1.3 | Canine search

Cadaver dogs work closely with a number of national DVI teams (e.g., [41]). Their capabilities and capacity to locate human remains through odor detection of decomposition, blood, and bone have increasingly been tested [42]. Use of professional canine search teams that rapidly transect a scene can assist in the first instance in assessing site extent through location of dispersed remains. A secondary role for canine search is pinpointing the location of human remains within search areas by line search, providing focus for more detailed follow-up. Dogs can also detect former presence of remains when they have been moved. Dogs trained to detect explosive and accelerant residue can also delineate areas of interest after explosion or fire. Detection dogs trained to respond to multiple scent types that work along search lines and have the utility of harness-mounted camera and GPS units to record and track areas searched makes them an increasingly versatile search tool for DVI [43]. At mass fatality scenes with a high frequency of dispersed, fragmented, and partially visible or buried remains, close coordination between canine, archaeological, and anthropological search elements may be beneficial.

3.1.4 | Geophysical survey

The potential for geophysical methods of remote sensing as one of a sequence of methods to augment large-scale search has been assessed and utilized [44]. There can been a tendency to view application of one geophysical survey method to search as appropriate. Often, for subsurface anomalies, this is by default ground-penetrating radar (GPR). While GPR can yield detailed results using very dense, time-consuming survey in suitable contexts [45], there are an array of commonly used methods available. These are more or less suitable depending on the search environment, available time, and investigative need. Results can differ dramatically on the same site between sensing methods, even changing over time as ground conditions (such as soil moisture) fluctuate [46]. It is often the case that after calibration and assessment at a specific site, utilizing multiple methods on a search area yields the best results.

The most obvious use of geophysics for mass fatality scenes is to detect and flag multiple surface and near-surface objects using metal detectors within managed spatial and recording controls (see Scene gridding and digital survey next). Repeat searches should be undertaken once evidence has been retrieved, as it is often the case that a single detection signal may represent more than one object in close proximity such as fragments from detonated devices, shell casings, or debris fields.

Magnetometry can be supportive in delineating the extent of buried evidence, such as impacts and craters from air crashes, or mass graves. Both detecting the extent of disturbance and the presence of buried metallic objects help to define and refine the relevant area for search. GPR and electromagnetic (EM) methods can be helpful by providing depth, volume, and contour of impact and buried features. They are therefore also helpful as a planning aid in determining estimates of the scale and potential time required for excavation. All geophysical results provide signals of anomalies, which always require further definitive assessment to determine if they represent evidence of investigative relevance [47, 48].

3.1.5 | Scene gridding

One of the most important archaeological contributions to mass fatality search and recovery is consideration for the spatial control of scenes. Without formal and detailed controls, maximizing evidence recovery and understanding events can be impacted.

The basic principles of visual search methods are described previously [49], and there has been assessment of comparative methods applied to mass fatality scenarios including grid and line search, with recognition of impacts of orientation, time of day, light availability, and searcher experience and skill [50]. The phenomena that impact visual search should be acknowledged and addressed. For example, direct sunlight effects due to solar position can be countered by walking line searches in different orientations across the same grid. Search at night improves recognition of both heat signatures using IR cameras and exposed burnt and fragmented bone, which have fluorescent properties best detected by combined ultraviolet (UV) and blue light [51, 52].

If search teams have been briefed to find missing persons, they may be mentally primed to recognize individuals from photographs of the deceased. However, taphonomic change may mean remains are skeletonized, discolored, or fragmented, and searchers may simply not register or differentiate remains from the background noise in a particular environment. Using archaeologists and anthropologists during searches improves recognition of fragmented and burnt human remains. Other specialists can improve a search depending on context, such as explosive ordnance disposal (EOD) technicians for explosive device components. Prior training should be provided in the recognition of the evidential material to be encountered and potential changes that impact it. This also assists in inuring team members to the expectations and psychological difficulties around human remains recovery (see Supporting implementation next). There are a number of benefits to formally laying out grids that should be considered.

Setting up a grid to assist in search and recovery need not be onerous or obstructive. For large scenes, setting up wooden or metal stakes or pegs at 50 m or 20 m intervals can be done by triangulating tapes or using electronic distance measurers (EDMs). This provides a basic series of orientated grid squares superimposed onto the landscape. Each square can be numbered to aid in organizing systematic search and designating an area location to any evidence found within that grid. Tapes can be stretched temporarily between pegs to form baselines as a visual guide to line searches within the grid square. Such searches benefit from running in more than one direction. The formal grid makes this accurate to organize, providing orientation for teams and control for managers. With grid pegs left in situ, it is straightforward to return for subsequent searches of particular grids.

The same grid pegs can also be used to organize a number of search methods in the same orientation. Geophysical search in 1 m spaced lines can be measured off the grid baselines by setting out tapes. If there is presence of unexploded ordnance (UXO), then 1-m wide lanes for canine or hand probe search can be set up from the same grid baselines. The same 1-m lanes can be used for fine fingertip search to search for and recover small objects.

For example, skeletal remains were found in a search for a missing person/s in a scrub/heathland setting. Cutting of vegetation by heavy machinery has both revealed and fragmented bones. To recover smaller objects, 10-m grid squares were divided into 1-m lanes to allow 10 person teams to undertake simultaneous detailed search to locate evidence that had not been detected by visual line walking. Fingertip search revealed personal effects, small bones, and fragmented bone during removal of the leaf litter to reveal the subsoil interface. An additional benefit of this formal gridding was to demonstrate patterns in located evidence. Certain lanes yielded more fragments. This reflected not that the evidence had a linear dispersal, but that some searchers found more in their lanes. This reflected their ability to recognize desiccated fragments of bone, as well as their experience and latent skill. This allowed quality assurance checks by using those “optimized” searchers to research other lanes, maximizing evidence recovery.

The spatial control that gridding a landscape provides is an aid to quality management: documented square-by-square assessment demonstrates dedicated search and allows accurate repeat search of exact areas. It is a method of providing confidence that search has been systematic. Grids greatly aid documentation (see Evidence of standards next). As a minimum, the location of any item of evidence can be manually recorded by using levels (to record vertical height) and by hand using temporary tapes between grid pegs, providing coordinates, and maps of evidence. This provides accuracy as a default if there are no digital recording systems available (see Digital survey next).

3.1.6 | Three-dimensional search

All landscapes are three-dimensional by nature and search should be designed with this in mind. Evidence and remains will in many cases come to rest on existing surfaces, whether the ground, on and in structures, on new surfaces created by deliberate burial such as mass graves, or accidental burial such as air crash impact craters. Surfaces holding evidence also become covered either by deliberate burial or through the collapse of buildings or soil, or build-up of debris. Locating evidence can be greatly enhanced by taking time to define all potential surfaces for search during response planning, and implementing their search in a logical, sequenced way.

The first surfaces normally dealt with are existing ground surfaces upon which evidence or remains can be observed. Searching and recovering evidence from these provides space to then work to extend search to elevations. In outdoors scenes, evidence may have come to rest in the higher elevations of tree canopies, ensuing complexity of recovery due to access and visual concealment issues. In temperate climates, seasonal searches may be needed to detect remains in canopies once leaf fall has occurred. In warm climates, presence of blow flies may indicate locations of remains above ground level during the active decomposition phase. Evidence may move over time, acted upon by gravity, wind, rain, and decay. Recording evidence found in these circumstances can be recorded by grid square: all evidence locations at height are essentially elevations within cuboid space above the grid. Exact 3D coordinate recording of elevations is greatly enhanced by digital methods.

Search inside buildings or structures such as tube-shaped aircraft fuselages can be divided into grids, though these may be irregular in shape or size to fit. Evidence and remains may be dispersed on walls and ceilings, especially after explosion or fire. The effects upon scenes caused by first responders, as they extinguish fires, recover the living, or make safe spaces to work, displaces evidence. Careful assessment should be made of such scenes, as the effects of explosion, fire, water, and collapse can expose and form new surfaces (such as drains, wall cavities, underfloor spaces, or cellars), with the force of energy (such as water from pressure hoses) and gravity transporting remains into such depositional reservoirs.

Evidence that has been buried in the ground is indicated by disturbance, normally visible at the ground surface. However, over time, bioturbation and plant growth may erase soil surface indicators, and the first indications may be at the humic/subsoil layer interface. Deliberate and accidental burial will require removal of the overburden to expose surfaces. This should be sequentially whenever possible (see Excavation and sequences of stratigraphy next), bearing in mind that there are always sequence to deposits. These may be difficult to discern on mass fatality scenes, but recognizing such sequences and three-dimensional evidence recording are standard archaeological practices.

3.1.7 | Digital survey

Adapted from civil engineering, archaeological, and crime scene applications, digital survey techniques have greatly enhanced the accuracy, speed, detail, and scope of mass fatality recording.

In open areas, rapid, accurate 3D coordinate recording of evidence and landscape features have been demonstrated using differential geographic positioning systems (DGPS), accurate to within centimeters [53]. A great volume of individual items of evidence can be recorded by a small team, with one person utilizing the GPS system, while evidence is sequentially numbered, photographed, and recovered. Drone units have the potential to record locations using GPS, if there are restrictions to ground access, for example, because of UXO or contamination issues [54]. Some remote regions have limited ground stations, so may have accuracy limitations surveying with GPS. Clear skies are also needed for satellite access. However, non-GPS recording at distance (up to a kilometer) by line of sight can also be carried out using EDMs (that measure with lasers), including using reflectorless systems. This makes it straightforward to record evidence at elevations. More recent systems combine both technologies. Digital coordinates can be downloaded and imported into survey and GIS software that can generate detailed maps and reporting material incorporating evidence numbers and details. Human remains can be surveyed by anatomical associations, providing body and body part positions, rendered into 3D images using specialist software [55], to support analysis and reporting. For example, in the survey of Kozluk, an atrocity crime scene related to the Srebrenica massacre of 1995, the execution site and multiple mass graves, hundreds of shell casings, and the positions of hundreds of bodies were plotted together, demonstrating overlapping distribution patterns [56]. These survey methods lend themselves readily to the simultaneous recording of different categories of evidence found in debris fields, for example, at air crash sites, where remains, aircraft parts, and personal effects may be interspersed across extensive landscapes.

Total scene imaging has been widely assessed and applied using laser scanners and photogrammetry [57, 58]. Stationary scanners can repeatedly image scenes in fine detail, combining with digital photography to produce 3D, rotatable crime scene images. Handheld scanning devices can provide very fine 3D images of evidence, such as cremated bone that risks damage, change or contamination when moved, allowing them to be assessed remotely before recovery, and retaining an accurate record of their in situ properties. Repeated scans can accurately document scene change during recovery and provide valuable coordinate, visual, and contextual evidence. The imagery can guide subsequent recovery, examination, and analysis, as well as communicate the properties of mass fatality scenes [59]. Photogrammetry can also be utilized with comparative accuracy by drones to provide remote recording [60].

There are clear options available for mass fatality scene search from a range of routinely deployed survey and imaging technologies that can accurately and efficiently record evidence location and scene evolution. Forethought is required in designing mass fatality survey as all evidential requirements cannot always be known at the outset. A rule of thumb is that the more comprehensive the survey methods used, the more data that are captured and the greater potential for unforeseen needs to be served.

3.2 | Standards

3.2.1 | Standards for evidence

Given the scrutiny and requirements of investigation, standard processes are necessary. Not only to ensure legal requirements are met, controlling the chaos, and organizing search and recovery, but also to provide confidence in, and explanation of, the implementation of response measures.

There are a number of guidelines to support DVI search, recovery, and examination processes, the most widely used being the INTERPOL protocols, adopted internationally to assist in management, planning, coordination, and standards for response [61]. Given the multinational composition of victims of many mass fatalities, overarching standards need to be agreed that comply with multiple jurisdictional needs. When a disaster occurs in countries with limited defined standards for crime scene and evidence-processing requirements, defining the process to implement can be complex: it is challenging to merge "bottom-up" and "top-down" decision-making traditions (see next), agree standards, and achieve effective implementation of processes that maximize evidence recognition and recovery.

In terms of scene recovery, there may be lack of resources, experience, confidence, or understanding of technical methods available to a response. There may be legal issues on deploying drones in national airspace or cultural prohibitions to deploying dogs, for example. There may be restrictions on the treatment and storage of human remains, or the export of DNA or other samples for analysis. There may be varying acceptable evidential requirements dependent on jurisdictional need. This is all made more complicated when points of contention, such as the nationality, identification, sex, age, or status of victims, cannot in many cases be determined before recovery, examination, and analysis are undertaken.

There has been much discussion about standards for human remains examination and analysis, and whether technical applications are universally practical for DVI response or not. A typical issue is mass DNA testing of commingled remains, with concerns about laboratory availability, costs, turn-around time of results, accessibility to resources for comparative sample collection, ethics, data use, and protections [62]. These issues are often raised when jurisdictions are resource limited. Going forward, cost–benefit analyses should be applied to determine the impacts of specific processes, including outcomes of not utilizing proven technical methods, such as DNA matching and subsequent skeletal reassociations of commingled cases.

The technical potential for recovering, accounting for, and identifying victims of mass fatalities are now well described. The potential is expanding, for example, forensic anthropologists are providing more formal input into screening, examination, and reassociation processes in support of pathologists [63]. Drone-use guidelines have been developed for scene recording [64]. The importance of personal effects and property and their treatment as part of repatriation are defined, and their contribution to identification have also been highlighted [65]. Discipline standards are described for a number of composite parts of the multidisciplinary processes supporting mass fatality response, for example, radiography [66]. There are also standards needed to ensure health and safety in complex, hazardous environments, staff welfare, and victim support [67]. These all interact in the multiphase, multidisciplinary, and multifaceted process.

With standards and response potential well described, the onus is on justifying – after informed assessment – why certain techniques or standards are (and are not) deployed in a response. This allows decision makers, judicial authorities, communities, families, and other stakeholders to understand the reasoning for the implemented process.

With the multifaceted technologies deployed in response today, consideration for their coordinated management and integration is required. For example, collecting digital coordinate data of remains and evidence at the scene is all well and good, but serves little purpose if there are no resources or know–how to integrate results into maps for search assessment, "nearest neighbor analyses" (in terms of assessing the relationships between cases in close proximity) or case and identification data. Complexities and impacts of technical responses are being assessed [68] as are the preparedness needs in planning at institutional, national, and regional levels, for example, in the United States [69].

Response design should consider how archaeological and anthropological methods can be implemented successfully into complex DVI processes, and what the potential outcomes will be.

Standards specific for archaeological and anthropological practices need to maximize the practical potential to recover evidence and remains, and contribute to a uniform and systematic examination and analysis. This is a complex task when there are cross-disciplinary standards that need to be applied in the workflow, through and between defined process steps.

3.2.2 | Evidence of standards

Communicating understanding of how archaeological and anthropological processes can assist DVI response can be achieved through the definition of those processes. SOPs and standard documentation can amply demonstrate how a process works, integrates disciplines, and records data. The flow charts to summarize processes for decision makers and for reference have been utilized, together with process step summaries (see e.g., [70]) and detailed forms (pro formas) for recording that prompt uniform assessment and documentation, whether it be an anatomical inventory of each case or the summarizing of autopsy analyses. Detailed SOPs provide guidance for the standardized treatments for evidence in the flow of work. For example, ICMPs DNA sampling of skeletal material procedure demonstrates how to efficiently prioritize, prepare, and sample skeletal elements, and has been widely utilized in DVI response [71]. Together, standard systems can demonstrate an effective process is in place, testable by quality controls to ensure competence in method implementation.

While pro forma completion can be considered onerous and time-consuming, it is an essential standard for complex DVI data and process recording. Archaeological field forms that record the position, inventory, and describe human remains have developed since the 1990s [72], subsequently adapted for mass fatalities, see, for example, a "checklist for the location, attitudes and properties of human remains" [36]. Besides capturing contextual and spatial data in the field, they provide the basis for case context and understanding at the examination phase of the process. Body forms for mass fatality use have evolved over 20 years, with latest versions capturing nearest neighbor data in the field. This assists with the spatial assessment of cases to aid reassociations of commingled and fragmented remains.

The case data in the field is also typically recorded on crime scene evidence numbering logs, survey coordinate data logs, and photographic logs and images. This provides the quality control cross-referencing needed to find, note, and correct errors in recording. Such errors will inevitably occur when thousands of items of evidence are recovered by teams in field and mortuary. Experience demonstrates such checks can reduce errors (such as case number or coordinate typos) during recording to less than 1%, most of which can be corrected when found. In addition to catching errors, it provides confidence that mass volume data capture systems are robust and are working effectively. This is important as errors that are missed may have legal ramifications. This may be issue of mistaken identification or questioning of contextual veracity when labelling errors provide cause to query whether evidence relates to differing crime scenes or events. Errors are more difficult to rectify once entered into databases.

What is the impact of applying standard processes of archaeological desk top research, search assessment, and excavation when implemented by archaeologists and anthropologists? The most obvious impact is the maximizing of evidence and remains recovery. Failure to do so may result in not accounting for the missing, a lack of case closure, or requirements for repeat search. For example, as a result of the review of past excavations and analysis of the skeletal inventories related to mass graves in BiH in recent years, the State Prosecutor ordered the re-excavation of a number of grave sites resulting in the recovery of hundreds of additional cases, leading to several hundred new identifications (e.g., see [73]).

The linear process of examination makes it logical to use case files that progress through workflow accumulating completed specialist forms and data, and this process has refined over time [74].

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This informs each stage, as each case examination evolves. Forensic anthropologists have a critical role in this multidisciplinary process, especially in screening evidence for human remains, and assessing commingled and fragmented cases. The subsequent reassociations would be impossible without the detailed multidisciplinary records that form the basis for decisions to merge cases.

What is the positive impact of implementing standard processes of systematic assessment of fragmented and commingled remains by anthropologists during examination? By way of illustration, between 2013 and 2017, a review was undertaken of 12 mortuary facilities in BiH holding unidentified remains, described in the investigation as "NN" cases (from *nomen nescion*: unnamed persons), recovered from mass graves and other sites related to the 1990s conflict. Over 3000 cases, thought not to have previously undergone formal anthropological assessment, underwent a standardized skeletal examination process. This was designed to sort commingled cases, documented using specifically designed and dedicated case inventory forms. Most cases were commingled and fragmented and nearly 6000 distinguishable sets of skeletal remains were recorded. As of 2019, the process led to 121 new identifications through DNA matching, over 100 new unmatched profiles, and 968 reassociations. Hundreds of cases were merged or closed [11, 75].

With anthropologists working closely with other specialists, including pathologists, radiographers, and odontologists, the importance of the multidisciplinary mass fatality examination process has been increasingly recognized with specific guidelines developed, for example, by INTERPOL [76]. A fully documented examination process that captures all analyses and collates results provides the evidence for decision making and certainties in formal identification.

The increasing importance of transferring information into formal databases has been recognized. Databases should reflect and be coordinated with the data fields of standardized recording forms. There are benefits to being able to collate case data for review, including merging and creating cases after commingled remains assessment. Analysis and tallying of anatomical elements should be possible to allow analysis of assemblages. The ability to query combined data within and across processes is necessary to provide statistical results and answers to investigative questions concerning specific events. For example, determining and scrutinizing MNI, demographic assessment, determination of nationality, or demonstration of patterns in cause and manner of death. The potential for data query and analysis requirements from databases is not necessarily realized at the onset of recovery. As pro forma data capture, databases should be flexible, being able to accommodate expansion of entry fields if required, and export in a wide range of data formats.

With modern media and communication, it is important to demonstrate standards and justify process implementation in real time. Besides obvious legal and safety necessities, formally communicating practical response measures to political, media, and community/family is a necessity. Increasingly, the ability of actors outside the cordons to collect, access, record, and distribute images and information about crime scenes (whether accurate or not) via satellite imagery, drones, photography, social media, and other platforms has grown. Mass fatality events often now have alternative narratives published about them before response phases have even begun. Dealing and living with commentary and reaction to perceived forensic and DVI procedures in now a "live" part of mass fatality scene investigation, and one which can impact management "inside the tapes."

3.3 | Taphonomic processes and the changing scene

3.3.1 | Dynamic change

Disaster scenes are dynamic, and recovery responses must plan for the changing nature of scenes. The recognition and understanding of taphonomic phenomena are key roles for archaeologists and anthropologists. Understanding (or not) affects decisions made concerning recovery and examination. High-energy impacts and fire greatly alter landscapes and structures, causing rapid taphonomic change, for example, with fire reducing bodies to fragmented, burnt bone, and debris. An innate skill of anthropologists on such a scene must be the recognition of such fragments. Archaeologists are practiced in implementing sieving processes that minimize destruction and sort collected debris through grades of ever finer mesh screens to retrieve evidence [77]. This aids recovery of elements that have better potential to yield DNA profiles in severely fragmented and burnt cases, for example, teeth or ear ossicles [78]. Sorting using conveyors or flotation techniques are standard archaeological practice, especially when dealing with soils with clay content that cling and adhere to evidence.

However, anthropologists and archaeologists normally arrive at scenes after first responders have completed their work. First response contributes to dynamic change, as the search for signs of life and, bringing scenes under safe control, for example, by extinguishing fires. Cremated remains are vulnerable to water dispersal.

Secondary responses to undertake safety measures at a scene can make further changes, for example, engineering works require to stabilize buildings or airplane fuselages by shoring and propping. Clearing areas to utilize machinery such as excavators or pumps, place props, or excavate sumps may move evidence and remains. Movement and depositing of layers of debris due to engineering clearance will seal an underlying surface and be detectable archaeologically at excavation.

3.4 | Change over time

Delays in mass fatality response, for example, due to aircraft crashes being in remote areas, may lead to scavenging and dispersal of remains. Skeletonization can occur within days and weeks in some environments. Bone weathers and fragments over time, more rapidly when it has been altered, for example, by burning [79]. Anthropologists can assess patterns of dispersal and deposition particular to an environment, such as typical behavior of local scavengers, and determine impacts on the ability to recover and analyze remains (see examples in [80]). Local communities may also move and bury bodies away from a crash site and utilize crash debris such as the aluminum from aircraft fuselages. Communities may undertake mass burials as they encounter remains after disasters such as earthquakes. Repatriation from such burial sites is a task suited to archaeologists who can assist in determining investigative relevance of graves, sequences of burial, and dating evidence (see Excavation and sequences of stratigraphy next).

Recovery procedures should include recording actions and impacts of first responders and any remedial safety works. Assessment of taphonomic phenomena determines what adaptations to search and recovery may be needed, and what expectations need to be adjusted in terms of the practical recovery of evidence and remains.

3.5 | Excavation and sequences of stratigraphy

3.5.1 | Sequences of stratigraphy

Archaeological assessment of the stratigraphy of a mass fatality scene provides a basis for understanding the nature, formation, and properties of the physical site. This can inform the designing of scene search and recovery procedures.

Stratigraphy studies strata and stratification to determine their order and relative position. Strata are layers of material, naturally or artificially formed, often one upon another. Such layering (stratification) represents the dynamic superimposition of material from separate single events, accumulating over time and burying cultural remains and natural sediments. Surfaces formed between deposition events that then become covered are referred to as interfaces. Stratification forms according to uniform and universal principles, described as "the laws of stratigraphy" [81, 82]. As such they are predictable.

All evidence falls within stratigraphic sequences, whether it is rapid sealing of a floor due to roof collapse, bodies buried and concealed in a mass grave, or the dispersal of remains and personal effects on an existing ground surface after a crash. Assessment provides the position of evidence within the layers of a stratigraphic sequence. This informs what part of a sequence are relevant to investigations, and which pre- and postdate events. Within the strata of interest, the sequence provides comparative dating and contextual associations. This demonstrates both relevance to the investigation and that standard and systematic procedures have been implemented.

There is always structure and stratigraphic sequence to deposits. For example, the buried environment is not simply "mud" or "dirt," thought to have no definable structure or subtlety [21], it is formed of a sequence of discernible and definable soil deposits. The intrusion of an air crash into this sequence creates a crater that cuts through existing layers, leaving a new surface (the crater floor and edges) upon which evidence and remains lie. Soil and debris may rapidly enter the crater through collapse, pressure, weather effects, or deliberate backfilling. This surface remains intact waiting to be revealed through excavation by removal of defined overlying deposits. Similarly, fires may result in a sequence of deposits reflecting serial deposit of soot, ash, and burnt debris, and collapse events as floors or walls give way. This leads to sealing of evidence and remains on the interfaces between layers. These can be revealed by excavating deposits in the reverse sequence, though clearly there is method, skill, and nuance required to discern ephemeral differences between layers in such seemingly chaotic scenes.

Rapid sealing of evidence under debris, collapse, or inundation layers can protect evidence from further effects, albeit obscuring them from view and making recovery more complex. This should be taken into account if there are time delays to responses. In certain environments, buried evidence can reach a taphonomic stasis where decomposition slows. There is potential for evidence and remains to be preserved for long time periods. For example, bodies of victims killed in 1992 and recovered from the Tomasica mass grave in BiH in 2013, had been buried under up to 9 m of clay and rock, sealed in an anaerobic environment. The bodies were placed in groups in the graves, separated by layers of clay. Careful excavation revealed a relative depositional sequence over time reflecting separate burial events [83]. Such was the preservation after 21 years underground that surviving tattoos provided identification evidence, cause of death could be determined by soft tissue analysis, and clothing and personal identity documents were retrieved intact [84].

3.5.2 | Different method, different results

Variation in excavation method can provide different results in terms of efficient use of resources and time, recognition of stratigraphic boundaries, location of evidence, demonstration of evidential relevance, and evidential recovery. Assessment should inform what method implementation will be most beneficial to this process.

For example, a blanket excavation by small grid units across an area is designed to locate material evidence, with the grid extending out from where evidence was pinpointed during assessment. The expansion of the excavation is determined by the quantity of probative evidence recovered within a specific grid unit. Units may be excavated in arbitrary 10 cm levels, with all material recovered is screened (sieved) through a 0.5-cm mesh screen. The logic is if an entire area is excavated, then there is confidence all evidence has been found. This approach may be beneficial when excavating a uniform deposit such as inundation of mud from water deposition or in the bioturbative zone of humic soil, where there is no stratigraphic differentiation.

In contrast, a stratigraphic approach to excavation uses discrete test trenches to locate the layers and deposits of investigative relevance and then excavates those in sequence, and in their entirety. Each identified deposit can be excavated in spits and sorted independently of other deposits to maintain stratigraphic (and evidential) integrity of everything in that deposit.

Any deposits that predate the interfaces created by the fatality event are left. This often greatly reduces the volume of excavation, with more efficient screening, as only material directly associated with the event is removed. The confidence in excavation comes by demonstrating that all strata related to an event have been excavated. This approach may be beneficial when there is observed stratigraphy.

It is rare for there to be no stratigraphy in mass fatality events, which tend to involve, alter, and impact surfaces upon which we live and move. It is often the case that the methods chosen and implemented need to be adapted during recovery. For example, when deposits are too unstable to excavate stratigraphically, or removing part of a surface (after recovery and recording of evidence) is needed to insert drainage ditches or sumps to drain water or aviation fuel.

Detecting stratigraphy is required if it is to be excavated and recorded. For example, a collapsed wall will have a limit to the extent of its debris. Where this edge is found, the interface between the debris and the underlying surface will be observed. This is the starting point for removing the debris to reveal the surface below and anything lying on it. In the same way, buried features can be tested using discreet test trenches, revealing features through recognition of soil differences and the exposure of the uppermost edge of where preexisting deposits where cut, truncated, or disturbed.

Once found, such features can be excavated systematically. Buried features like impact craters and graves greatly benefit from controlled stratigraphic excavation. Revealing the edge of a crater that has a rounded "lip" to its profile is indicative of an aircraft impact, the result of the embedding of the nose/fuselage, confirmed by the presence of glass and aircraft debris. Defining the extent of the crater and related deposits in plan allows the controlled removal of this material without the necessity to extend into surrounding sterile landscape. The ability to stratigraphically define such features in a landscape are improving with coordination of multidisciplinary remote sensing and imaging, precisely pinpointing features to physical test [85].

The cost/benefit of implementing different methods should be part of response assessment and planning. The pros and cons of application in different contexts have been researched and published [16, 86, 87].

3.5.3 | Managing stratigraphy

Managing a mass fatality can be assisted through the application of stratigraphic methods. Defining stratigraphic phases through assessment of the surviving physical material at a scene can break recovery down into stages, allowing a controlled recovery that reflects (as closely as possible) the sequence of events.

It is complex to ensure a scene is searched and excavated by stratigraphic stages, especially when the input of archaeologists and anthropologists may come after initial interventions have taken place. Success in this approach necessitates keeping the scene clean and stratigraphic boundaries under observation. However, it is easy to lose track of strata and interfaces (often because of accumulation of mud and debris, effects of rain or flooding, over excavation, or rushing recovery). Keeping strata under observation and thereby demonstrating their continuity needs careful management and proficiency by teams applying the necessary technical methods. This requires archaeologists and anthropologists to be given supervision and control of their implementation. Use of formal archaeological forms recording strata manages and demonstrates standardized in situ data recording of evidence and has a wide precedent and peer-reviewed use [16, 88]. The association of evidence and remains to specific stratigraphic phases also benefits investigation, providing demonstrable sequential dating and contextual association to specific events and locations.

As with any change to procedures or treatment of evidence at a crime scene or during an examination process, adapting or altering archaeological methods during recovery should be justified and documented. Necessary adaptions may be required, for example, due to a changing environment, for example, due to flooding, access or safety incidents, or observed deterioration of evidence.

Application of these methods naturally benefits mass fatality investigation: The discipline mission of archaeology and anthropology are to provide "the most accurate possible reconstruction of past events" [89].

3.6 | Cycles of examination

The skill sets of forensic anthropologists in recognizing, sorting, differentiating, assessing, and reassociating human remains form a proven central role in the examination phases of DVI response. Skeletonized, commingled, and fragmented remains are typical phenomena encountered during DVI. As such mass fatality incident response should by default include anthropologists and their contributions to process methods in design and implementation.

3.6.1 | Examination starts in the field

The combined discipline expertise and coordination of archaeologists and anthropologists assist in recognizing human remains in a variety of contexts, whether burials, fire, crash, or bomb scenes. The in situ assessment of evidence means examination starts in the field. Recovery and documentation of discrete cases of remains at this stage can only assist subsequent examinations. Moving remains and evidence alter context and can lose information.

Examination processes designed to minimize information loss and increase information flow between process steps have been implemented. Initial in situ definition of cases through anatomical assessment helps prevent commingling of cases as the point of recovery. The contextual observations available to anthropologists in the field aid differentiation, saving mortuary examinations time and resources. The same observations and documentation of remains also provide the mortuary with nearest neighbor data to aid the re-association process.

For example, the excavation of WWI mass graves at Fromelles, France in 2009 undertook sampling before bodies were moved from graves. The temporary mortuary was set up beside the grave, allowing rapid analysis to be undertaken that informed on-going excavation. For example, an initial lifting of the crania and neck of a case followed by radiographical assessment revealed the clothing insignia designating regiment and nationality. This prepared archaeologists and anthropologists excavating the rest of the case to expect specific locations around the body where evidence might be found, reflecting known uniform and webbing (belt and pouch harness) patterns [12].

The potential to use novel examination methods in the field including portable x-ray are being explored [90] as part of screening and sieving procedures. Another benefit to using x-ray and metal detection methods during assessment is to screen cases in situ for safety reasons: ordnance has been found in a number of instances in bodies recovered from mass graves. This is less hazardous to deal with before cases are moved than during fluoroscopy screening in the mortuary. The collection and sorting of debris and soil to recover fragmented remains and other evidence (and discard material not of investigative interest) is another key role of field examination.

3.6.2 | Continuity

The deployment of anthropologists and crime scene technicians in the field who then attend examination provides an opportunity to maintain continuity of primary understanding and evidential controls from field to mortuary. There are benefits to designing an examination process so that personnel that recovered evidence also take part in formal examination. After the re-excavation of the Kozluk mass grave site in BiH in 2015, the pathologist and anthropologists that assisted in the field recovery also undertook the examination process [73]. This aided evidence recognition, evidence association, awareness of contextual anomalies, and continuity of case documentation. There are staffing, time, and cost implications to such field examination approaches, but the benefits should be considered during response design.

3.6.3 | Separating brings understanding

There is a large body of literature exemplifying and detailing the development of the anthropologist's role in formal DVI mortuary examination processes (e.g., [61, 91]). Initial assessments of cases at the start of the examination process benefit from standardized anthropological assessment (to determine age, sex, stature, and population affinity), particularly with regard to those that have skeletonized, fragmented, and commingled status [15]. This informs the case strategy for sequential steps in the process. The subsequent anthropological sorting of cases into discrete skeletal sets is an important assistance to pathologists, allowing division of cases into subcases when it is clear there are multiple individuals. The formal laying out of a case into separate skeletal sets benefits subsequent numbering, examination, analysis, and sampling, and has been developed according to context and need [92–94].

Careful case documentation, tracking, quality control, and case management are needed with the separation of skeletal sets from within cases, as well as other evidence and samples. Such is the complexity of case development in many DVI scenarios that it is becoming increasingly important to consider having anthropologists in management positions in the examination workflow to ensure standards and controls are consistent [95].

3.6.4 | Piecing things together

Pathologists benefit from anthropologists and radiographers undertaking assessments supporting their determinations of cause and manner of death [63, 96, 97]. The survey of individual skeletal trauma and patterns of trauma across skeletal assemblages is assisted by reassociating fragmented remains to allow observation of trauma injury. This also allows differentiation of different types of trauma, for example, gunshot and blast injury [98]. Anthropologists can also assist in retrieving ballistic evidence from bone that has been visually or radiographically observed. Physical association of matching anatomical and fractured elements also allows case reassociations.

Anthropological assessment of skeletal phenomena to define specific unique traits that can be matched to antemortem records aids identification, contributing to assessments by pathologists, odontologists, and radiographers [99]. The difficulties in accessing comparative antemortem data for identifications in some scenarios make anthropological assessment a useful tool [100].

Adapting anthropological assessment to the specific nature of assemblages is increasingly important when faced with extreme commingling and fragmentation. For example, when loose bones and fragments are accumulated and packaged together, whether during collection at the scene or as a result of separating extraneous materials, could not be associated to specific cases during examinations. Detailed procedures and standardized recording forms are required if anthropologists are to be able to process all skeletal material examined under such circumstances. It is not uncommon to encounter the remains of multiple individuals commingled within the same case (see, e.g., [101]).

The input of anthropologists is extremely important in providing a useful status for all skeletal sets within such cases, whether it leads to identification or not. The demonstrable accounting of all remains as part of accounting for all the missing is an increasing requirement of DVI investigation.

At the end of examination, it is helpful for anthropologists and radiographers to assist in reviewing case clothing and personal effects before further processing, storage, or repatriation. Blast, crash, and burning effects can fragment bone which can adhere to clothing.

3.6.5 | Prioritized DNA sampling

The potential to resolve many commingling and fragmentation issues has been greatly enhanced by refinements in extracting DNA profiles from degraded bone [8]. Anthropologists have a key role in sampling skeletal elements for DNA, guided by research into the most effective sampling strategies [102], and targeting bones with higher success rates for DNA extraction. ICMP assessed more than 10,000 samples to determine which yield best results, including the femur, teeth, the petrous bone, talus, and carpals [7]. Similar priorities have been determined in aDNA research, with increased focus on specific parts of skeletal elements such as tooth cementum, ear ossicles, and cortical bone. This places further responsibility for anthropologists to assist with sampling, not only to identify the specific anatomical feature of a skeletal element to sample, but to do so in a process that ensures documentation before destruction, and minimizes impact to the remains [103]. All of this benefits the potential to successfully extract DNA from disarticulated and fragmented remains, with an efficient and cost-effective use of resources. Sampling can be undertaken at multiple stages in examination workflow, applied on a large scale at the outset. Samples can be stored while processing systems are organized and refined, and the DNA analysis is undertaken in laboratories, independent of on-going examination and time-consuming investigation [8].

3.6.6 | Augmenting analysis

The degree of fragmentation in many mass fatality cases makes them too degraded or limited in potential to DNA test. As time progresses in large assemblages such as the Srebrenica massacre (17,000 cases) or the WTC (over 18,000 cases), new identifications tail off and most on-going results link and reassociate cases. The volume and complexity of assessing these assemblages have led to research in the application of statistical and algorithmic methods to determine potential for further targeted sampling of fragmented and disarticulated remains [104]. Developments in DNA analysis also hold potential for review, resampling, and case progression over time [105].

The detailed documentation, inventory, and database entry of the complete anatomical status of each case, skeletal set, and fragment are required as a basis for successful application of analyses to assess such assemblages. This must be built into response design from the outset.

The resource and expertise requirements for such detailed examination processes and analysis are not available in all responses. The potential for remote assistance through visual and data analysis is being developed. This can contribute to assessment, interpretation, and documentation of cases, assisting in determination of identification and cause and manner of death. This greatly extends the potential capacity for appropriate DVI responses to be implemented more widely than at present [106].

3.6.7 | Reviewing the evidence

After examination, the collation of data including results from sampling such as DNA provide the basis for a review of the case to determine if identification of remains can be made at this stage, or further assessment is needed. A key role of anthropologists is to utilize results to undertake reexaminations of commingled, disarticulated, and fragmented cases utilizing all case data. Typically, assessment (especially DNA matching) will find there are reassociations of skeletal sets within cases, and between cases, requiring adjustment of case documentation.

An outcome of review is to state what actions need to be taken to complete the identification process for each case, including further reexamination if elements of different cases are attributed to an individual. Assessment should include collation of any evidence providing identification, including both positive and presumptive methods. Dedicated case review recording forms should capture all collated data to provide pathologists and case teams with evidence to agree and confirm case status and any recommendations for further investigation.

Reexaminations, especially with DNA-matching data to hand, often lead to errors in prior physical matching being noted that result in separation of skeletal sets into new cases for further testing. Reexamination with such assemblages is a repeating process as new case data are determined.

DNA matching progresses many cases for which there have been no other identification resolutions, by both confirming identity and reassociating skeletal sets. In many mass fatality incidents, especially crashes and fire scenes, identification may be made from a single bone.

In many cases, skeletal material that cannot aid in identification or be associated is placed in storage, designated as unidentified or "ossuary" material [107]. It is very important for case documentation to record and justify this procedure, so it is clear to stake holders why progress in certain cases has reached a stasis.

3.7 | Reconciling across processes

3.7.1 | Collating data

The accumulated documentation from search, recovery, and examination provides archaeologists and anthropologists with the opportunity to reassess results. Improvements of database organization and standardized recording allow data from across different stages to be collated, compared, and queried. This is especially important in mass fatality events where remains are commingled, partial, and fragmented, and may be recovered from multiple scene searches or from multiple scenes. A review process to cross-correlate case and field data should be undertaken to identify ways to account for the missing as fully as possible.

For example, detailed anthropological inventories of cases will determine there are missing anatomical parts to individuals. A tally of the minimum number of individuals assessed by major skeletal elements (e.g., by left and right femora, humeri, or calcanei) provides totals by element. This can provide statistical data on how many individuals are present in an assemblage. Comparing this to total DNA profiles for an assemblage provides insight into whether the material in the assemblage accounts for all the parts of the missing, or whether there are outstanding substantial gaps: in the inventory of remains still to be accounted for. This "gap analysis" may lead, for example, to the assessment that there are more DNA profiles to be determined within the assemblage, or there are multiple major body parts that are absent.

3.7.2 | Reviewing the scene to assist identifications

A review of the field documentation and survey data from a mass fatality scene is a next step in utilizing the gap analysis of case inventories and highlights the importance of undertaking detailed field recording of the anatomical properties of cases. Comparing case and survey data can reveal several things.

The spatial distribution of identified but partial cases and nearby unidentified body parts can be analyzed to assess whether they may be associated. Recording in situ anatomical coordinates of remains and their nearest neighbors in body forms during recovery is a prerequisite for this [28]. Utilizing computer programs to sort and visualize spatial case distributions can prioritize cases to physically assess for potential reassociations [108]. This may confirm nearest neighbors that can be physically reassociated or determine DNA sampling is needed to confirm potential associations.

For scenarios where there are surface remains, spatial analysis combining terrain assessment and the positions of remains may show gaps in distribution that provide clues on where to focus further search. Variations in terrain, light, and slope may have impeded effective search leaving areas that were not systematically surveyed. Scavengers also routinely move fragmented and disarticulated remains across areas already searched.

In the same way, spatial assessment can be made of terrain together combined with the locations of incomplete cases that have not been identified (perhaps because no body parts yielded viable DNA or other identifying features). Focusing on the area where such cases were recovered may yield further remains that can provide positive identification. Body part distribution may demonstrate postmortem patterns, for example, providing directional focus for further search to find further body parts scattered by air crash impact or explosion.

In some jurisdictions, recovering all remains is a requirement, and communities and families typically wish everything to be accounted for. Such review demonstrates due diligence in addressing all these concerns.

Assessment of recovery and case data can also estimate how useful such spatial assessment might be, when correlated by event type. The WTC data analysis demonstrated the potential for integrating remote-sensing and geospatial data [109]. Spatial data recorded significant differences in body completeness and identification success rates between locations associated to specific events [10].

3.7.3 | Reviewing the scene to assist evidential potential

Spatial assessment of identified remains may provide investigative evidence. Assessment of the spatial distribution of DNA identified bodies and associated body parts at the Tomasica and Kozluk mass graves in BiH contributed to evidence that the graves had been robbed by heavy machinery. Bodies were DNA matched to nearby body parts that when spatially plotted were found to be separated by stratigraphic boundaries representing undisturbed versus robbed areas of the graves. The body parts had been separated and dropped in the backfilled soil during clandestine removal [73, 83].

The movement of bodies and remains by perpetrators is endemic. Undertaken to hide evidence, prevent identification, and conceal crimes, such tampering is ubiquitous around the world. The recovery and analysis of remains left behind in primary graves those found at secondary locations have provided numerous DNA matches to reassociate body parts. The DNA matching therefore connects crime scenes. After the Srebrenica massacre, many primary graves were dug up and remains taken to dozens of secondary graves [73, 107]. This demonstrated patterns of criminal intent and conspiracy to hide evidence [110].

There are demonstrable benefits of correlating spatial survey, field, and examination data to assist in furthering identifications and providing investigative feedback. Whether proving the need for repeat searches or providing evidence for undertaking search for new scenes, review should be a formal process step considered in response design.

Process reviews are possible if detailed field and case data are captured and entered into queryable databases that can sort and export data lists. The ability to collate, associate, and cross-correlate records opens avenues to assessing case data in flexible ways. Whether cross-discipline assessment of MNI, matching DNA results, assessing reassociations of fragmented remains, or plotting identified cases against spatial distributions. The technologies to develop response capacity, and to query, coordinate, track, visualize, and review data are being explored and implemented within disciplines, and within DVI response frameworks (e.g., [111–113]).

3.8 | Considerations for archaeology and anthropology in response design

3.8.1 | Awareness of process potential

Effective response in a particular disaster and mass fatality scenario requires knowledge of the potential technical support available, and

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what might be applicable considering the scale, nature, and investigative requirements of the event.

It is fair to say that many jurisdictions globally responding to mass fatalities do not have resources or knowledge to deploy a gold standard response: the technical complexity and coordinated multidisciplinary application of search, recovery, examination, and identification processes described in this article exceed capacity for many. There is then a paradox. As technical methods and processes develop alongside legal necessities for identifying victims and gathering evidence, it may become more difficult for jurisdictions to meet such standards in response without wider assistance.

Is there willingness to apply the technical methods described in this article? In some jurisdictions there may be limited political, legal, or cultural desire for undertaking an extensive process of formal identification. However, the potential methods for identification are readily known by communities and governments in the era of mass media. Demands and pressure for action go hand in hand with the civil response to disaster.

A common property of disasters and mass fatalities is that victims are from multiple nationalities, who often cannot be differentiated without a formal response process. INTERPOL's "DVI command and coordination support" for its country members sets out a basis for equity in response to mass fatalities.

If the technical potential for integrating archaeological and anthropological methods is understood, then responses can be informed, designed, and tailored to the resources available. Successful application of methods within processes requires appropriate practitioner availability and experience.

3.8.2 | Legal expectations

Besides national legal requirements to identify and provide burial for victims, there are requirements under international conventions for effective investigation to identify victims and gather evidence for legal purposes including criminal prosecutions. When individuals are successfully identified, families and communities have rights of repatriation and commemoration. Principles require an authoritative account of events pertaining to a death, including confirmation and certification of death. These are necessary for families and communities to secure rights under international obligations including compensation. These rights may depend on the verified documentation of search, recovery, identification, and burial for victims [24].

Expectations under law, and of families and communities, place responsibility on response design to consider and utilize appropriate methods to fulfill these responsibilities. Archaeological and anthropological methods can contribute significantly to an investigative process that is then able to realize these obligations.

The more a breadth of technical methods can retrieve data throughout a mass fatality response, the more it can be applied for necessary outcomes. Whether it is accounting for the missing, allowing legal settlements for families, rights to truth, or provision of criminal evidence. Response should be designed to ensure the evidence produced can satisfy all outcomes. Archaeologists and anthropologists should implement methods with the prospect of a broad range of evidence use outcomes in mind.

The more detailed the evidence provided by response processes, the more exhaustive the account of events. This fulfills the right to know for families and communities and is a provision for legal enquiries. It also limits speculation and provides alternatives to counternarratives that form where limitations in evidence gathering otherwise lead to unanswered questions and gaps in explanation.

3.8.3 | Cost and availability

There has been an expectation that technical methods will not be implemented in responses in some jurisdictions due to costs and restricted availability, for example, access to DNA testing. However, lack of availability has reduced, as suitable laboratory capacity has grown in recent years. Costs have also fallen greatly. DNA matching is the most successful positive identification (and reassociation) method available for the fragmented and commingled skeletal remains typically encountered by anthropologists in mass fatalities. These are often from a restricted age and sex range, with few ways to individuate cases. For example, before DNA matching was deployed, a little over 100 victims of the Srebrenica massacres were identified through anthropological and other assessments [114]. As of 2020, 6981 of a total 7017 victims have been identified by DNA matching [18].

Can requirements of humanitarian law be fulfilled, in terms of responsibilities to identify the missing, if the processes of identification and evidence collection are not applied? There is a lack of research into the comparative costs of implementing mass fatality response processes: is DNA-led identification more or less expensive than other methods? Can costs be allocated according to the impact of each method? Contexts vary, and where there are good antemortem records, processes where finger prints and odontology can be applied have been very successful [115, 116]. But the tens of thousands of skeletal cases in storage around the world as a result of mass fatalities and human rights violations remain unidentified.

There are overall costs. Communities and families need identifications for a number of reasons including inheritance, remarriage, property ownership, and insurance claims. The balance of cost must be judged not only in financial terms but also in terms of wider costs, including the cost of not identifying victims. Certainly, implementing effective processes such as the ICMPs support of the identification of the missing is relatively low cost, at several million dollars a year. By comparison, the underwater search for the Malaysian flight MH370 had cost $200 million by 2017 [117]. Although circumstances differ, the practical costs of deploying archaeological and anthropological methods in tandem with DNA matching and necessary examination and identification processes are cost-effective when measured against the success rates of positive identifications for complex cases. If the processes are now relatively cost-effective, are there any practical reason that one standard cannot be applied? Not to do so invites inequalities in the rights of the missing, dependent on affordability and availability of appropriate forensic science [118]. The inequality within and across responses seems not to lie in financial costs.

3.8.4 | Bottom-up, top-down

All mass fatality scenarios are unique, and response requires design that allow adaptation to methods and processes to cater for what is found during recovery and subsequent stages of investigation. In practical terms, devolving responsibility down to managers on the ground can ensure this flexibility. "Bottom-up" decision making and organization is a standard concept and part of management organization in emergency response in a number of countries, including the United Kingdom. In mass fatality scenarios, this allows recognition of immediate practical risks, whether resources and methods are adequate or how method implementation may need to be adjusted to maximize evidence and remains recovery.

Top-down management can overly proscribe adherence to set methods that are not efficient or effectively adapted to a particular scene or limit the processing evidence and remains that have specific properties. Conforming closely to a blanket "standard" method applied as a demonstration of good practice and competency may be effective in controlling the scene encountered and can produce standardized documentation. However, there can be a tendency for the appearance of what is applied to be a focus rather than considering how it is applied, and why. Flexible method delivery that maximizes potential for evidence recognition and recovery is the desired outcome. Determined implementation of a set procedure whatever the conditions or scenario can often result in lost understanding, evidence, time, and resources. Top-down management systems also make it time-consuming and cumbersome to propose process or method change. Clarity on how to resolve practical problems blur with each step away from the operational process, reducing urgency and the understanding needed to agree to resolutions. Bureaus within organizations should be managed to be proactive, enabling, and supportive of operations, not restrictive [119].

The unique nature of the phenomena encountered in any landscape or assemblage of remains mean by habit archaeologists and anthropologists are inured to adjusting their methods to ensure effective data collection. Approaches to managing archaeological method implementation in the field have been discussed previously [36], for example, in terms of responding to large volumes of evidence.

All adaptations need to be effectively recorded to document and justify change in a formal policy or method change recording forms. Proactive communication and feedback between management levels is essential for bottom-up management to succeed, as is trust and confidence of managers that practical operators can be left to implement the most appropriate method within the described latitude of defined response parameters.

3.8.5 | Supporting implementation

Any planning and design of response benefits from training and practice. Extending knowledge and experience within disciplines increases capabilities to respond. Training across disciplines through complex response stages is essential if effective organization and consistent method implementation are to be achieved. Such training exercises invariably highlight issues in communication, process delivery, method variance, knowledge, documentation, and overlap of responsibility. Training produces experience, trust, cohesion, and efficiency.

For example, in practical terms, archaeologists benefit from training in search and excavation methods in varying environments. Anthropologists benefit from practicing sorting, assessing, and organizing fragmented and commingled remains. Combined disciplines benefit from practicing field recovery of remains and completing cross-referenced documentation.

Training and practice also highlight where there are limitations in resources, including qualified staff, equipment, logistical support, funding, and communications. During a multidisciplinary exercise simulating a plane crash at a UK airport, archaeologists and anthropologists had to adapt gridding methods to deal with ground inundation and obscuring caused by fire service efforts to put out aviation fuel fires. Branches of the response services determined their radio communications ran on separate channels. The exercise pinpointed issues provided solutions and allowed group discussions to develop coordination.

Extending from this is the development of capacity both nationally and internationally. National capacities for archaeological and anthropological work can readily be trained for DVI response. Many jurisdictions may have limited capacity. For example, there are few practicing forensic anthropologists in BiH other than those employed by ICMP. When projects finish and funding stops, capacity can be lost. Cross-training medics and dentists has been an effective way to build necessary anthropological expertise, for example, in ICMP training programs in Iraq and Libya [120].

The nature of mass fatality events and environments requires response design to ensure risk assessment, health and safety, and staff welfare are addressed. Practical management of disaster response from this perspective have been described [121, 122]. The specific experiences of archaeologists and anthropologists in deployment have also been discussed, for example, the differences in dealing with soft tissues versus skeletal material, health and safety, pressure of teamwork, constraints of working in a crime scene environment, encountering threats in the environment, psychological impact of the nature and scale of events, and the limitations of authority and decision making in roles [119, 123].

4 | CONCLUSIONS

Archaeology and anthropology have made significant contributions to mass fatality and DVI response, highlighted in the case studies in this article. Technical developments have grown from the wider disciplines to form a forensic focus. The cross-disciplinary nature of the process has brought close cooperation and merged discipline-specific data into process-driven results: whether it be joint pathologist–anthropologist examination of skeletal fractures or use of DNA-matching data, anthropological assessment, and field coordinate data to plot distribution of an individual across the landscape. The discipline contributions have been uneven over space and time, but implementation of methods as part of a standard response process is achievable, if they are shown to meet the technical, legal, and investigative requirements for recovery of evidence and identification of victims.

4.1 | Demonstrating standards

The breadth of archaeological and anthropological technical support has evolved over time. Methods have been tested, defined, and implemented. There are clear precedents for method use, and standards have been published and utilized.

Archaeological approaches to search including gridding and use of DGPS provide a basis for undertaking, documenting, and demonstrating systematic search. Extensive research into postmortem effects upon bone and strategies for its recovery have allowed high confidence in remains retrieval.

Technical methods and SOPs in anthropological analysis have contributed to mass identifications by assessing, sorting, and reassociating fragmented and commingled bone.

Formal documentation in the form of standardized recording forms and databases record procedures and results of archaeological and anthropological methods and form a basis for quality checks and balances to be undertaken.

4.2 | Justifying implementation

Archaeologists and anthropologists have defined methods, SOPs, and standardized recording, demonstrating potential for process implementation. Such methods have also proved revelatory to investigations in terms of the capacity to recover buried evidence, dating evidence, and bringing order to the chaos of assemblages of commingled and fragmented remains. They have also provided realistic expectations on what methods can achieve, whether it is the contextual restraints of utilizing geophysical methods or the limitations to identifying fragmented remains.

All methods utilized should be justified in terms of their predicted contribution, estimated outcomes, and by their measured results. The capabilities of various methods are now known. If decisions are made not to utilize suitable methods, then this should also be justified. There are ethical (and possibly legal) concerns if response design does not incorporate methods known to improve rates of recovery, for example. There is a responsibility to undertake assessment of methods so that processes maximize the potential evidence and victim location, recovery, examination, and identification. Such assessment ensures competence and resilience in response.

4.3 | Recommendations

Response design should consider the range of archaeological and anthropological technical tools available and consider what best practice constitutes for specific methods.

Response should be designed to ensure evidence is gathered and remains processed to a standard that results in data having the potential and integrity to be utilized for all perceived needs. Estimates of the potential costs and resource requirements of method use should be part of design. Lack of resources to implement technical support are a common problem.

Pressure to provide rapid results and answers that impact effectiveness of processes should be avoided. Response design should cater for and justify method adaptations. Every scene and response are unique. This is the basis for understanding potential responses must be tailored to the context, formed around processes that can resolve the problems encountered at scenes and in subsequent workflow.

Standards for methods must be defined and documented. Discipline best practice should be considered as the default, with any context-specific adaptations justified. Standardized recording forms for documentation should be agreed, and adaptations justified. Preparedness plans for response need adaptive and flexible design built into their structure.

Archaeology and anthropology practitioners should be consulted about method application potential and should be part of working groups to define process workflow and organization. Training and capacity building develop skills and understanding for the complex multidisciplinary process of DVI.

Bottom-up management organization should provide practical operators with the scope to make agreed judgments on adapting methods and processes to optimize efficiency of response.

It is hoped this article informs decision makers of the potential for archaeology and anthropology to support mass fatality response and acts as a prompt to consider approaches to organizing complex processes.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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