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Radiologic Evaluation of Mass Casualty Victims: Lessons from the Gander, Newfoundland, Accident[1]

This study describes the use of radiologic methods in the identification of 256 bodies after the crash of an airliner in Gander, Newfoundland. Two hundred thirty-one (90%) of the victims were identified positively with dental and/or fingerprint comparisons. Radiologic data confirmed identification in 29 of these victims. Seventeen bodies without dental or fingerprint identification were presumptively identified with a variety of data, which included radiologic characteristics in four cases. Eight bodies were identified with an exclusion matrix. Radiologic input was critical in two of these. The procedures described provide practical information for radiologists in a mass casualty disaster investigation.

Index terms: Forensic radiology

Radiology 1988; 168:229-233

On December 12, 1985, an Arrow Air DC-8 airliner, carrying 248 USA Army servicemen and eight civilian crew members, crashed and burned in a remote, heavily wooded area shortly after take-off from Gander, Newfoundland. All 256 people aboard were killed. A task force directed by members of the Aerospace Pathology Division of the Armed Forces Institute of Pathology (AFIP) was assembled to investigate the accident and identify the victims. After a thorough survey and mapping of the crash site, including a precise localization of all bodies and personal effects and a sequential alphanumeric listing of the bodies, all remains were transported to the USA Air Force Mortuary at Dover Air Force Base (Dover, Del) for identification and preparation for burial. This paper discusses the radiologic methods used in the identification process, including the application of recent advances.

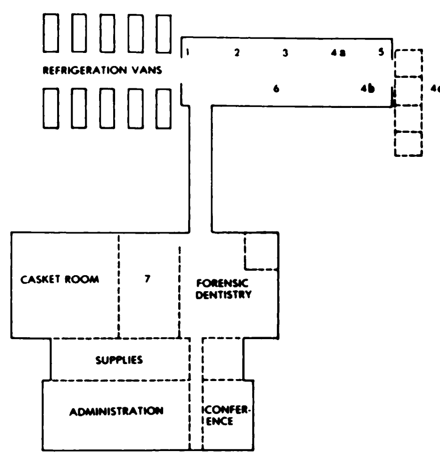

Figure 1. Line drawing of the mortuary building and warehouse shows the location of the assembly line stations. *1* = AFIP photographers, *2* = collection/categorizing of personal effects, *3* = fingerprints by FBI, *4* = medical radiographic facilities, *4a* = reading area, *4b* = portable unit, *4c* = field units, *5* = dental radiographic station, *6* = oral surgical examiner, and *7* = autopsy station.

METHODS

The task force for the identification of remains comprised pathologists, radiologists, dentists, anthropologists, photographers, Federal Bureau of Investigation (FBI) fingerprint specialists, a systems engineer, and administrative personnel. Four radiologists took part in the process. Two (M.E.M., F.J.W.) arrived at the mortuary just before the transfer of the remains and stayed throughout the initial radiologic evaluation; the other two (M.J.M., J.E.L.) participated after preliminary autopsies were completed.

In the mortuary, a multistation "assembly-line" type operation (1-3) designed to standardize and facilitate the examination of a large number of victims was established (Fig 1). Bodies were stored in aluminum transfer cases in refrigerated vans. Frontal photographs were taken of each victim to provide a visual record of the injuries. Next, all visible clothing and personal effects were removed and catalogued. FBI personnel obtained fingerprints whenever possible. Subsequently, radiographs of every body were obtained to provide a record of injuries. Thereafter, forensic dentists transected the mandibular rami of each victim. Radiographs of the mandibular rami were obtained prior to the postmortem dental examination. Finally, full autopsies were performed on all; the last of four female victims was identified on the basis of anthropologic criteria alone.

Initially, a portable radiography machine was borrowed from the base hospital. Portable lead shields were used to protect personnel. Subsequently, four self-contained radiographic units were obtained from USA Army mobile hospitals. Each of these fully shielded units contained a tube, table, film processor, chemicals, and a darkroom. Radiation safety was monitored by the base hospital radiation safety office.

The protocol for the initial radiologic examination of each body required only 14 × 17 inch (35 × 43 cm) film. On intact victims, anteroposterior projections of the head and neck, chest, abdomen, pelvis, and upper and lower extremities were obtained. On average, this was accom-

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The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the Departments of the Army, Air Force, Navy, or Defense.

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plished with 12 radiographs. All radiographs were labeled with the alphanumeric identification of each body. Four technologists were used in each station. Radiographs were screened for proper technique and position by the radiologist as they were developed. Repeat views were obtained immediately if required. Special projections were also obtained at this time. Radiologic findings were recorded on a standard skeletal diagram (Fig 2). Fracture sites, amputations, and other injuries were noted without a detailed written description. Where appropriate, annotations were made regarding surgical clips and sutures, orthopedic devices, personal effects, foreign bodies, and other potentially identifiable features. Radiographs and the radiologic reports were kept beside each body.

Almost all of the medical and dental records of the victims were destroyed in the fire. Therefore, it was necessary to contact previous duty stations, close relatives, and civilian medical/dental facilities to obtain any available studies. A similar procedure was used to obtain radiographic and dental studies on the civilian crew members. Antemortem radiographs were examined for unique characteristics that might match those of a victim. A revolving illuminator was used to display radiographs and make comparisons of premortem and postmortem radiographs. By placing premortem radiographs on the top roller and postmortem radiographs on the bottom roller, rapid searches for matching pairs were performed.

Identifications of bodies were made according to several categories, each with differing levels of confidence. Positive identification (category I) required one or more objective criteria, such as matching fingerprints or dental characteristics, identical skeletal appearances, and unique postoperative changes. Presumptive identification (category II) required a combination of less specific findings, some subjective, such as personal effects on a body or positive correlative findings between autopsy observations and anthropologic, medical, or radiologic data known about a given individual. Facial reconstruction drawings were also used as needed in this category.

For bodies that could not be included in either category I or II, an exclusion matrix method was used (Table 1). The matrix aligned specific antemortem data available from the individuals not yet identified with specific postmortem data available on the bodies not yet identified. This group was designated category III. Medical exclusions (M) were based primarily on the presence or absence of the vermiform appendix and/or the presence or absence of circumcision. Dental (D) and radiographic (X) exclusions were based on comparisons of available premortem records and radiographs to postmortem examinations and radiographic findings. Antemortem and postmortem radiographs were closely scrutinized with an emphasis on dissimilarity rather than similarity. Anthropologic exclusion criteria (A) included:

Race.—caucasian excludes negro, negro excludes caucasian, mixed excludes nothing.

Age.—exclusion when reported age differed by more than 4 years from the age range estimated from the remains.

Height.—exclusion when reported height differed by more than 4 inches from the estimated height.

Body build.—heavy excludes light, light excludes heavy, medium excludes nothing.

Since many of the criteria used in category III identifications were subjective, a methodology was necessary to integrate and appropriately weigh the observations of the radiologists, pathologists, dentists, and anthropologists being entered into the exclusion matrix. It was in this capacity that a systems engineer was used in a role independent of the various specialties to design a reliable and reproducible scale that would ensure the same identifications occurred no matter which body or name was used first. Close work with each investigator determined the confidence in dissimilarity between antemortem data and postmortem examinations, a confidence score was assigned by specialty to each comparison (eg; race, age, height, body build, presence or absence of vermiform appendix, medical radiographs, and dental examinations). The confidence in the degree of dissimilarity on radiographs was assigned ten grades from 0.0 to 1.0, with 1.0 representing 100% certainty of dissimilarity, 0.4–0.6 representing a 50% certainty of dissimilarity, and 0.0 representing 0% certainty of dissimilarity or 100% certainty of an identical match of premortem and postmortem radiographs (Fig 3). Confidence scores by specialty were then entered into a computer and analyzed in conjunction with confidence scores of all investigating disciplines. With this method, both intraspecialty observations and interspecialty observations were controlled.

RESULTS

A set of radiographs for each body required an average of 30 minutes to complete and present to a radiologist. Approximately 10% of the radiographs needed to be repeated. The initial examination of all victims was completed within 5 days.

Fragmentation injuries and burns caused by the crash and fire precluded the use of visual recognition to aid identification in all but two of the 256 bodies (Fig 4). Approximately one third of the bodies were relatively intact, one third were partially intact, and the remainder were fragmented. Seven medical radiographs were recovered from the crash but were not readable. Thirty-six usable antemortem dental radiographs were recovered. Additional medical radiographs were received on 128 military and two civilian victims, while additional dental records and radiographs were received on 179 military and all eight civilian victims.

Two hundred thirty-one persons (90% of the total) were identified with standard methods (category I). These included fingerprints (51 of

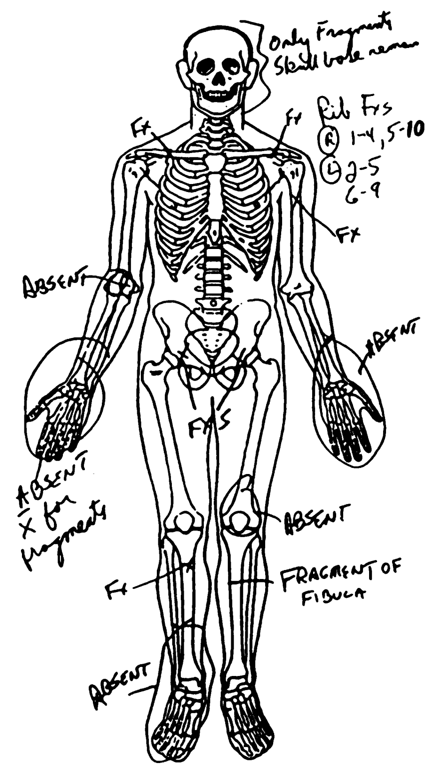


Figure 2. Skeletal diagram from an actual case demonstrates location of fractures and other pertinent information.

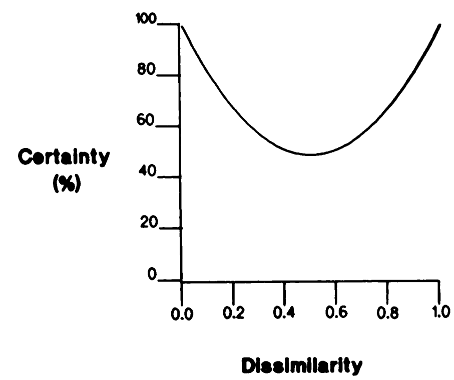


Figure 3. Graph representing confidence in the degree of dissimilarity between antemortem radiographs and postmortem radiographs of an unidentified body. Dissimilarity indices were subjectively decided by M.J.M. and J.E.L. A dissimilarity index of 1.0 represented 100% certainty that antemortem and postmortem radiographs were from different people. Conversely, a dissimilarity index of 0.0 represented 100% certainty that antemortem and postmortem radiographs were from the same person.

Figure 4. Severe burn and amputation injuries, as seen in this victim, were commonplace.

a. b.

Figure 5. **(a)** Antemortem radiograph of one of the passengers shows a small bone island in the distal radius. **(b)** Postmortem radiograph of a victim reveals an identical bone island when allowance is made for slight differences in rotation.

Table 1
Exclusion Matrix

Name No.	Body No.* 1	2	3	4	5	6	7	8
1	A	H	R	B	MA	DRB	B	...
2	...	A	A	AB	...	BA MD	AB	A
3	A	...	RH	H	HMA	HDR	H	...
4	...	A	RAH	HB	M	HD RB	HB	...
5	XB	B	B	X	MXA	DR	...	...
6	RA	RH	...	R	MRA	...	R	R
7	MX	H	...	...	MA	MDR	...	...
8	RA	R	...	RB	AMR	B	RB	R

* M = medical, D = dental, X = radiographic, R = race, A = age, H = height, B = build.

231), dental examination (113 of 231), or a combination of the two (67 of 231). Radiologic studies confirmed 29 of these identifications. Fifteen of the radiologic confirmations were of victims who were identified with fingerprints or dental examination. Examples of radiologic identification in three cases included a naturally occurring abnormality, a bone island (Fig 5), orthopedic surgical changes (Fig 6), and the unique anatomic configurations of the lumbar spine and calcaneus of one individual.

Seventeen category II identifications were made with radiologic comparisons and personal effects (four of 17); personal effects alone (11 of 17); a combination of personal effects, medical/surgical history, and anthropologic features (one of 17); and anthropologic features alone (one of 17). This last case involved the identification by exclusion of one of the four women on board. Three of the four had already been positively identified.

The final eight bodies were studied with the exclusion matrix (category III). Radiologic findings added confidence to four exclusions in this category and were crucial to the ultimate identification of the last two bodies; both were severely burned and of similar age, race, and anthropologic features. Antemortem chest radiographs were available on one of the two bodies. Severe thoracic trauma to the first victim precluded a match to the antemortem radiograph. However, when these antemortem radiographs were compared with the postmortem radiographs of the second body, significant dissimilarities were present. Therefore, it was confidently concluded that the two sets of radiographs were of different individuals.

The anatomic areas used in radiographic identification included the lumbar spine (nine cases), cervicothoracic spine (four cases), knee/tibia (four cases), ankle/foot (eight cases), wrist/forearm (two cases), sternum/clavicle (one case), and ribs (three cases). Orthopedic fixation devices allowed positive identification in four instances. Multiple areas of comparison were used in four cases.

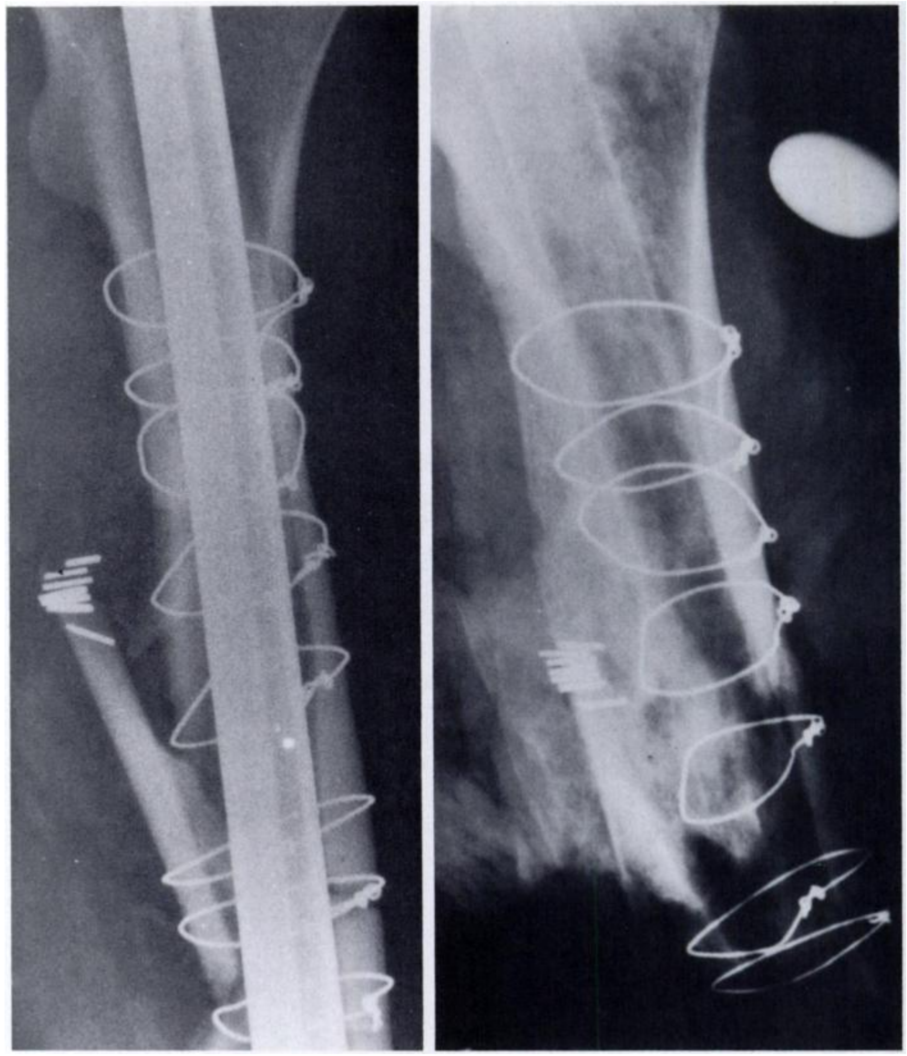
DISCUSSION

In our society, every attempt is made to identify each victim of an accident so that the remains may be returned to the next of kin. In addition to social and religious customs, legal considerations regarding survivorship benefits and estate settlements also require positive identification of the deceased (4). When the remains are burned, mutilated, or fragmented, identification often requires the expertise of a multidisciplinary team, particularly in the setting of a mass casualty disaster. Because of the extreme variability of disaster scenarios, improvisation is often necessary (2-4).

Lichtenstein et al (2) have divided the radiologic investigation into two separate but related processes: radiographic screening and victim identification. Screening involves the initial radiographic evaluation of the remains, a procedure of fundamental importance to the investigation. Department of Defense Aerospace Pathology protocols require radiologic examination of all victims. Civilian investigations usually limit radiologic examination to cockpit crew members and passengers not otherwise identifiable. This phase of the investigation requires knowledge of the number and names of victims, the location of the actual investigation (crash site, hospital, coroner/medical examiner office, mortuary), and the availability and type of radiographic equipment at the investigative site. The requirement and availability of radiology technologists and supplies must also be determined (film, screens and cassettes, processor, chemicals, numerically sequenced lead markers, film jackets, and radiographic reporting sheets). Liaison should be established with local radiologists for supplemental help should the need arise (2,3). Radiation protection, including monitoring, should also be arranged (2). All antemortem radiographic studies should be located and requested.

It is often not feasible to use the fixed radiographic equipment of a hospital. Portable radiographic machines provide satisfactory images and may be more readily available (2-4). Portable machines can be modified to operate from existing electrical supplies to obviate the need to constantly recharge batteries (1-3). Self-contained mobile USA Army field radiographic units like those used in this study might be procured through local Civil Defense or Department of Defense officials.

Good quality radiographs are essential. Fourteen-by-seventeen inch radiographs are recommended for the initial survey (2,3). Use of a standardized large format radiograph minimizes problems such as ordering and storing multiple film sizes, the need for a variety of cassettes and screens, a greater number of films to completely examine a victim, and difficulties estimating film requirements (2). Our average of 13.2 radiographs per body, including retakes, is very similar to the figure used by Singleton (4) (13 radiographs) during the Noronic investigation. Occasionally, smaller radiographs are needed to image fragmented remains or to reexamine a limited anatomic region. Lichtenstein (2) has recommended the use of grids to reduce scatter, and Sanders et al (5) used optical magnification to compare antemortem and postmortem studies. To our knowledge, the importance of screen-film combinations has not been previously emphasized in mass disasters. Because radiographic identification is totally dependent on subtle similarities and differences of skeletal structures on antemortem and postmortem radiographs, bone detail screen-film combinations are recommended to optimize characteristics of cortical and trabecular bone.



a. b.

Figure 6. **(a)** Antemortem radiograph shows a comminuted fracture of the left femur, eight cerclage wires, seven closely aligned surgical clips, and an intramedullary rod. **(b)** Postmortem radiograph of a left femur with a nearly identical pattern of postoperative change up to the point of traumatic amputation. The rod had been removed prior to the crash.

We found that preprinted whole-body skeletal diagrams were more advantageous than dicated or handwritten reports, which have been previously recommended (2). The diagrams allowed brief sketches with concise annotations of the injuries. This approach more accurately reflected the injuries seen on the radiographs and reduced reporting time.

Identification of the victim is the second goal of the radiologic investigation. Two types of identification are recognized as legal proof of identity: positive and presumptive. Positive identification depends on recognition of characteristics considered unique to a specific individual. This is achieved by discerning no dissimilarities between premortem and postmortem records, including dental studies; finger, palm and foot prints; and certain radiologic findings. In contrast to positive identification,

Figure 7. Postmortem coned anteroposterior projection of lower cervical and upper thoracic spine of a victim. Subtle differences in shape (C-6 is bifid, C-7 is round) and size of spinous processes and variations in angulation of the caudal surfaces provide multiple sites of comparison between antemortem and postmortem radiographs.

presumptive identification separates a subgroup of persons from the population rather than an individual. Nevertheless, a certified identification may be made when multiple antemortem and postmortem variables are compared and there are no dissimilarities. Variables used for presumptive identification include visual appearance, personal effects, medical records, anthropologic data, serologic studies, radiographic studies, and passenger lists.

The radiologic criteria that can be used for both positive and presumptive identification are numerous. Precise matching of trabecular patterns, cortical irregularities, normal variations, degenerative disease, and traumatic deformities on antemortem and postmortem radiographs can provide convincing proof of a victim's identity. Although a single skeletal peculiarity can provide positive identification (5), in most cases, the greater the number of matching skeletal features, the greater the certainty of identification (2-6). Anatomic areas of particular value are the paranasal and mastoid sinuses (7), the pattern of costal calcification (6), clavicles (5), the skull, spine and pelvis (4), and the presence of orthopedic devices or old fractures. Additionally, we found the spinous processes of the cervical and thoracic vertebrae to be very useful, particularly those of the lower cervical and upper thoracic areas. Size and shape of the base, angulation of the body, and bifid spinous processes reveal significant individual variations (Fig 7). We also found postmortem radiographs showing old fractures or surgical interventions to be particularly valuable. Likewise, congenital deformities such as spina bifida occulta, partial or complete sacralization of a lumbar vertebra, more than five non-rib-bearing lumbar vertebra, and vertebral fusions can be extremely helpful.

Victims still unidentified with positive or presumptive criteria may be identified by exclusion. This process is predicated on knowing the names of all the dead and procuring available demographic, medical, dental, and radiographic data on them. Each discipline involved in the investigation seeks to confidently conclude that antemortem and postmortem studies are from different individuals by discovering contrasting characteristics. Progressive elimination of all bodies but one under consideration for a special individual results in an identification and facilitates additional identifications by reducing the size of the matrix. Careful scrutiny of the previously described skeletal landmarks reveals radiologic criteria useful in the exclusion. Even though radiographs of bodies distorted by fire, trauma, or rigor mortis are difficult to compare with antemortem radiographs, enough anatomic variation may be identifiable to conclude that the two sets of studies are from different individuals. Combining exclusions by radiologic criteria with those of other disciplines proved to be crucial in the identification of the last eight bodies.

Fortunately, mass casualty disasters are uncommon in the United States. However, with over 400 million people flying on USA commercial aircraft each year, and many more millions traveling on buses, trains, and ships and living and/or working in our cities, the potential for a mass casualty accident is ever present. Radiology has been proven to have a valuable role in mass victim identifications (1-14), and the procedures described in this report provide updated practical information to aid the radiologist who participates in an investigative process. ■

Acknowledgments: The authors thank Alan J. Davidson, MD, for his invaluable assistance in editing this manuscript, and Bonnie Yelverton for her assistance in the preparation of the manuscript.

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