Lewis Lorton,[1] *D.D.S., M.S., COL., U.S.A.;*
Michael Rethman,[1] *D.D.S., M.S., LTC., U.S.A.;*
and Richard Friedman,[2] *D.M.D., M.P.H.*

The Computer-Assisted Postmortem Identification (CAPMI) System: A Computer-Based Identification Program

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ABSTRACT: The Computer-Assisted Postmortem Identification (CAPMI) system was developed at the U.S. Army Institute of Dental Research to facilitate rapid identification of human remains. The increasing requirement for dental based identification of high-energy fatalities and decomposed remains has dovetailed with the development of computer capabilities permitting automation of most of the highly repetitive chart-by-chart screenings characteristic of traditional identification taskings. This report summarizes the concepts upon which CAPMI is based, describes how it works, and reviews suggested applications and limitations. CAPMI software is available to governmental, civic, or humanitarian organizations at no cost.

KEYWORDS: odontology, computers, information systems, forensic dentistry, computer identification

The three commonly accepted modes of positive identification of human remains are comparison of visual, dental, fingerprint postmortem data, or some combination of these, with antemortem information. A fourth method, gene mapping using deoxyribonucleic acid (DNA) probes, will likely provide data which may revolutionize forensic sciences in the near future. This technology is in its formative stages at this time, however.

Although fingerprint comparison is considered the most specific of routine identification methods (because no two persons have yet been shown to possess identical fingerprints), the utility of fingerprint or visual comparisons or both is limited in disasters where considerable destruction of soft tissues by fire, dismemberment, decomposition, or some combination of these is present. Furthermore, the lack of a comprehensive fingerprint database limits the utility of fingerprint comparisons for forensic science purposes. Fortunately, however, antemortem dental information is usually more accessible for military and civilian populations since this information is routinely obtained for normal clinical use. Additionally, dental data

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[1]Chief of bioengineering branch and research dental officer, respectively, U.S. Army Institute of Dental Research, Walter Reed Army Medical Center, Washington, DC.

[2]Associate professor, Department of Oral and Maxillofacial Surgery, Medical College of Virginia, Richmond, VA.

have been used successfully to identify remains when mass disaster energy levels have been so high and consequent destruction so great as to virtually preclude successful use of the other acceptable methods even when sufficient antemortem data were available.

The Computer-Assisted Postmortem Identification (CAPMI) System was originally developed by the U.S. Army Institute of Dental Research (USAIDR) in 1983 as a means to improve forensic science examiner efficiency by relegating aspects of repetitive chart-by-chart comparisons of ante- and postmortem records to a computer.[3] Sophisticated software was developed by USAIDR to produce most-likely to least-likely listings of matches of postmortem remains and antemortem records. Both nondental and dental characteristics are compared to produce lists of the most probable ante- and post-mortem record matches, thereby permitting forensic science examiners to concentrate efforts on making positive identifications rather than repeatedly sorting through all possibilities. CAPMI was also designed to permit eventual integration of all pertinent data into a comprehensive database of electronically stored dental records to be constructed at the time of each servicemember's entry into the military and to be updated routinely thereafter.

System Function

There are two situations in which an automated system of data compilation is invaluable for forensic science purposes: mass disaster identifications and record maintenance for at-risk populations. Mass disasters which produce multiple fatalities provide a severe trial for the physical, mental, and emotional resources of forensic science teams. Even under ideal circumstances, the positive identification of a large number of mass disaster victims may be extremely stressful, time-consuming, and costly. These factors adversely affect the victims' families and the public as well. An automated system, such as CAPMI, can quickly eliminate implausible records from consideration by reorganizing the database so that the most-probably-correct records will be identified for prompt manual review. CAPMI does not attempt to "make identifications," but only facilitates the work of the forensic science investigators by relieving them of time-wasting tasks inappropriate to their level of expertise. The CAPMI system has been effective in expediting prompt matching of individual antemortem dental records to complete and fragmental dental remains in both simulated and actual disaster identification problems (for example, the Gander, Newfoundland, crash of an Arrow Airlines' aircraft in December 1985). In cases where unknown remains provided an average amount of dental information (7 or more non-virgin teeth) and the antemortem record was contained in the database, the correct match was consistently found at or near the top of the computer generated "best-matches" list. This selective power can be attributed not to any hidden magic, but instead to the great variability inherent in dental information. For example, CAPMI permits 35 combinations of restored surfaces (MOD, DO, and so forth) for each of the 32 possible permanent teeth.

The CAPMI system *always* compares the record of interest, known as the "key" record to every record in the database. Each tooth-by-tooth comparison is either a match, a mismatch, or a possible match (where the later condition of the tooth could have reasonably evolved from the earlier state). The key record is compared with all records in the database, and the number of tooth matches, mismatches, and possible matches is tallied for each database record. In the final processing step, records in the database are reordered so those with the highest number of tooth matches and possible matches are promoted to the head of a complete listing of available records.

[3]CAPMI system specifications: It is an MS-DOS based application which will run on any IBM compatible with MS-DOS version 2.0+. It will sort 300 records/min and will accept input from the keyboard or specially designed commercially available optical mark read forms. It is available for no cost to governmental, civic, or humanitarian organizations upon application in writing on official letterhead to: CDR, USAIDR (attn: CAPMI Program), WRAMC, Washington, DC 20307-5300.

Unique or near-singular dental anatomic features, tooth orientation, restorative materials, and radiographic appearance are some of the parameters used in confirming positive identification by forensic dentists. These are not used by the CAPMI system because CAPMI performs only the initial record comparisons and sorting. Testing has shown that incorporation of these additional data (in the sorting step) would only increase processing time while decreasing the power of the system due to mismatches induced by the subjectivity inherent in the recognition and identification of these entities. Such highly specific characteristics are instead used to confer positive identification by the forensic dentist once the search has been focused by CAPMI on the most likely record matches.

Maintenance of "at-risk" CAPMI files on persons in or expected to enter potentially pernicious environments would facilitate rapid identification of their remains because antemortem data would be quickly available and easily transferred (by phone lines) to a forensic science identification site where it would arrive in a format permitting immediate use.

Data Structure

An example of an Optical Mark Read (OMR) form which may be used for CAPMI is shown in Fig. 1. It includes information fields of nondental characteristics such as height, weight, eye and hair color, age, sex, and blood type. This form will likely soon be used to

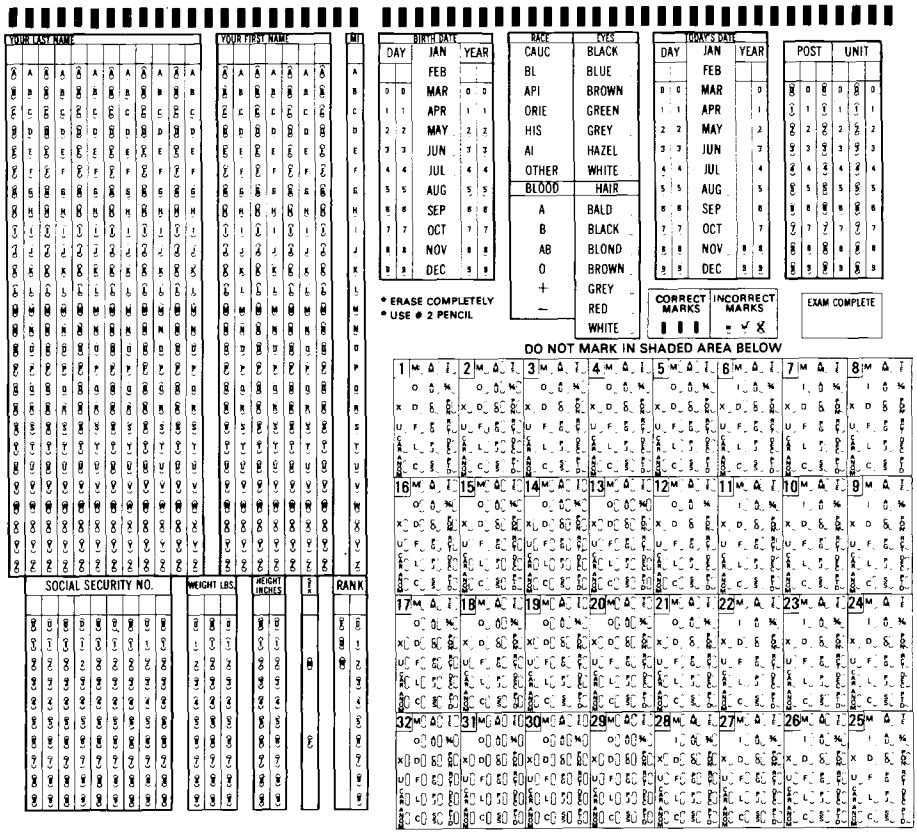

FIG. 1—*OMR form for use with the CAPMI system. This form is proposed for data entry of routine dental examination results into a national database for military personnel.*

enter soldiers' dental conditions into a national database which could be used for forensic science purposes should the need arise. The dental portion of the database (lower right-hand portion of OMR form) consists of fields for each permanent tooth numbered one through thirty-two. Any combination of the following primary descriptors may be entered: mesial (M), occlusal (O), distal (D), facial (F), lingual (L), missing (X), crown (C), or unerupted (U). Additional modifiers, such as pontic (PON), root canal therapy (RCT), or a dental restorative material code, may be added. A complete list of codes is given in Table 1. Since the database to be compiled by the widespread use of this form will have uses other than forensic, many dental characteristics (for example, restorative materials, caries, and so forth) which have limited value for CAPMI are included.

Two other OMR forms (Figs. 2 and 3), both incorporating an Armed Forces Institute of Pathology dental chart, are used at mass disaster sites. These forms may be used as the initial charting media at the disaster site, thereby minimizing paperwork. Rather than recording dental information on standard dental records and subsequently transferring this information into the computer record, examiners can record dental characteristics directly onto the appropriate form as antemortem and postmortem information is obtained. Tooth characteristics are recorded in blanks corresponding to individual tooth numbers, matching bubbles are shaded, and conditions may also be diagramatically depicted. The forms are machine-read, and the data stored. The arrangement of the dental charts on these forms facilitates side-by-side viewing of the diagrams of ante- and post-mortem dental states by forensic science examiners as well. Note that these forms have fewer computer codes than does the OMR form in Fig. 1, but do have an additional code, "JFM" (jaw fragment missing). As an alternative to these OMR forms, any standard forensic science ante/postmortem charting record could be used as an interim measure followed by manual data entry at a later time.

Surfaces are charted for CAPMI use only if they are restored at the time of the examination or if restorations were present at one time and have since been lost. Carious surfaces are not recorded. The charting of caries has been shown to downgrade the matching process—apparently as a result of variable judgment concerning incipient decay, decalcification, and

TABLE 1—*Codes for use with OMR form depicted in Fig. 1.*

X	missing
U	unerupted and/or impacted
CAR	carious
ANOM	anomaly
M	mesial
O	occlusal or incisal
D	distal
F	facial
L	lingual
C	crown
AM	amalgam
AU	gold
CO	acrylic or other non-metal
PG	porcelain or acrylic to metal
PJ	porcelain jacket
SS	stainless steel
TE	temporary
3/4	three-quarter crown
PON	pontic
RCT	root canal
DEC	deciduous
PTD	partial denture

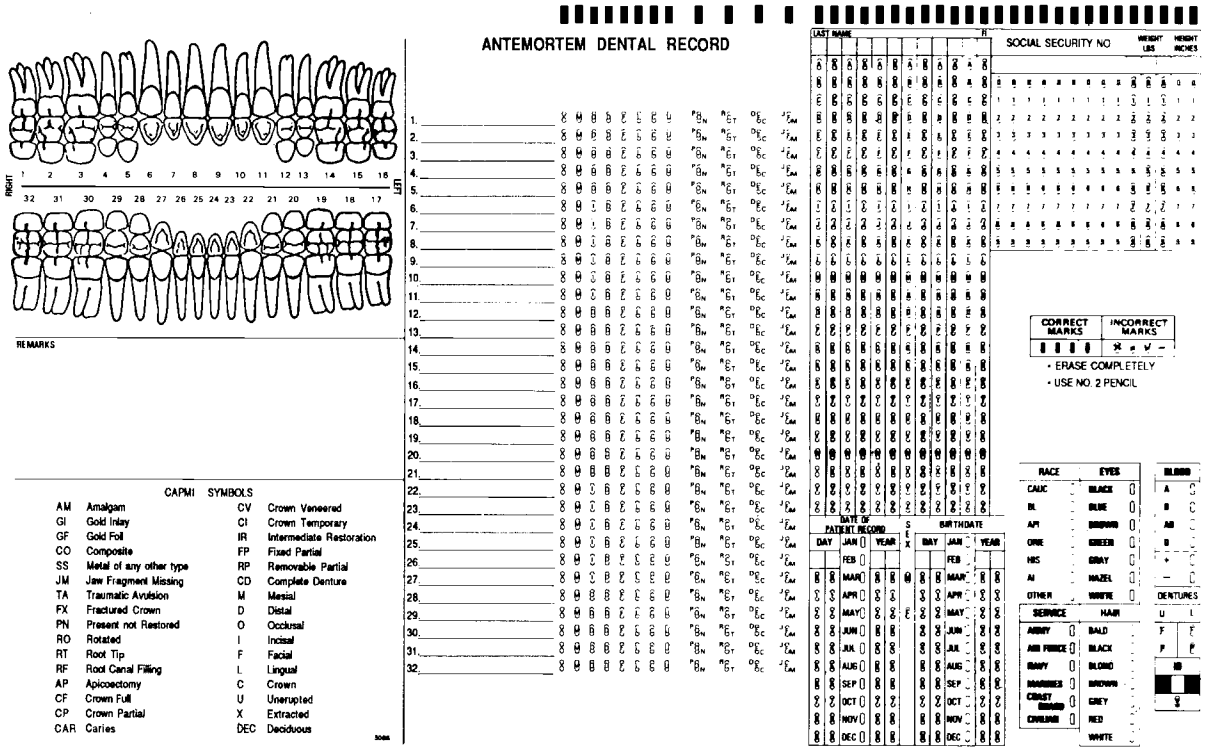

FIG. 2—*OMR form for use with the CAPMI system at a disaster scene. Antemortem data are culled from records collected from suspected decedents' health care providers. This form is based upon an Armed Forces Institute of Pathology design.*

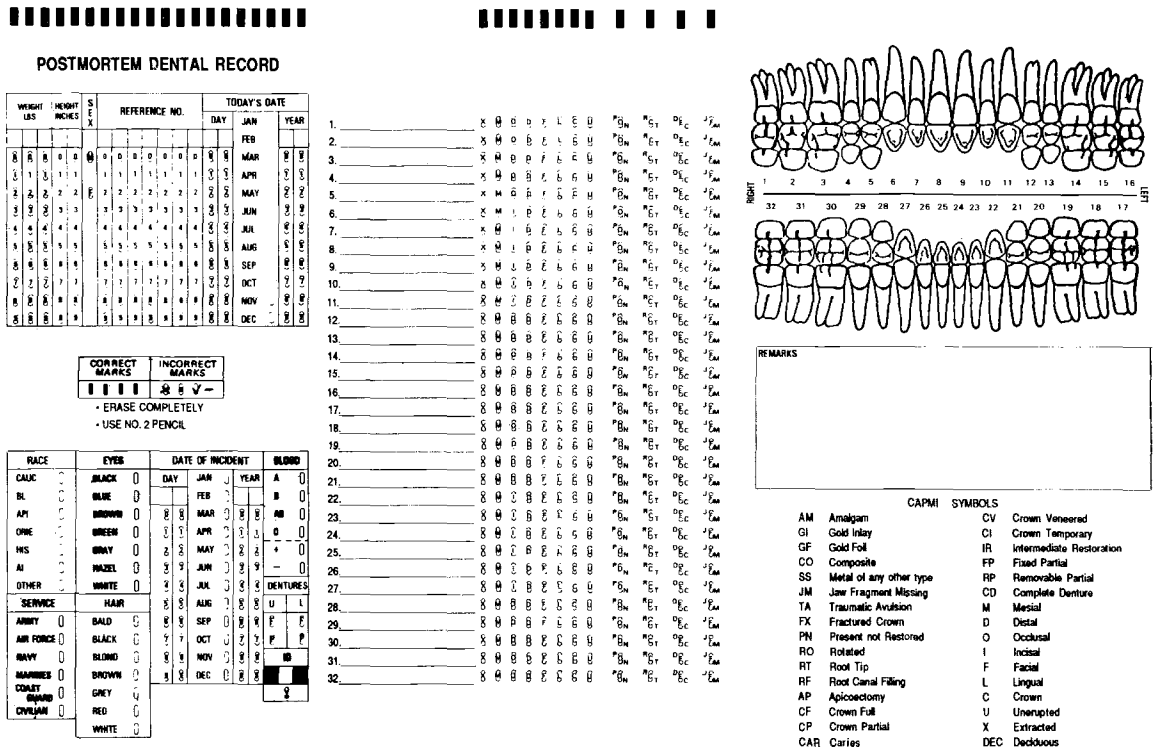

FIG. 3—*OMR form for use with the CAPMI system at a disaster scene. Postmortem data are the results of forensic science examiners' examination of remains. This form is based upon an Armed Forces Institute of Pathology design.*

erosion of tooth structure. If a tooth has had no restoration, no entry is made in the data base. CAPMI interprets this "no entry" as a virgin tooth. The forensic science examiner may wish to record caries or distinctive restorative features on a pictorial dental record; this is unnecessary for the computer comparison, but may be maintained for archival purposes or to facilitate the eventual positive identification of remains.

The Comparison and Sorting Process

If the charting of a postmortem tooth matches the antemortem suspect, a *match* is scored. When a postmortem state is different, but could have evolved from the antemortem, a *possible* is recorded; for example, an antemortem tooth was virgin, the postmortem has an MO amalgam. When a postmortem state is different and could not have reasonably evolved from the antemortem, the comparison is scored as a *mismatch;* for example, an antemortem was a MO amalgam, and the postmortem is a virgin tooth. The presence of a large number of possibles is logical and expected, especially if several years have passed between the time of antemortem record and death.

The terms antemortem and postmortem are not used within the CAPMI program. The data base to be searched is always known as the **Object** file. The record to be matched is always part of the **Key** file. Object and Key files are treated the same at all times by the CAPMI system. Correct antemortem to postmortem logic is always preserved because the program utilizes the date of each record to maintain the correct temporal relationship. Ante- or post-mortem records may be used as Object or Key files so that sorts can be done in either direction. This is valuable because in some situations it may be necessary to use both the antemortem records and postmortem records set as the Object file at different times. The importance of this software feature is best illustrated by a hypothetical example:

> A plane crashed, killing 105 people. An identification team arrived and charted all of the recovered postmortem remains. The postmortem records were entered into a CAPMI **Object** file. As antemortem records were brought to the site, each was entered into a CAPMI **Key** file and a comparison was performed. As the investigation progressed, all of the postmortem remains in the object file were identified. Somewhat later the discovery of several additional dental fragments was made. The postmortem records were then moved out of the **Object** file and replaced by accumulated antemortem data. Chartings of newly recovered postmortem remains were then entered into **Key** files and compared with the Object file, now consisting of antemortem records. CAPMI produced lists of most likely matches for the newly discovered remains, allowing forensic science examiners to match promptly the newly uncovered remains to the appropriate antemortem records.

A user chosen option allows the data base to be sorted using both dental and nondental fields. If consideration of nondental information is requested in combination with a dental sort, CAPMI will list (in order of decreasing probability according to the maximum number of tooth-by-tooth matches and to the minimum number or mismatches) only those records with *no* nondental mismatches. Typically used sorts are confined to the tooth fields only since both ante- and post-mortem dental data are usually more easily obtained. The nondental sort remains available for use if needed, however.

Applications/Limitations

There are four situations in which an identity search might be considered:

1. A large antemortem population of records and a small or large number of postmortem remains—the classic mass disaster. The Gander, Newfoundland, plane disaster of 1985 is a good example. CAPMI facilitated prompt identification of soldiers' remains.

2. A large antemortem database and a few postmortem remains—typically a missing persons file to be searched when unknown remains are uncovered. The U.S. Army Central Iden-

tification Laboratory facility in Hawaii uses CAPMI to search Vietnam-era records whenever remains are released by the Vietnamese government.

3. A small antemortem database and a large number of fragmented postmortem remains. CAPMI was used in Poland following the 1987 crash of a Soviet built airliner with 183 passengers plus crew abroad. The database consisted of highly fragmented remains, and the antemortem records were incomplete. CAPMI software was altered somewhat (tallies of *mismatches* were found to be more effective) for this problem. Necessary software changes are presently underway to make this option easier to utilize.

4. A small number of antemortem remains and a correspondingly small number of antemortem records. This is best typified by a small-scale accident with few deaths and a limited number of antemortem records. Any computerized system would likely be of little value in such a circumstance since the memory and logic requirements for such a task are within the capabilities of human recall.

The limitations of the CAPMI system are similar to the limitations of any forensic science identification technique. As with a fingerprint database, an antemortem database for comparison purposes must both exist and be available. A high degree of accuracy must be assured at each step of the CAPMI process, although perfection is not requisite to successful use, especially if dental fields alone are used for comparison attempts. Computer capabilities are necessary.

An important point deserving reiteration is that the CAPMI system is a sorting tool, not a method to identify victims positively. Below a finite number of victims or matching possibilities or both, CAPMI is impractical (potential matches of approximately 40 or less). Small numbers of possibilities can be more easily matched "by hand" within a reasonable amount of time.

Conclusion

The CAPMI system represents an advance in forensic science guided by computer application. The system has been developed and successfully tested in both simulations and real-life disasters. Although CAPMI has been used only in mass disaster situations thus far, it could become a valuable aid in nationwide attempts to match unidentified human remains to known missing persons' physical and dental data.

The limitations of timely, accurate information accumulation, processing algorithms, and storage requirements are inherent in any computer-assisted process. With each application and advances in technology, the authors continue to improve the basic CAPMI system, thus facilitating faster and more cost-efficient identification of human remains.

Address requests for reprints or additional information to
Col. Lewis Lorton
U.S. Army Institute of Dental Research
Walter Reed Army Medical Center
Washington, DC 20307-5300