



# Investigation of Disaster Victim Identification

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## Abstract

In any mass disaster case, irrespective of type of disaster, victim identification is very substantial. This procedure is culmination of distinctive fields of forensic science including anthropology, odontology, radiology, and fingerprint and DNA analysis. All experts of these fields collaborate together and manifest their knowledge and expertise to identify the victims in a disaster. The review focuses on the discussion on identification of victims using different forensic tools and methodologies. The December 2004 tsunami disaster is used as an example to illustrate the working of forensic experts and methods and techniques used in identification of the victims. The newer methodologies and advancement in victim identification techniques are also discussed.

## Keywords

Disaster victim identification · Forensic odontology · Forensic anthropology · DNA · Forensic radiology · PMCT

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## 8.1 Introduction

The fundamental part of forensic investigation is identification. This process completely relies on the information gathered from antemortem and postmortem records along with DNA, medical, or dental records [1]. The use of identification for legal requirement is practical to infer the fatality incident (event or disaster).

Human identification investigators have a humanitarian and legal responsibility to identify every individual where possible, so that they can be returned to their families [2]. These investigations are needful for socio- and medico-legal purposes and are performed in cases such as natural and man-made disasters or in case of highly decomposed or dismembered body to conceal the identity of the deceased. Disaster victim identification (DVI) is an acute and challenging task which involves specialists from various fields including pathologists, archeologists, anthropologists, odontologists, radiographers, biologists, etc. [3] DVI can also be described as course of action used to favorably identify deceased victims of mass fatality incidents (MFI) [4]. These incidents give rise to a large number of victims. On the basis of number of deceased, MFI can be subdivided into major, mass, or catastrophic [3].

The procedure of DVI consist of five phases: [4, 5]

1. Scene
2. Mortuary
3. Antemortem data
4. Reconciliation
5. Debrief

Mass fatality incidents (MFIs) take place in many forms and can be categorized into two categories, namely, natural and unnatural. Natural incidents include tsunamis, earthquakes, and hurricanes, while unnatural incidents are terrorist attacks and air crashes [4].

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## 8.2 International Police Organization (Interpol)

Interpol is an international organization that addresses the issue of DVI. This organization has laid guidelines according to which the entire procedure of victim identification should be followed. The first DVI manual was published in 1984 [3]. The Interpol philosophy aims to stimulate DVI teams to make use of “best practice” to obtain maximum results in DVI operation [5].

This Interpol organization claims that there should be permanent disaster victim identification team. Interpol recommended that the 187 member countries should adopt common procedures and protocols for victim identification in any disaster irrespective of cause of disaster or number [3]. These recommendations are made to achieve and maintain improvement of standards [6]. The Interpol standing committee made three working groups: Forensic Pathology, Forensic Odontology and Police [7].

The Forensic Pathology working group is subdivided into:

- DNA anthropology
- Imaging
- CBRN-E

The Forensic Odontology includes:

- Dental forms
- Expert qualification
- CT imaging

Police work includes:

- Victim recovery
- IT/large data
- International DVI management exercise
- AM data collection

DVI guide aims to contribute to the efficiency and effectiveness of disaster handling [8]. The methods for identification process are divided into groups: primary and secondary identification methods [5].

The Disaster Victim Identification is part of the INTERPOL operations police support the Directorate. This DVI unit consists of a team of police and scientist and helps in preparing countries so that they can respond to catastrophic events involving mass fatalities [9]. The three major or primary identification include:

- Comparison of dental traits and characteristics
- Fingerprints
- DNA profile

Other traits including tattoos, body piercing, clothing, or jewelry can also be recorded and are useful for establishing identification. Interpol has contracted a Danish IT company for its data software which is used to compare data entered into it from both antemortem and postmortem records of missing people [3, 5].

A vast number of discipline can be utilized to reinforce the identification of victims. Techniques include visual identification of both the body and the belongings recovered from the body, fingerprinting, radiology, inspection of unique medical features, anthropology, and dental comparisons [4].

### **8.3 Working Conditions**

A temporary morgue is usually constructed where the victims are taken for examination. Bodies are firstly cooled with dry ice, then packed in body bags, and tagged with labels or tracking number. Body bags are usually stored in containers having temperature below 0 °C. Cooling is done to prevent putrefaction of the body.

For identification of human remains, which are highly decomposed or partially skeletonized, certain methods are used. Forensic dactyloscopy, forensic odontology, forensic anthropology, and pathology are disciplines which assist in identification of the deceased. Fingerprints and palm prints along with the external body detail are recorded first. Person's belongings like clothes, jewelry, tattoos, scars, etc. are also recorded [10].

Autopsy is performed latter to external analysis to expose prior surgery. The odontologist checks for dental records and prepares the radiographs which assist in age and gender estimation of victims. Anthropological findings are also recorded side by side. Postmortem findings are mentioned on pink Interpol form, whereas antemortem findings are mentioned on yellow Interpol form [8, 11].

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### **8.4 Key Tasks for Victim Identification [5]**

#### **8.4.1 Evidence Collection**

The evidences are recovered from the disaster site. These evidences include fragmented or complete evidences like fragmented or complete jaws, teeth, or bones. The bodies recovered from the site are usually mummified or dismembered. There is rarely any case in which the entire body without any injuries is found. Documentation and photography of the evidences are a must while collecting the evidence.

#### **8.4.2 Examination and Recording**

The officials from different disciplines employed at the site are responsible for maintaining safety standards and occupational health during analysis and documentation. They analyze the samples and make proper record of the information gathered from the evidence.

#### **8.4.3 Interpretation**

Forensic officials search and compare antemortem and postmortem data and compare the records. Once the comparison is done, forensic experts discuss and re-examine the information to generate a final report.

#### **8.4.4 Reporting**

Reports are imperative and are used for making a final decision. Reporting starts right from the initial assessment when officials reach the crime scene. All the minute things are noted down including the tagged labels of the bodies recovered. Separate DVI forms are available for recording the information. For instance, yellow Interpol forms are used for recording antemortem data, while pink Interpol forms are used for recording postmortem data. The information provided by the family members are also recorded, as it is also very beneficial in the investigation. All the reports are compared and studied, and a final decision is made by the forensic experts and lead investigator official.

#### **8.4.5 Presentation**

Officials are recommended to use a standardized format for data presentation. Standardized data ensures accuracy, clarity, and factual summary of collected and interpreted evidences. Proper guidelines are provided to officials for presenting the information they collected.

#### **8.4.6 Protocols**

Use of protocols is mandatory while dealing with any disaster case. The changes are made in the protocols accordingly; it depends upon the type of disaster. The officials along with the lead officers discuss the conditions and make changes in the protocols. The employed staff has to follow the guidelines and work according to them. For example, Interpol has given guidelines for working in different disaster cases. The guidelines provide information regarding sample collection, handling, analysis, and storage of information. Moreover, the guidelines are updated according to the recent developments. [22]

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### **8.5 Forensic Odontology**

Teeth being unsusceptible to the unpropitious conditions of the disasters can be used as a great investigative tool; hence, forensic odontology has played an imperative role in identifying large number of victims [12]. Forensic odontology is the study of teeth for legal issue and is considered as one of the primary identification method in identification of victims in mass fatality incident [8]. Dental teams are implored in collecting and recording both antemortem and postmortem data which are further compared and noted [5].

Forensic odontology comes into play in all of the five phases: [12]

- Scene
- Postmortem
- Antemortem
- Reconciliation
- Debrief

### **8.5.1 Scene**

At the crime scene or disaster scene, the odontologists are guided to collect and locate as well as document the image before retrieval. Protection of evidences is an imperative point to keep in mind during the collection procedure [12]. Proper equipment including overall suits, boots, rubber gloves, and helmets should be used, and guidelines should be followed. Dental remains which can easily get carbonized are reduced to fragile components [5]. Protecting these fragile evidences at the scene and during transportation to the mortuary is censorious and leads to difficulty in obtaining PM evidences and further identification procedure. The recovery method or procedure require accounts mapping including GPS and aerial photography of the disaster area [12].

### **8.5.2 Postmortem/Mortuary Team**

The mortuary team collects the information which is required for investigation. A proper area is constructed with all facilities for body examination. Different specialists including fingerprint expert, police, pathologist, DNA expert, and odontologist examine the body and register their findings on the pink Interpol form. Usually, forensic odontologists are employed to examine the body for confirmation of their findings [8].

Photography and documentation are done side by side. Personal belongings, clothing, and external body of the deceased are photographed. Other items such as watches and pocket contents are not used as direct proof, but these things act as a corroborative evidence [12]. The postmortem lead officer or in-charge should record all the findings in DVI form for each body. During dental examination, all the details are registered on the postmortem F1/F2 Interpol form [13]. Certain parameters followed by experts include the following: Jaws should not be removed by the odontologist until and unless more specific examination procedure is required. Use of computer technology and database software saves time and labor and reduces the risk of transposition error. Equipment used for examination includes dental mirrors, cheek retractors, probes, alcohol, or other chemical solvents for washing away the debris, tweezers, and toothbrushes. All these equipment should be properly sterilized because this might become a barrier in DNA cross-examination [12]. Battery-powered X-ray machines are usually used for dental radiographs. The use of nondestructive techniques should be done to get more access to dentition. Mandibular dissecting technique is recommended because it is nondestructive and it allows

easy access to both the maxilla and mandible by helping in repositioning facial tissue after autopsy [5, 8, 12].

Dental age estimation is an imperative parameter for identification [13]. Postmortem dental age estimation allows forensic experts to match the questioned dental evidences to that of suspected ones from the missing persons list. Morphological and radiological age-related parameters are used for age determination from teeth. Secondary dentine formation, enamel wear, cementum incremental lines, etc. are some of the points which provide aid in dental age investigation.

If the teeth sample is recovered as such, without any damage, then 2-D radiographs are used to apply Kvaal technique. After the development process, extraction methods are performed for examination. Genetic identification proves to be a commendable tool in identification of disaster victims [8]. DNA extraction from teeth can also act as complement method. Dental pulp material is a good source of DNA and is used for analysis purposes [5]. Canines and premolars are two vital teeth which can be extracted and sent to forensic DNA laboratory [8].

### 8.5.3 Antemortem Team

Antemortem information is obtained from family members of missing people. Family members can tell the information regarding healthcare centers from where the deceased went for treatment and other medical or dental information. All the dental records, CT scans, x-rays, dental models, mouth guards, and dental photographs should be collected. The content and source of original dental record can be analyzed and are noted on Interpol forms [8]. Some dental forms might be of poor quality because of abbreviation, nomenclature, discrepancies, or poor handwriting. In this case, forensic odontologists can also visit the treating dentist to gather information and clarify the problems of deceased searching, collecting, receiving, quality assurance transcribing, and analyzing which are crucial steps in quality system of DVI process [5, 12].

The dental teams elucidate and decipher the records onto yellow Interpol form, using FDI notation. Accuracy is paramount; hence, disparity should be classified, and further doubt should be referred to an antemortem team leader for arbitration. Care should be taken during elucidation of radiographs. After transcription, one must check the quality which is part of the protocol to be followed to avoid jeopardizing the quality of data gathered [5, 8, 13].

### 8.5.4 Reconciliation

In the reconciliation phase, odontologists compare the antemortem dental record with the postmortem record and make a record of findings.

Software likes DVI system international is a useful application for comparing large number of records. The end decision is taken by odontologists, who manually check and discuss the findings. Certain discrepancies are usually found in the

comparable data. Radiographs and anatomical data are usually checked, and individualistic features are noted. Superimposition technique is also performed on dental structures. Other information like dental implants and radiographs of long shapes aid in comparison procedure.

For quality assurance, the report made by the officials should be standardized, unbiased, clear, and impartial; all the conclusions should be made in layman language without using technical terms [12].

### **8.5.5 Debrief**

In debrief stage, the major focus is to review all the aspects of identification of disaster victims. This is done to check whether the earlier procedures performed are accurate or the protocols need to be improved for further use. All the details gathered in the above stages are checked and presented to the odontology coordinator; all the information including staff rosters, occupational health safety, management, security, reports, quality assurance, methodology, and future needs are also recorded and presented [13]. Every stage right from the commencement of disaster to debrief is checked and analyzed. Proper checklist is suggested to be made. DVI record register consists of all the aspects of quality management in DVI cases and is available without any cost if needful [8].

If the disaster occurs at a large scale causing immense destruction to the population, then it is very difficult for forensic odontologists to deal with the situation. This may cause error because of time and cost for examination, analysis, and sampling of deceased bodies. Byard and Winskog suggested that one must focus on the number of cases that need to be re-examined [5].

Proper SOP (standardization operating procedures), forward planning, standardization, and international cooperation are important to provide an effective response to any DVI incident [5].

Forensic odontology is an imperative method which has been developed enormously since 2004 after recent developments in odontology in the tsunami case which include computer-aided 3-D imaging, forensic radiology, forensic craniofacial reconstruction, and virtual autopsy. Newer diagnostic tools in forensic studies and analysis are developing, and the protocols for DVI operation are also optimized timely [5, 12].

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## **8.6 New Methodologies in Forensic Odontology**

There is much more specificity, sensitivity, and speed in odontology field because of newly introduced advancements and methodologies. New methods are used for analysis and interpretation of dental evidences and had made the investigation much easier and quicker than before [14].



### **8.6.1 Photography**

New cameras and photography tools are invented which assist in analysis. With the addition of measurement feature, there is no need to manually calculate the dimensions of the teeth or any dental sample. The software itself provides the entire details of the evidence making the analysis frequent and specific.

### **8.6.2 CAT Scanning**

Teeth and jaws can be scanned by unique features. The data is stored and can easily be compared with the antemortem records.

### **8.6.3 Barcoding**

This technique has been used in the past, but newer modifications have increased its specificity. It can store more information regarding the person as compared to prior ones.

### **8.6.4 RFID Tags**

RFID stands for radio-frequency identification. This is used for locating and identifying tagged living or non-living things. A microchip is used which stores information and tag number. The digital information is converted to interpretable information by the use of antenna.

### **8.6.5 3-D Scanning**

Documentation of evidences can be done by 3-D laser scanner. The scanner is a very effective tool as it can measure the level of bite marks. Moreover, one can obtain tool impressions by using this 3-D scanner. Intraoral 3-D maps are also useful as they have high resolution and, hence, assist in investigation.

### **8.6.6 3-D Printing**

Re-creation of dental images in an accurate manner is very helpful in testing the missing fragments of the jaw found at the disaster site. The jaws are printed via 3-D printers, and hence, the missing fragments are compared.

These evolving technologies will provide great aid in investigation of disaster victims. These methodologies help in collection, interpretation, and storage of dental data. Results are usually specific, quicker, and accurate.

## 8.7 Case Studies

- The first dental identification was done in the year 1849 in the United States. Dr. Oscar Amoedo was the first person who used dental evidence for identification in mass disaster. He analyzed the samples in the fire disaster that was held in a charity bazar in Paris in 1897; hence, he is considered as the father of Forensic Odontology.
- In 9/11, thousands of people lost their life in the attacks on the World Trade Center in the United States. Victims were identified using the DNA extract found in their toothbrushes.
- In India, the first case of dental identification was done in 1191. The first human identified using dental evidence was M. Raja Jayachandra Rathore, a native of Canouj. He passed away in battle and was identified on the basis of his false anterior teeth [14].

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## 8.8 Forensic Anthropology

Forensic anthropology is the study of the evidences or material believed to be of human origin to answer the questions related to medico-legal investigation or identification [15]. Anthropologists have been part of disaster victim identification for a century. Earlier anthropologists were employed to generate biological profile from dead remains [3]. Nowadays, forensic anthropologists can develop and implement quality assurance and quality control. The bodies recovered from the disasters are usually decomposed, cremated, distorted, partially burnt, or fragmented on combination of such conditions. The officials employed for locating, recovery, and analysis must have skills and expertise to deal with such cases. They must know how to distinguish the bodies on the basis of their remains, so anthropologists deal with several such cases and play a vital role in disaster victim identification process. Forensic anthropologists work in some phases of the DVI process [5, 14, 16, 17].

### 8.8.1 Scene

Generally, forensic anthropologists and pathologists are not part of the crime scene investigation, but in mass fatality incident, they might need to visit the crime scene to identify the remains. They overlook the preservation procedure at the site; in addition to that, anthropologists can identify, collect, and recognize the evidences which they can analyze further. Poor management or preservation can affect the integrity of the evidence and might lead to barrier in reconstruction of events. Anthropologists can also recognize and identify spatial temporal relationship b/w bodies and associated evidences. This also helps in identifying the number of individuals. Mapping of the scene is an imperative step during the investigation. The scene should be photographed and documented properly [16].

### 8.8.2 Mortuary

The DVI mortuary involves various specialties including radiology, fingerprint, pathology, photography, and DNA collection. After the collection of the evidences, they are sent to the mortuary for analysis. Separation of anthropologist samples takes place in this case. The bone samples are distinguished, human or non-human, recognizable or non-recognizable, and amalgamated remains separated. After separation, the skeletal anthropologists analyze to infer the location of the bone inside the body and position (left/right) of the bone in skeleton and soft tissues [14].

All these evaluations can aid in determining the number of deceased and generating the biological profile including age, gender, and stature of the individual. Proper reports are made by anthropology experts regarding ante-, peri- and postmortem findings [13, 15, 16].

The bones recovered from the affected area initially appear to belong to a single individual but after closer examination can reveal that minute fragments of other individuals also commingled with them. The muscles and bones of different individuals can be collected or analyzed as a whole and can be predicted to be of different individual after analysis. Before analysis, it is imperative to sort or separate the commingled bones before X-ray, photography, and DNA analysis.

These coalesced evidences are responsible for inappropriate assessment, and hence they need to be separated after discovering such samples; it is important to re-examine the samples and make reports accordingly and split into multiple new cases. For instance, if the X-ray is taken before the split, it will contain all the merged remains, and the results will not be accurate.

Other information that forensic anthropologists can provide are details regarding skeletal pathologies, skeletal anomalies, and variation. This information is potentially useful and aids in identification procedure.

Forensic anthropologists have knowledge regarding bones, bone remodeling, and taphonomy. Forensic archeologists and anthropologists cooperate with each other and show their expertise. Forensic archaeology has developed advancement techniques in mapping, searching, and processing a crime scene. Interpol DVI guide helps in the mapping procedure and provides labels for all the recovered evidences or bodies found at the crime scene. The recent trends include use of electronics mapping equipment such as drones and GPS. Such devices help DVI team map a disaster site. Geographical information system provides useful information and helps in recording the location of human remains. The location and evidences can be electrically recorded in mobile phones or other GIS-linked devices [17].

The identification of deceased migrants is not possible by using techniques such as DNA, odontology, and fingerprints. There is a need for development of alternative methods for identification such as forensic anthropological biological profiling. Having knowledge regarding human anatomy and variability, anthropologists are considering new advancement methods to analyze decomposed and skeletonized samples. Anthropologists can help in identification as the ideas and newer methodologies are evolving.

The skills and expertise of forensic anthropologists are usually underutilized. These scientists can play an important role at disaster site during initial site assessments. They can generate bacterial profiles during postmortem from skeletal remains. During reconciliation, anthropologists check quality assurance and quality control protocols. Proper reports and pink integral DVI forms are [checked] made, and errors are checked. This field is essential for identification of maximum number of deceased in disasters [3, 13, 15].

### **8.8.3 Case Study**

In February 2009, Victoria situated in southeast Austria experienced the most destructive bushfire. This bushfire caused loss of several lives and properties. The forensic team including anthropologists, odontologists, and pathologists reached the site within 48 h of the disaster. The analysis and identification of deceased was carried out in the Victorian Institute of Forensic Medicine in Australia. Anthropologists played an essential role in initial site assessment and contributed a lot in identifying and recovering the skeletonized remains from the disaster site. Forensic anthropologists differentiated humans and non-human skeletal remains and generated biological profiles including age, gender, and stature. Moreover, they assisted in inferring the number of individuals at the crime scene [15].

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## **8.9 DNA DVI**

Deoxyribonucleic acid or DNA is an essential tool for identification in case of missing person, paternity disputes, and other criminal cases. Interpol has recommended DNA profiling as an imperative technique along with dactyloscopy, odontology, and pathology [4, 6, 10, 18].

### **8.9.1 Antemortem Samples**

Antemortem data can be collected from three sources as stated by Interpol guidelines:

1. First-degree relatives
2. Body fluid or autopsy sample of the victim
3. Personal belongings used by the deceased/victim

Buccal swabs, blood samples, or FTA cards can be used for collecting samples from the blood relations or families of deceased. Guthrie cards are also considered as antemortem samples.

First-degree relatives are usually considered because they provide good profile for identification person. A person with a forensic genetics background is also

required at the crime site. He would assist in collecting antemortem samples. Proper documentation of relationships and samples collected along with chain of custody is required. Interpol DVI forms should be filled out side by side as they ensure that all protocols are followed. Forms are considered as an essential thing for identification procedure. They are considered as an efficient way of collecting important and accurate data.

Family details provided by the witnesses and analyzed by the geneticists are documented by the sample collector. This information is required for pedigree.

A proper record of genetic and contact information should be maintained including sample type name, date of birth, gender of missing person, first name of person providing sample, relationship to missing person, etc. Buccal swab and other specimens collected are received and sent to the laboratory where they are stored at 4 °C. Interpol regards DNA sample as bio-bank samples. Bio-bank samples are either medical specimens or blood stain specimens. These specimen are used for screening purposes. These specimen are used for storing samples and preventing them from contamination. They are labelled with identify of donor. These stored samples are directly analyzed through DNA technique.

There has been an evolution in the use of cards for collecting samples for analysis. Some countries use Guthrie cards for identification. PKU cards were also used in Southeast Asia when identification of tsunami victim was performed in 2006.

Some DNA laboratories make an Excel database including all the information of the deceased, missing person.

AM data includes the personal belonging of the victims. The profile generated from personal objects can be easily compared with DNA profiles. Certain limitations might occur regarding the owner of that object or who has handled that thing. These parameters may generated mixed DNA profiles [6, 18].

## 8.9.2 Postmortem Samples

The collection, method of handling, and maintenance of specimens is dependent upon the type of disaster and the circumstances at the site of disaster. If proper record is not maintained, then it creates a barrier in identification. So, the official should make sure that they should follow Interpol protocols right from the initial assessment and cover all the procedures they follow and note down the findings.

Proper labeling, photography, written notes, and chain of custody should be maintained; kits for assessment including tubes, scalpels, and labels are used. Specific 1 M numbers should be provided or labelled to everybody. Forensic pathologists sit together and decide at an early stage which part of the body needs to be analyzed and needs to be deposed.

The DNA gets easily degraded by temperature, humidity, chemicals, and UV radiation. As stated earlier, samples should be kept at 4 °C. Preservatives like Genofix, common salt, and alcohol can be used; white rum can be used as a substitute if absolute alcohol is not available.

The samples are collected according to the condition of the body and the circumstances. In general, blood or soft tissues are considered for DNA analysis. In putrefied bodies, bone or tooth samples are considered for genotyping process. Putrefied bodies do not contain soft tissues because of degradation. Also, the quality of DNA decreases with time, and soft tissues are generally collected with swabs. Analyses done with soft tissue/fresh material are less time-consuming and less laborious. If the integrity of the sample is maintained, only then the DNA genotyping is easy. In mass disaster cases, generally, in postmortem process, the samples like blood or other body fluid or tissue samples are limited and have less integrity. Degraded DNA inhibits the extraction of large DNA fragments thus reducing the chance of victim identification.

The main study thing which affects sample quality is contamination; proper guidelines are needed to follow during sample collection from bones and teeth:

1. Protective clothing and clean sampling areas
2. Sterilized instruments
3. Storage in appropriate containers and in adequate temperature conditions

All the samples should be packed in sealed containers, and they should not leak. Every sample should be labelled properly, and proper chain of custody should be maintained [6, 18].

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## 8.10 DNA Analysis

DNA analysis is done by officials.

- Sample processing
- Isolation of DNA
- DNA profiling

### 8.10.1 Sample Processing

Processing of the sample collected from the disaster site is mandatory. All the tissues, blood samples, and mouth swab sampling cards need to be processed prior to extraction.

In case of disasters, there is a high rate of contamination. Hence, it is required that the officials should clean the samples and remove all the debris and other contaminants from the samples. For an instance, if a bone is recovered from the disaster site, it should be washed with tap water and then rinsed with ethanol. Tissue samples collected from the crime scene, either normal or burnt, are cut into slices. Blood samples are generally spotted on a sterile cloth and dried completely. All samples are treated separately to avoid contamination. The area where all these samples are processed is cleaned with sodium hypochlorite solution before and after

treatment of every sample. To deactivate nucleases and to destruct extraneous DNA, UV irradiation is used. [18, 23]

DVI manual provides people guidelines regarding the same collection; officials follow that instructions and work accordingly.

DNA qualification is performed by kits like Quantifiler™ [18].

## 8.10.2 Isolation of DNA

DNA extraction is performed on the basis of type of sample and the guidelines followed. Certain variations in the protocols are made at the disaster site according to the situation and type of case. PM samples recovered from the site include bones, tissue, blood, or other body fluids. DNA extracted from the samples are then quantified, and degradation is checked. Certain preservatives like from alive paraffin are used to store bio-bank samples.

During extraction procedure, the process followed should be gentle so that the DNA is not affected by any means and preservative removed. Quantification process proves better when high pH and high temperature are provided. Proper protocols should be followed for extracting of DNA. Little negligence can lead to loss of integrity of DNA samples.

Polymerase chain reaction technique can also be used for analysis. Use of FTA cards for collecting AM samples and then applying PCR is a commendable technique. It is less laborious because there is no need of extraction procedure and hence saves time and labor [6, 10, 18].

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## 8.11 DNA Profiling

### 8.11.1 STR (Short Tandem Repeats)

In human identification, fluorescent PCR multiplex is a standard method. It is expedient that both antemortem and postmortem samples are analyzed for the same STR loci.

The analyst must record the set of markers and kits used for DNA profiling, and one should not discard the sample if it does not match with the questioned sample during profiling.

A number of kits like CODIS and European and Interpol standard sets of markers are employed and are available for analysis.

### 8.11.2 SNPs

SNPs are useful for contaminated degraded sample because the DNA fragments are short. SNPs are an imperative tool for DVI and kinship analysis. One STR marker is similar to 15 SNPs. For kinship analysis, set of 52 SNPs are developed and tested.

The only limitation is that the amount of DNA for SNP analysis is not adequate because of degradation. SNPs used for DVI have been proved to be beneficial.

### **8.11.3 Mt. DNA**

Mt. DNA is the gentle material which is transferred from maternal side to the offspring. This DNA is more resistant to contamination because of circular structure. Mt. DNA is more abundant as compared to single-copy STR. This DNA is useful for kinship analysis. Mt. DNA is not much informative as compared to nuclear autosomal STR markers.

### **8.11.4 Y-Chromosome DNA**

Y-chromosome contains both STR and SNP markers. These chromosomes help in establishing parental lineages.

Postmortem data of parents, samples collected, can be used for identifying offspring by Y-chromosome analysis.

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## **8.12 Matching of DNA Profiles and Statistical Analysis**

The findings or profiles are firstly cross referred with AM and PM records. Proper software has been made by the Interpol team to assemble all data collected. The data contains all dental records and physical, anthropological, and pathological details. Ideally, profiles are compared and calculated, and report is generated.

First choice of markers is STR analysis.

Software is made applicable to handle Y-chromosome.

SNP Data and Mt. DNA Data

Software handles three parts of the DNA process.

- Registering the data
- Laboratory routine
- Matching, calculation, and reporting

### **8.12.1 Challenges**

- Fragmented remains are the main barrier which makes identification process difficult.
- In case of fire, contamination, or putrefaction cases, the DNA can't be used for DVI because of loss of integrity.
- Forensic identification focuses on direct identification and individualization using biologically stable molecule that is DNA. High temperature, microbial



infestation and putrefaction breakdowns the DNA, which makes identification impossible.

- DNA analysis is based on type of incident from which samples are collected. Recovered remains vary from intact bodies to complete fragment tissues or bones.
- “Mixed samples” are usually recovered from the crime scene which is also a limitation. [24]

### 8.12.2 New Outcomes

- Scientists are working on new primer sets which would amplify short DNA segments.
- Certain methodologies and technologies are going to be introduced which will fetch information from degraded DNA segments.
- Degraded sample profile would be compared with standard forensic STR profiles.

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### 8.13 Case Study

- On August 29, 1996, DNA typing was first used for disaster victim identification. The “Spitsbergen aircraft disaster” found 141 passengers dead along with the crew onboard. DNA typing technique was followed for identification and re-association of highly fragmented bodies. STR (short tandem repeats) analysis was performed at 8 loci, of 257 body parts; 139 out of 141 individuals were identified. Reference DNA samples of two individuals were not available. DNA typing showed 100% success rate in identifying victims in aircraft disaster. Hence, DNA typing is employed as a means of identification [6].

DNA is considered as one of the essential methods of victim identification in cases of DVI. DNA typing is performed, and it starts with collection procedure. Collection of antemortem samples and postmortem samples is done, and then analysis and matching procedure follows [10, 18].

#### 8.13.1 Fingerprints

After the external examination of nod, fingerprints are collected by specially trained officials employed for recovering fingerprints of deceased. In mass disaster cases, generally putrefied and skeletonized bodies are recovered which have crushed injuries and mutilated face and body. The fingerprint expert takes the fingerprint by moving the degraded finger of the deceased with a gloved finger. This is only possible because of slippery condition of the skin. Tri-Tech forensic spray is used for clarity of ridges of fingerprints. Use of this spray is recommended than to use the conventional ink. The spray dries easily, and antiseptic ridge builder helps in getting clear prints. Conventional methods are not being used because they lead to

smudging; black printing ink was applied on paper, and then fingerprints were rolled on the fingerprint card. Fingerprints are then photographed. Proper record is maintained regarding the tag number of the body. The recorded fingerprints are matched with the antemortem record. Glass technique and tape methods are also used for collecting fingerprints. The glass technique is similar to the ink technique, the only difference is change of substrate. Microscopic glass slide is used as a substrate to capture the impressions.

Tape technique is also adopted by using normal transparent cellophane tape. The finger is applied with adhesive surface containing the ink, leaving an imprint on the substrate. The tape was peeled off from the surface and placed on fingerprint card. Black powder and white adhesive lifters are used for recovering the fingerprint. The time span between black and white identification and confirmation is calculated [10, 13, 17].

### 8.13.2 Radiography

Culbert and Law first used radiology for human identification in 1927. In case of mass fatality incident, the first use of radiographs was held in 1949 in Canada. This was the first time x-rays were used for disaster victim identification [2].

Radiology has multiple functions in mass fatality incident. It helps in detection of extraneous matter that may be hazardous to on-site investigators. The role of radiology has increased in human identification and mass fatality examination. Forensic radiology has become an imperative tool in causality identification [1, 11].

Radiology is used to reveal the exact position and location of evidences which assists in victim identification. The use of mobile PMCT scanners was first reported in Japan. Mobile CT scanner was first used by Ruddy and colleagues in small-scale mass fatality incident. A little advancement occurred, and then a new tool, namely, tele-radiology stem, for remote data reporting was introduced. This system evaluated and distributed PMCT scans globally and helped in identification of victims affected by disasters. This system was termed as FiMAG system. After using this system in varied disasters, many countries like Switzerland, Scandinavia, Japan, and Australia illustrated the benefits of mobile PMCT tool. It has the ability to collect information and aids in identification [2].

The International Society for Forensic Radiology and Imaging was established in 2012. Its main focus was to develop and strengthen the field of forensic radiology and imaging across the world. New advancements and techniques were launched in the field of forensic radiology. Six working groups were made for recommending development regarding certain areas including:

- (a) Data acquisition
- (b) Reading and reporting of images
- (c) Education
- (d) Certification and accreditation

- (e) Networking
- (f) Disaster victim identification

ISFRI suggested that radiographs should also be used as a modality in DVI. Radiographs include plain films, fluoroscopy, and digital or computed radiographs. Computed tomography is also a development in the field of radiology.

MRI was made part of postmortem imaging. MRI can be used in those cases only in which antemortem reports are available. The International Association of Forensic Radiographers proposed the use of radiographs for:

1. Identification of cause of death and factors related to it
2. Disaster victim identification
3. Identification of potential hazardous
4. Collecting evidences for legal procedures

Proper protocols and guidelines are made for the official who works with radiographs. Quality and standards are maintained for standard approach [1, 2, 11, 16, 19].

#### Fluoroscopy

Surface investigation through fluoroscopy usually takes 15 mm. In this, radiological images throughout the body are taken. The machine is moved along the length of the body to capture the images.

#### Plain Film

These radiograph stations require a separate staff. The radiographs are examined by radiographers or forensic pathologists.

#### Dental x-rays

Dental x-rays are generally undertaken by forensic odontologists. They work affectively according to the type of case. Earlier, conventional dental x-rays were employed, but now Nomad™ digital x-rays are available.

#### Mobile CT

By the introduction of postmortem computed tomography, the other methods are now not used widely. Mobile CT is a new practice and replaced all other modalities. This technique is useful for dealing with disaster cases involving chemical, biological, radiological, or nuclear materials [2].

### 8.13.3 Postmortem Computer Tomography

PMCT plays an imperative roll in forensic investigation of disaster victims.

PMCT scanner includes lorry-based mobile phone, and it can be used at the mortuary where examination of bodies is done. The scanner used for radiography should be integrated so that it can handle the body without disturbing it. This technique is done without opening the body; opening of body bag is done in cases where enhanced CT scan is required. Manipulation is required sometimes; opening of body bag and manipulation is done only if the lead investigator gives consent. All

the manipulations done to the body are recorded; entering the radiology room requires lots of precautions. Officials entering the room must follow the instructions provided to them. Radiation protection materials should be worn. The official performing the imaging should be a forensic radiologist or DVI-trained radiography specialist.

The entire body bag should be scanned first in one go, and then further scanning of specific organs or parts is done. Robotic biopsy technology is a newly introduced technology for obtaining biopsies and fluid sampling using CT image control.

The images produced after the radiography are either digital or in file format. After imaging, hard copy of scans are taken, and specific points which are useful are selected and recorded.

Proper provision for storing data should be made so that no evidence should be left. Interpretation of images is done by specialists of different forensic fields including pathologists, anthropologists, radiologists, and dentists. Antemortem images are usually collected from family members of deceased. These images are used for comparison and identification of deceased. Comparison is done with PM data [19].

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## 8.14 Case Study

On December 2004, Sumatra-Andaman earthquake with a magnitude of 9.0 on the Richter scale along with a tsunami caused devastating effect to the people, properties, and natural resources. This disaster not only affected Thailand but also had massive impact on countries like India and Bengal and Andaman oceans.

Proper disaster victim identification or DVI team was set up for investigation and identification purposes. The DVI team consisted of three sub-teams:

- Antemortem team
- Postmortem team
- Logistics support team

A separate team, namely, “necrosearch” team, was made. This team was guided to collect victims to the autopsy site.

The Belgian DVI team comprised of:

- Policemen (having expertise in recovery, logistics, scientific laboratory, and photography)
- Medical examiner from forensic background
- Forensic odontologist
- Civil protection unit (for care and transport of body and machinery)
- Psychologist
- Medical doctor and his team (for medical needs of team members)

Postmortem team required forensic experts from different disciplines and a military personnel. Antemortem team consisted of five policemen, psychologists, and social assistants.

The Belgian DVI team got assistance from international DVI teams including France, China, New Zealand, Australia, etc. Several members of DVI teams were employed in database organization at Thai Tsunami Victim Identification Information Management Center in Phuket [20].

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## 8.15 Methods Employed for Body Examination

Bodies from disaster sites were recovered by local men prior to arrival of the DVI team. After proper management of all the facilities like electricity, air conditioning, water supply, and proper ventilated autopsy room, PM identification team was divided into four sections:

- Fingerprinting
- Medical examination
- Odontological examination
- DNA sampling

First working area was the Fingerprint section. Fingerprints were taken by gloving and de-gloving method. Finger skin of the victim was carefully removed by de-gloving technique and was further gloved on the finger of the official. Powder was applied on the detached skin, and impressions were taken on the clean sheet.

A separate fingerprinting room was there which was very useful. After taking impressions, the body was sent to the autopsy room for external and internal analysis.

Clothing and personal objects were removed, cleaned, photographed, and recorded.

External body examination included:

- Height
- Description of scars, marks, moles, tattoos, and congenital abnormalities
- Description of physical characteristics (hair color, axillary, pubic and arm hair description)

The internal autopsy conducted by the experts was limited to abdominal cavity, gall bladder, and genital area only.

After the autopsy, the body was sent to third section where dental evidences were analyzed by forensic dental experts. Experts used dissecting technique for forensic dental analysis. This technique leads to easy access of both maxilla and mandibular dentition. Photography was done separately for the upper jaw, lower jaw, and teeth. The officials followed Interpol guidelines for investigation. Forensic odontologists

checked for oral anatomical abnormalities, attrition, and missing teeth. All the observations are recorded on F1/F2 forms provided by Interpol.

The recovered bodies were putrefied and fragmented; hence, for DNA analysis, femoral shaft sampling was performed. This sampling was performed by anthropologists. DNA sampling was carried out in a different area. Sterilized tools and equipment were used for this procedure to avoid contamination. Premolars and canines were also collected because they contain a sufficient pulp material for DNA analysis.

Further, the body was transported to the radiology area where the odontologist took dental radiographs of the deceased. Earlier, dental x-ray was used, but after sometime, the officials were provided with Nomad™ for facilitating dental analysis task.

Postmortem work was quite hectic, firstly, because of the number of victims and, secondly, each examination section was given 20 min per body examination. Officials faced lots of problems due to lack of time.

The findings stated that most of the victim died because of drowning and blunt trauma. The final desk performed duty as follows:

- Checking that all examinations are carried out properly
- Checking that tag number or labels were given to each body
- Checking the quality of radiographs after x-rays
- Quality assurance and quality control of all documents and reports.

After all the procedures, the body was stored in a refrigerated container, and its location and container number or body bag number is recorded by the body handler [10, 16, 20].

### **8.15.1 Identification Process**

All the information from the PM teams was collected for further reconstructive identification. Dental, medical clues, fingerprints, DNA reports, and other physical attributes were collected for making reconstructed profile of an individual. The reconstructed profile was made in order to compare with AM data.

Interpol AM and PM forms were filled separately, and during reconstructive identification they were checked. AM data or information was collected from acquaintances, co-workers, friends, and even doctors of missing persons. It is imperative to collect photographs and fingerprints of the missing person. Fingerprints can be collected from old documents and other items which were used by the victim itself. These things may include shampoo bottles, perfume bottles, etc. Hair samples, toothbrush, and other personal stuff of the victim were also collected. These items were required for DNA analysis. DNA acts as a key tool in kinship analysis. Hence, to infer the relationship, blood or saliva samples of the relatives were also taken.

Antemortem teams were employed to collect certain details from the victim's family including:

- Medical reports
- Dental reports
- Morphological characteristics
- Photograph of victims
- Description of clothes, jewelry, and other personal stuff of the victim

All the collected data was then sent to the Identification section, and then proper data file was made in the computer. PlassData™ was used as a software which allowed research and automatic comparison of all recovered data.

The Interpol guidelines helped a lot in positive identification of multitudinous victims. For DNA identification, Interpol form contained DNA document in which methods to be followed and markers to be followed and markers to be used were enlisted. This was made for uniform comparative application all around the world. All the PM and AM data was uploaded in PlassData™ software. After that, daily automatic research for missing people was started. If the computer showed a match, then manual analysis is performed by the officials.

The final report was sent to the reconciliation board which comprised of forensic experts and investigative officials. Final decisions were taken by the board, and after confirmation, death certificates were issued, and bodies were released [5, 6, 8, 16, 18].

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## 8.16 Modern Advancements

The concept of forensic identification is enhancing with the coming years. Many advancements can be seen in the identification tools in the past few decades. The Interpol has set certain guidelines for working at the disaster site. Most of the countries follow those protocols in case of emergency. There are other practices and protocols used by some other countries [10, 17, 21].

Johnson and Riemen introduced modern fingerprint technology. This technology focuses on capturing digital fingerprints for disaster victim identification. New advancement in fingerprint technology has brought a new revolution in the field of ridgeology. Digit fingerprints captured by the experts from mass disaster site are more accurate and efficient. This methodology saves time and labor. The gloving and de-gloving method usually employed for fingerprint collection is tedious and is not much accurate as the ridge impressions of fingers are not clear [4, 7, 14].

Genetic profiling is also a new methodology implemented for mass fatality investigation. It helps in importing different allelic data formats on different indexes. The data is imported according to the type of samples and the scenario of the disasters.

PATPCR-v 2.25 software is a lab-developed software. It is useful in kinship analysis. It can evaluate three types of parent-children relationship including:

- Single parental
- Conventional paternity trios
- Paternity and maternity cases

Gene Codes Corporation has developed a new bioinformatics tool called M-FISys for mass fatality identification. It is helpful in searching DNA profiles and tracking samples among the collaborating laboratories. Tillmar et al. introduced the massively parallel sequencing (MPS) for DNA identification of biological samples. By using this technique, a good amount of DNA can be obtained from the decomposed and degraded samples or remains. Research and advancements are still ongoing in this field, and positive comparative identification can be done using this technique.

CrimTrac provided a software known as NCIDD software. This software is used by all jurisdictions in Australia for direct matching. At the time of bushfires in Australia, CrimTrac was testing the CODIS 6.0 software for pedigree and relationship analysis. NCIDD software was employed for identification procedure and to detect the matches between antemortem DNA profiles and the profiles obtained from the postmortem DNA samples.

Virtual autopsy is growing quickly in forensic identification. It is used not only in craniofacial reconstruction but also in the entire autopsy process. Virtopsy project has different imaging methods [8]:

- 3-D photogrammetry-based optical surface scanning
- Multi-slice CT (MSCT)
- MRI (magnetic resonance imaging)

Virtopsy is a noninvasive approach; it helps in providing unambiguous, objective, and coherent documentation of forensic findings for testimony in court.

Craniofacial reconstruction (CFR) is used when the corpse face is unrecognizable due to mummification, calcination, or any other means. The main objective of CFR technique is to reconstruct the face of the unidentified body. This method is quite helpful in identification of victims. Currently 3-D manual methods are used. Use of clay or plasticine is done, but this method requires high skills and expertise. The improvement in imaging technology has introduced computer-based CFR methods.

Forensic odontology plays an imperative role in identification procedure in DVI. There is a need for antemortem records for comparison. Adequate antemortem records and proper skilled expertise in postmortem identification prove to be efficient and accurate for identification. Forest has introduced an imaging technology in odontological analysis for accurate identification [8, 13, 21].

Barone and Di Maggio prepared a ground-penetrating radar (GPR) which can be used for investigation procedure. This radar can locate the exhumed remains in the locations which cannot be documented easily. The location of such remains is very essential prior to identification.



## 8.17 Conclusion

Disaster victim identification is a major task for forensic investigators. These disasters can be natural or man-made. Each disaster has its own scenario, and the scenario defines its own methodologies for identification of the victims. Different forensic disciplines including anthropology, odontology, radiology, pathology, DNA, and fingerprint work together for identification of the unidentified bodies. Antemortem and postmortem data should be made accurately by following the DVI guidelines. The final results are made on the basis of these antemortem and postmortem records. This chapter consists of all the procedures and protocols followed by different forensic experts. There will undoubtedly be many more advancements made in this field which will make the identification process much easier and efficient.

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