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The Role of Forensic Anthropology in the Examination of the Daegu Subway Disaster (2003, Korea)*

ABSTRACT: Meticulous recovery of victims in the Daegu subway disaster was possible, because charred and fragmented victims were left *in situ*. Because bodies were piled one over another within the train, appropriate methodology during the recovery was critical to identifying the victims. The disaster area was thoroughly documented with notes, photographs, and schematic drawings of the various locations. The recovery team, comprising two medical examiners and one forensic anthropologist, decided when charred body parts and cremated bones were linked to the same individual based on the anatomy and forensic anthropological examination. Without these recovery procedures, it would not have been possible to efficiently harvest representative DNA sample from most of the victims' body parts. After the entire process of identification, 136 victims were positively identified, and six victims remained unidentified. This study supports the crucial role of forensic anthropologists in the recovery of victims, especially in fire scenes.

KEYWORDS: forensic science, forensic anthropology, disaster, identification, fire scenes, recovery

During the past decade, several mass disasters have occurred in Korea, such as the collapse of the Sungsoo Bridge in 1994 and the Sampoong department store in 1995. Taskforce teams, whose members come mainly from the faculties of the National Institute of Scientific Investigation, managed the former disasters. The concept of using established teams of specialists, like the National Transportation Safety Board (1), did not exist in Korea at that time. Furthermore, the recovery and investigative teams in Korea did not include specialists such as medical examiners and forensic anthropologists.

The Korea Disaster Mortuary Operational Response Team (KDMORT) was formed in 2002 to manage mass disasters in Korea. The Air China crash near Kimhae Airport in 2002 was the first mass disaster managed by the KDMORT (2,3). The organization includes divisions of forensic medicine, forensic odontology, physical analysis, forensic biology, forensic radiology, and forensic anthropology.

The Daegu subway disaster occurred around 10:00 AM on 18th February 2003. The male perpetrator began the fire by spilling a bottle of paint thinner on the floor of the number 1079 train. All passengers were evacuated from the train within a few minutes. However, when the number 1080 train arrived at the station opposite, the fire was burning in the number 1079 train. A locomotive engineer reported to the Subway Control Center and waited for the command. Meanwhile, the fire shifted and ignited the number 1080 train, which burst into flames instantly. The automatic door system in the train number 1080 train malfunctioned because of the fire, and because the passengers could not open the doors manually, they crowded into the first two rooms where they struggled unsuccessfully to escape. All victims were exposed to intensive heat for about an hour. After the firefighters extinguished the fire, they tried to recover the victims' bodies but quickly realized that recovery was not possible without help. One specialist from the local jurisdictions asserted that the victims could only be identified through DNA analysis of the charred and fragmented body parts that could provide DNA for analysis. And he also recommended that completely cremated bones should be collected but not analyzed. The assertion was that there was no way to analyze the cremated bones or to obtain sufficient DNA for analysis. In contrast, the division of forensic anthropology in the KDMORT argued that forensic anthropology expertise during the recovery could contribute significantly to the identification of victims in mass disasters (4–7) and that the charred body parts and completely cremated bones could potentially be link to specific individuals. The KDMORT convinced the committee of the bereaved and the law-enforcement authorities that a meticulous and scientific investigative approach could be used during the recovery to establish the positive identification of the victims (8–11).

The 2003 Daegu subway disaster differed from the 2002 Air China crash near Kimhae Airport in many aspects. The subway fire involved intense heat and an unknown number of victims. The charred and fragmented victims were left *in situ* and represented an open disaster site wherein the remains were not disturbed by nonmedical personnel such as firefighters, soldiers, and police officers. Victims were piled one over another within the narrow interior

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structure of the train. The charred body parts and completely cremated bones maintained their three-dimensional morphology because the trains had stopped when the fire started.

The purpose of this study was to introduce the KDMORT and to describe the crucial role of forensic anthropologists in the recovery of multiple-fatality incidents, especially in fire scenes.

Methods

While the number 1079 and 1080 trains were moved to the Walbae Vehicles Base, where vehicle maintenance is operated, to isolate them from the scenes, we modified the chain of command (12) and established a flowchart of information as shown in Fig. 1. With the help of the firefighters, a medical examiner divided the disaster area, comprising the interior structure of the rooms of the trains, into sections according to the quantity of the remains (Fig. 2) and *in situ* photographs were taken. Two recovery teams, each comprised of two medical examiners and one forensic anthropologist, recovered the bodies from the trains to ensure that the work was reliable and unbiased.

As the surface debris was cleared with brushes, all the charred, scattered, and fragmented body parts were located. During this process, the anatomical locations were noted for main body portions and attempts were made to conjoin the fragments. As each body part was located, it was assigned a "Ca" (for cadaver) number and the conjoined bones were assigned a subdivision number. For example, the information record "A12Ca01-3" indicated that the charred body part was located at room A of the number 1080 train and in area 12 (Fig. 1), and that it was the first numbered cadaver and the third bag of conjoined bone fragments. During the recovery, anthropological analysis of cremated bones was performed both to reconstruct the biological profiles and to separate and identify the commingled bone fragments according to specific morphological or structural features.

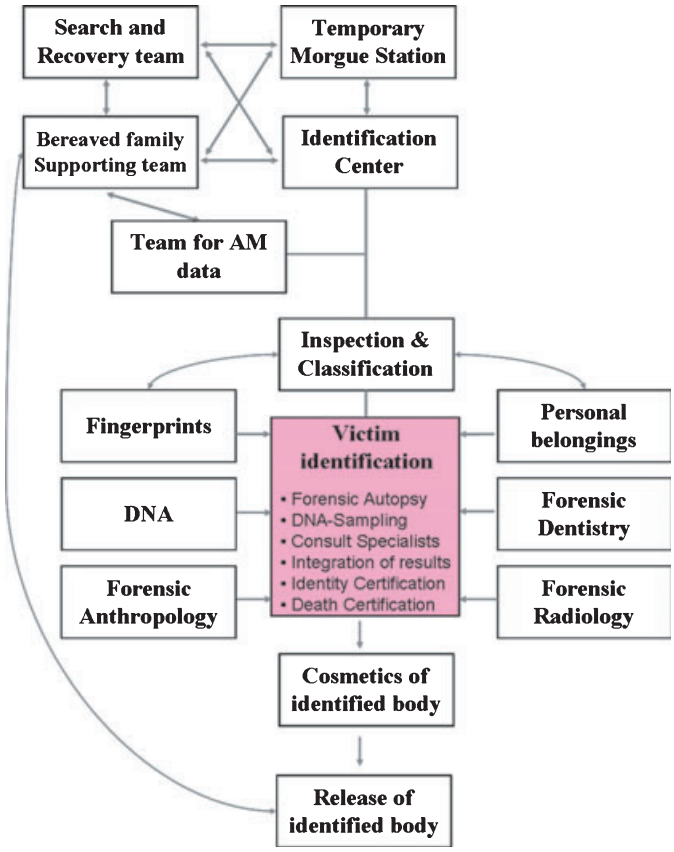

FIG. 1—*Schematic drawing showing the flowchart of information that was followed in the Daegu subway disaster.*

Occasionally, we could not link cremated bone fragments to the neighboring body parts at the scenes. In this situation, the unassociated bone fragments were collected and packed in zipper bags and assigned an "Fr" (for fragments) number. The designation "B03Fr02" meant that the unassociated bone fragments were collected from room B of the number 1080 train and in area 03 (Fig. 1), and that they were the second bag of fragments collected from this area. In those cases, an appropriate anthropological remark for the contents was also recorded, such as "male's right upper extremities" or "female's left hip bones" for subsequent reassembly in reference to the results of DNA analysis.

Only after the recovery teams announced that charred body parts and completely cremated bones were linked to the same individual, the schematic features of the corpse were drawn (Fig. 3) and photographs of most or all of one victim's body parts were taken with their corresponding area number and assigned number (Fig. 4). After the records were made at the scenes, we suggested to the division of forensic biology the appropriate part of a charred body from which to harvest a DNA sample. The body was then removed from the original location and placed in a steel tray for subsequent autopsy, including dental investigation and DNA sampling.

Still inside the train, the recovery teams cleaned the area in which the body was found to look for any personal effects of the victims. Once belongings were found, they were assigned to a corresponding area number and sent to the division of physical analysis for identification, cleaning, and reconstruction to their original condition.

To prepare for the equipment procedures (release the body to the bereaved and/or prepare for the funeral), the recovery teams began to reassemble the individuals. The charred body parts and the conjoined bones of each victim were laid out on a board in the anatomical position. During the reassembly of the victim, the surfaces of the body parts and bone fragments were brushed, and all the debris from each body was collected and stored in another zipper bag. The focus of reassembly then shifted to linking unassociated fragments based on the results of DNA analysis and the anatomical continuity. For example, suppose that there was a situation where three bodies were found in a specific area, "B03Ca01," "B03Ca02," and "B03Ca03." Based on DNA analysis the first and second bodies were determined to be male and the third body was determined to be female, and the second body had its own right upper extremities. In this case, the unassociated bony fragments that had anthropological comments such as "B03Fr02_male's right upper extremities" could be linked to "B03Ca01."

Results

The recovery team tried to link the charred body parts to the cremated bones based on anatomical continuity and anthropological examination. It took 7 days to recover all victims. Another 2 days were required for the recovery team to clean the inside of the trains. At the end of 10 days of recovery, nothing was left except for the steel frame of the trains (Fig. 5).

Anthropological remarks on the unassociated bone fragments were cross checked before these fragments were packed in the zipper bag. Bone fragments were identified by specific morphological

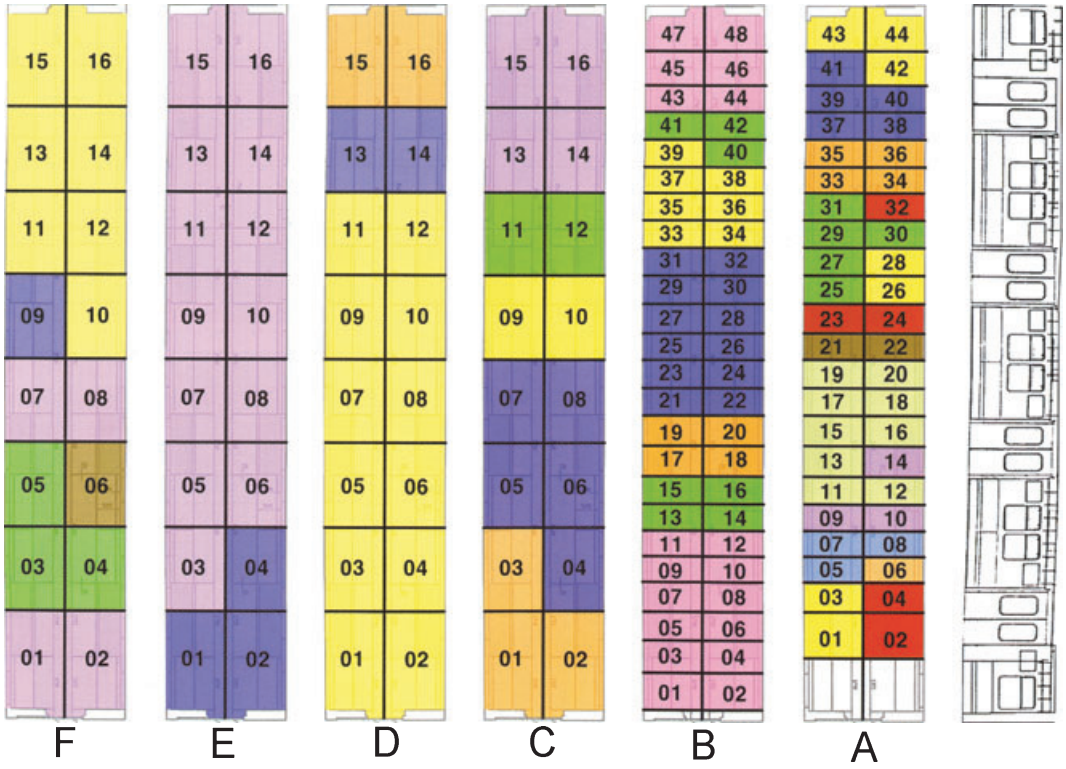

FIG. 2—*Map of the interior structure of the rooms of the number 1080 train. A large number of victims were found in rooms A and B, so each room is divided into two foot intervals. The rest of them are divided into six foot intervals. Different colors on the schematic drawing represent the time it took to finish the recovery process; red – more than 30 h, pink – 24 to 30 h, purple – 18 to 24 h and so forth.*

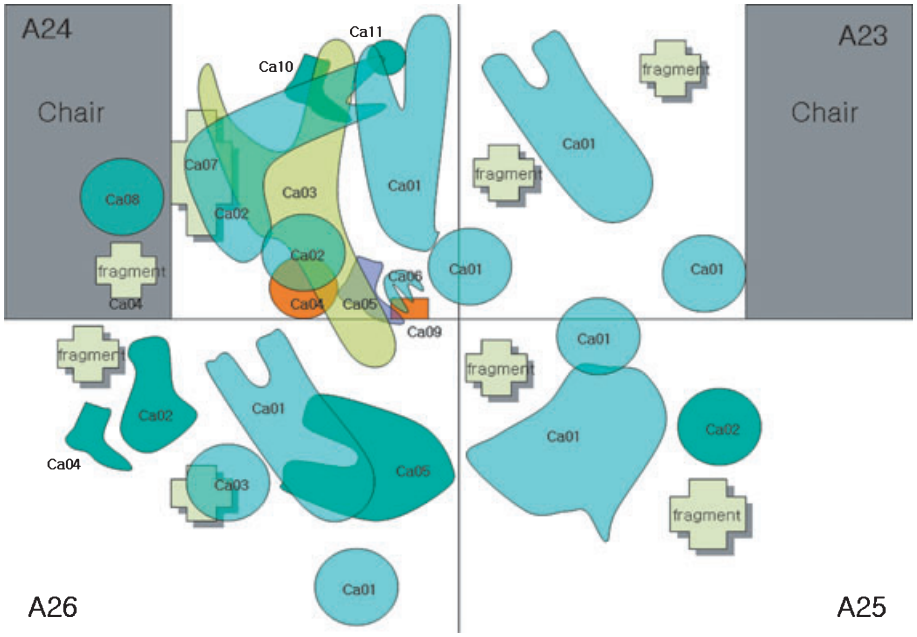

FIG. 3—*Schematic drawing reconstructed by computer program* (MS OFFICE, EXCEL) *which was based on hand drawings made on site during the recovery process, showing the postures and layers of victims. In area A24, we could recognize Ca01 is the most superficial; Ca02 is just beneath the Ca01 and this body is bent; Ca03 is the lower half of a body beneath Ca02. There are steel chairs for passengers along the wall (square gray boxes), and fragment on the chair of area A24 was linked to Ca04. Other fragments were united later.*

or structural features and were classified as belonging to the axial or appendicular skeleton. Determination of sex from the skeletal remains was based on skeletal indicators, especially those of the pelvis. Specific bone markings for the muscle attachment of the deltoid, gluteus maximus, rotator cuff muscles, and so forth were also considered.

Reassembly of the victims was needed to prepare for the equipment procedures. Stainless-steel trays lined with white Styrofoam

FIG. 4—*Every body part and bone fragment was tagged with their corresponding area number. A good example of recovered fragments tagged with the area code is shown. The information record "A24Ca03" indicated that the body part was located at room A of the number 1080 train and in area 24, and that it was the third numbered body. If there were cremated bones that were linked to this body, they would have been assigned as "A24Ca03-01," "A24Ca03-02."*

FIG. 5—*An interior structure of the room of the number 1080 train after the recovery when nothing was left except for the steel frame of the train.*

board were used for reassembly, and the victims, whose charred body parts and completely cremated bones had been determined to be linked to the same individual, were laid out in the anatomical position. Fragmented bones were reassociated to victims based on the results of DNA analysis and the anatomical continuity. The DNA analysis allowed us to link the cremated bones of a male's right upper extremities to the same area or the nearest victim who had been identified as a male, and had no right upper extremities.

During the reassembly of remains from room C area 14 (Fig. 2), we found small amounts of cremated bones of only the upper and lower extremities that could not be used for identification. However, a charred torso without any bone fragments of the upper and lower extremities, which had been identified by DNA analysis, was found in the morgue of the hospital (it might be the one out of several bodies removed from the train by firefighters at the end of extinguishing the fire). We were able to reconstruct a partial femur from fragmented lower extremity bones and perfectly matched this reconstructed partial femur to the broken lower extremity surface of the already identified torso (Fig. 6). Linking these remains reduced the estimate of the number of victims.

The division of physical analysis tried to reconstruct the original condition of the personal belongings, which had become damaged in the fire. They reconstructed hundreds of materials such as keys, rings, watches, buttons, shoes, and books. In room E area 8 (Fig. 2), we found completely cremated bone fragments without

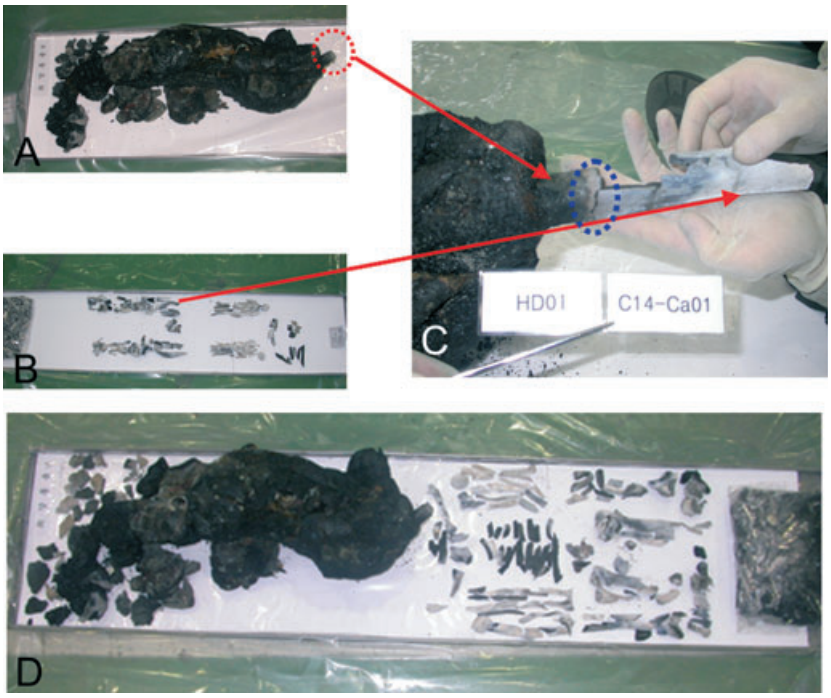

FIG. 6—*Photographs illustrating the reassembly process of identified victims. (A) Charred torso which yielded DNA. (B) Small amount of fragmented bones recovered from room C in area 14 and which failed to yield DNA for identification. (C) Reconstructed partial femur was perfectly matched to the broken lower extremity surface (red dotted circle) of the torso (blue dotted circle). (D) Charred torso and re-associated fragments were laid out on the same tray. This photograph is a good example of the reassembly process.*

FIG. 7—*Photographs illustrating the identification of a victim through anthropological analysis and personal effects. (A) Because fragmented bones were completely cremated, only a forensic anthropological examination was possible and the examination suggested the victim was a female, 150–160 cm tall, and in her fifth decade of age. (B) One metallic watch was found to be associated with the victim. The original condition of the watch was reconstructed by the division of physical analysis. (C) Engraving on the watch states "as a souvenir of 30 million products for Anicall (cell phone) by Samsung." We reviewed antemortem data of missing people and found a positive match for a 46-year-old woman, about 153 cm tall who owned the metallic watch with this engraving.*

any associated soft tissue, and the only associated personal effect recovered was a metallic watch. Forensic anthropological examination suggested that this victim was a female, 150–160 cm tall, and in her fifth decade of age. DNA analysis of the cremated bones of this victim did not yield positive identification, but the original condition of the metallic watch was reconstructed. We reviewed the antemortem data of missing people and found a missing person who matched our profile and had an identical watch. Thus identification was possible by physical analysis of the personal effect along with the anthropological examination (Fig. 7).

Thanks to the multidisciplinary team effort, we were able to declare the number of victims with reasonable certainty. There were 142 victims, which comprised 136 positively identified and six unidentified individuals, in the number 1080 train (Table 1). Despite the careful investigation, about 30 bags of bone fragments remained unassociated with the body parts. These were delivered to the committee of the bereaved and were cremated after a joint funeral service.

After a representative of the bereaved signed the formal documents, each identified body was returned to his or her respective family. The entire process of investigating, identifying, and returning the victims of the Daegu subway disaster to their family members took about 4 months.

Table 1—*Number of identified and unidentified victims in the Daegu subway disaster.*

	Detail Description	Individuals
Identified victims	Perfectly identified from possible examination (DNA, forensic odontology, personal effects, forensic radiology)	136
Unidentified victims; undetermined	Victims whose DNA results have no comparative antemortem data (no objective data from family)	3
Unidentified victims; impossible	Victims who neither yielded DNA nor associated personal effects (two males, one female: anthropological results)	3
Total		142

Discussion

Disaster victim identification normally comprises several procedures covering different disciplines: recovery of victims, mortuary center, collection of antemortem data, and identification center. An appropriate flowchart of information suitable for the unique circumstances in Korea was suggested for managing mass disasters. Before the Daegu subway disaster, recovery of the victims of disasters such as the 2002 Air China crash near Kimhae Airport was performed by firefighters. Because of the impact of the crash, the bodies of the victims were scattered widely, so only fragmented body parts could be collected. DNA analysis played an important role in identifying the victims at that time.

The Daegu subway disaster challenged the KDMORT to take a meticulous investigative approach in the recovery and reassembly of the victims because it was an open population disaster, charred and fragmented victims were left *in situ*, and the scenes was not compromised by nonmedical personnel. Some specialists tried to identify the victims by DNA but found that they could not harvest a DNA sample from every body part and fragmented bone. The division of forensic anthropology proposed that the recovery team should involve a forensic anthropologist, and all concerned parties agreed.

During the recovery, we established information records for victims using designations such as "A24Ca04-01" and "F08Fr01" identifying the location, train, and area of recovery. Each body part that was expected to yield DNA results was assigned a "Ca" number. The fragmented bones linked to the body part were assigned a subdivision number, but other fragmented bones were given a fragment or "Fr" number. This process helped us reassemble the victims. The recovery team announced that charred body parts and completely cremated bones were linked to the same individual based on the anatomic and forensic anthropological examinations. Thanks to the recovery procedures before the DNA analysis, it was

possible to harvest representative DNA samples from most or all of each victim's body parts. Without the recovery methodology employed, most of the cremated bones, which did not yield DNA, would have been left unassociated from the victims. Such anthropological examinations also reduce the number of samples necessary for DNA analysis, such as has been reported for the World Trade Center human identification project (13).

The entire process of identification of victims in the Daegu subway disaster took about 4 months. The actual time of completion was about 2 months, which included 10 days of recovery, 40 days of DNA analysis, and 10 days of reassembly. After the recovery, subsequent analyses such as autopsy, forensic odontology, and forensic radiology were performed. Problems arose because of claims for indemnity from the government by the bereaved, so equipment procedures took about 2 months.

Forensic anthropology is intertwined with other medical and scientific disciplines such as human anatomy, paleontology, archeology, and anthropology (14). Therefore, forensic anthropologists may be asked to identify fragmented skeletal remains from fires, cremations, and mass disasters (15,16). Recovery of skeletons requires skill and an understanding that once the remains are disturbed or removed, they can never be returned to their original condition. Forensic anthropological examination must be performed from the beginning of the recovery process when bodies are commingled and cremated.

We have demonstrated that forensic anthropological investigation can help in the appropriate recovery and accurate identification of disaster victims, especially in fire scenes. The Daegu subway disaster experiences also show that official protocols should be established and followed.

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