The Role of Forensic Anthropology in Mass Disaster Resolution

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On Dec. 12, 1985, a military charter DC-8 crashed shortly after takeoff at Gander, Nfld., Canada. All 256 aboard were killed, making this the deadliest U.S. military aircraft accident in history. The investigation team (consisting of forensic pathologists, odontologists, radiologists, anthropologists, graves registration personnel, and systems engineers) succeeded in identifying the remains of all 248 manifested passengers and 8 crewmembers. The unique contribution of anthropology necessitates that a forensic anthropologist be included in all phases of casualty resolution from recovery and initial processing to final evaluation, rather than being summoned as a last resort. This approach would yield immediate information on "unknowns" and would eliminate subsequent duplication of effort.

AS THE NUMBER and variety of mass disasters increase, the need for effective methods of establishing identification becomes critical. Since these disasters result in human remains that are incinerated, mutilated, fragmentary, partially skeletonized, or rapidly decomposing, it can be extremely difficult to establish visual identity. Dental records and fingerprints are used to make most of the positive identifications. But the problematical cases linger: remains without dentition or prints, those too badly damaged or too incomplete to yield much information. In an attempt to circumvent these problems, physical anthropologists are increasingly being asked to lend their expertise with bones to establish physical identity.

This has resulted in a new area of specialization for anthropologists, "forensic anthropology," defined as "the application of the physical anthropologist's specialized knowledge of human sexual, racial, age, and individual variation to problems of medical jurisprudence" (14). Since 1971, there has been a Physical Anthropology Section of the American Academy of Forensic Sciences; although it ranks among the smallest of the 10 sections, it grows each year.

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The techniques of forensic anthropology rely on familiarity with bony landmarks and surrounding anatomy and on knowledge of trait frequencies in populations. Since physical characteristics are general and exclusionary, an anthropologic evaluation is usually insufficient to establish positive identity, but it does eliminate many possible identities. The presence of bone injuries or disease processes can further individualize the remains. Antemortem radiographs can be matched with the remains (11), though this task more often falls to an odontologist or radiologist.

There are many excellent overviews of the range of forensic anthropology (4,13,14,16,18,19). This report is an application of anthropologic techniques to a particular set of circumstances: the crash of an Arrow Air DC-8 in Gander, Nfld., on Dec. 12, 1985.

EXAMINATION OF REMAINS

The investigation had been proceeding for over 3 weeks before the services of an anthropologist were requested to help with particularly difficult cases. These included 50 incinerated and dismembered remains for which no positive identity could be established due to insufficiency of individual remains and/or lack of antemortem records (the military medical/dental records were also on the plane and many were totally destroyed). As a physical anthropologist employed by the Army and experienced in current death cases, I was sent on Jan. 8 to the port mortuary at Dover Air Force Base, DE, where analysis of the remains was ongoing.

After an initial briefing, my first task was to evaluate 70 sets of pubic symphyses which had been excised, tagged with the processing number assigned to the remains, and cleaned. The pubic symphysis is a critical bony area for determining sex and age in adults. Males are characterized by short pubic rami, a small subpubic angle, lack of ventral arc and subpubic concavity, and a broad medial aspect to the ischiopubic ramus. Females show long pubic rami, a greater subpubic angle, ventral arc, subpubic concavity, and a narrow medial aspect (6,12). Two of the 70 subjects proved to be female.

After the late teens, the symphyseal face of the pubic

bones undergoes morphologic changes related to wear and tear of the intervening cartilage pad and surrounding tendons and ligaments. The early horizontal ridges and grooves give way to a smooth, eroded face with marginal lipping. These progressive changes have been extensively studied and related to age ranges (9,20), giving a fairly reliable age estimate to the trained observer. Pubic ages of the individuals I examined were found to range from 19–42.

My next task was to examine the 50 problematic remains to assess sex, age, race, stature and body build, bony peculiarities, and anomalies. It was first necessary to determine that each body bag contained the remains of just one individual. None was complete. Four of the remains consisted only of lower torso (hip to mid-thigh), one was head and shoulders, and two were hemipelves with legs and feet.

Having evaluated the pubic bones of all but five of these 50, I had indicators of age and sex. For those five individuals for whom no pubic bones were recovered, sex was easily determined by the remaining soft tisues; all were males. Ages for these individuals were determined by observations of dental root development and alveolar resorption (viewed radiographically, with assistance from the odontologists), presence of osteophytic outgrowths on axial skeleton, epiphyseal closure on the iliac crest, medial clavicle, vertebral centra, shoulder, wrist, and knee (5,8,9).

Race was (and usually is, in forensic cases) the most difficult biological feature to assess for a number of reasons. There are few population-specific skeletal or dental features. Racial traits in these hard tissues may not be equivalent to what is seen in the soft tissues. Furthermore, we can only assess biological race, which may not equal the ethnic identity associated with the person in life. The three major stocks (Caucasoid, Negroid, Mongoloid) were distinguished in these remains by distinctive dental and cranio-facial features (Table I), hair color and form, proportions and curvature of long bones (17) and, rarely, skin color in unburned areas of the body.

Living stature was estimated by using a series of equations that predict stature based on specified length measurements of limb long bones (22). If the bones are incomplete, as was the norm in these remains, stature could still be predicted, although with decreased precision, using a different series of regression tables (15). Both sets of equations are particular as to sex and race

Body build or muscularity was evaluated by muscle markings on bones and by general size. The pubic bones were again of value in devising a relative ranking according to body size

In an attempt to identify individuals, I looked for evidence of old fractures or surgical interventions on the remains themselves and on their postmortem radiographs. With a pathologist, I reviewed the antemortem radiographs available for comparison. This exercise did not prove profitable because medical records listed a number of broken fingers, toes, and wrists, but these parts were missing on many sets of remains. Just one person was positively identified in this way. The left femur in one set of remains was surgically wired to promote healing from a fracture; there was a large irregular callous with extensive new bone formation and minimal remodeling The medical records of this individual listed a badly broken leg and other injuries suffered in a car accident in 1981 and described the wiring in detail. Antemortem and postmortem radiographs were identical.

I looked at 60 additional sets of remains (previously identified through dentition or prints), in concert with pathologists, to correct the anatomic inventory records. Incineration results in extensive fragmentation and shrinkage of remains, rendering many portions unrecognizable to the untrained eye. Consequently, some body bags still contained three feet or two left legs or mismatched cranial and postcranial material. Nonassociable parts were removed from the body bags.

Meanwhile, the crash site was again being searched. Two fairly complete sets of remains, close to 300 isolated body parts (limbs and limb portions, cranial fragments, teeth), and remnants of dental records were found and shipped back to Dover AFB. Dental remains were analyzed by the odontologists, and the anthropologist identified all the body parts. Some of the isolated hands and feet could be printed and were reassociated with their respective remains. Each of the other recovered limbs was compared with remains missing that par-

TABLE I. RACIAL FEATURES OF THE SKULL AND DENTITION.

	Caucasoid	Negroid	Mongoloid
Cranial	large, high, rugged	massive, long, smooth	smooth & rounded; parietal boss
Facial	narrow & long; sharp-featured	low forehead; wide interorbital	wide & flat; broad anterior malars
Nasal	high narrow root; projecting spine; high sharp sill	low rounded root; flaring aperture; guttered sill	low ridged root; rounded aperture; blunt sill
Jaws	triangular palate; prominent chin	rectangular palate; prognathic	parabolic palate, slight prognathism
Teeth	small & crowded; Carabelli's cusp	large & well-spaced; mesial diastema, occlusal tubercles	shoveled incisors; enamel extensions; bulbous molar crowns; short roots

These are traits most useful in this project. For more complete listings, see (1,4,6,7,13,14,19,21).

ticular portion in an effort to associate these isolated body parts. Despite the provenience data, no associations could be made due to absence of intermediate bone for direct articulation. These nonassociable portions were later to be disposed of in accordance with AR 638-40, para 8-10a.1.

TEAM INTERACTION

One of the most profitable aspects of this investigation was the continual exchange of information and daily updates on the status of those remains not yet positively identified. As each specialist worked, he or she supplied information to systems engineers, who incorporated the data into a decision-making matrix. Anthropologic data consisted of information on sex, age, race, and stature, along with confidence intervals for each determination. While the computer mathematically narrowed the range of possibilities by comparing postmortem descriptions with antemortem records and vice versa, the rest of the team performed a similar task over many roundtable discussions. By pooling medical, dental, anthropologic, and material data, we manually narrowed the range of possibilities. Similar results were obtained by both methods, providing a useful system of checks and balances.

After nearly 3 months of analysis, the remains of all 256 persons on board were identified. The continual interaction of team members was the key to the 100% success rate; identifications were confirmed by as many means as possible. Most of the positive identifications were due to fingerprint and dental data, but anthropology played a significant role in the last identifications. In one case, pathologists had determined the very incomplete remains to be female, and just one female remained unidentified. Anthropology independently confirmed the sex through the pubic bones, and supplied an age and height entirely consistent with that female.

In a second case, osteologic analysis demonstrated that the two hemipelves and legs were from the same person, although they had been recovered at a great distance from each other. They were then associated by direct bone articulation with a previously identified intact torso and head. A portion of lower vertebral column later found at the site could also be directly associated with these remains, rendering this individual virtually complete.

In a third case, an arm, identified by fingerprints, was the only portion that could be reassociated with the head and shoulders of this individual. Nothing further could be associated with four torsos.

The final eight identifications were developed by means of an exclusion matrix. Age, race, height, and body build, as assessed by the anthropologist, were major exclusionary components, along with medical, dental, and personal-effects data. In many other cases, anthropology supplied valuable substantiation to identifications based on other criteria.

EVALUATION

The need for a forensic anthropologist on a disaster team has been recognized (2–4,10), but perhaps the extent of what a well-trained anthropologist can do has been overlooked. The usual procedure has been to call in an anthropologist as a last resort, when actually we are capable of providing valuable assistance from the first day of investigation. Anthropologists are accustomed to looking at bone—incomplete, fragmentary, burned, with or without soft tissue—as few others are.

An anthropologist is indispensable in assessing the number of individuals represented in recovered remains. Body portions subsequently demonstrated to belong to one person had been given separate numbers, so at one point there appeared to be, on paper, more than the number of individuals who had been on the passenger and crew lists.

I found many of the postmortem radiographs to be unuseable for the purposes of judging age and antemortem fractures, due to overlaying and jumbling of remains in the body bags. During initial radiography, while pathologists are involved in autopsies, the anthropologist can help orient the remains, knowing which areas are most important for analysis. They can sort out commingling, and draw up accurate body-part inventories. Information on unknowns can be assembled early. If sent to the disaster site, the anthropologist can rapidly distinguish bone from non-bone, associate incomplete remains, and segregate individuals, saving time at the lab later on. Subsequent duplication of effort can be avoided.

The benefit to the anthropologist would be great as well, if called in at the beginning of a project. First-hand knowledge of contextual and procedural information is helpful in interpreting remains. Being able to examine the "easy" cases as well as the difficult ones lets us test ourselves and builds confidence among team members.

The anthropologist also needs to work through the project until completion of remains processing, as in the Gander project. Records and body parts continued to be received for several weeks, necessitating daily reevaluations and updates. No one else could assess confidence intervals for the often-subjective anthropologic observations. The final exclusion matrix was heavily dependent on anthropologic input. In addition, the sense of closure is vital to appraising one's own efforts.

Fortunately, major disasters are not common. But because they are not, we need to take advantage of the ones that do occur, and view them as unique learning laboratories for the investigators. There are really very few "hopelessly unidentifiable" cases when the remains are analyzed by the combined expertise of a t of specialists. The unique contribution of anthropology necessitates that a forensic anthropologist be a part of that team, to be included in all phases of casualty resolution.

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