TECHNICAL NOTE

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A New Algorithm for Use in Computer Identification

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ABSTRACT: On 9 May 1987, a Soviet-made IL-62M Polish Airliner, LOT Flight 5055, crashed, exploded, and burned, killing the crew and 183 passengers. A forensic science team from the Armed Forces Institute of Pathology, comprised of 6 dental officers, 3 forensic pathologists, and 3 medical photographers, worked in concert with the Polish forensic science team. The small number of antemortem records and the extreme fragmentation of the remains presented a new scenario for computer use.

Typically, the Computer-Assisted Postmortem Identification (CAPMI) software is used to compare remains against an antemortem database. Results are listed by the number of tooth-to-tooth matches based on restorative or other characteristics or both. The Polish disaster confounded this approach to some degree, however, and suggested a reconsideration of the theory on which the sort is made, that is, that the cases with maximum number of matches to preexisting dental records would be the most likely identification (ID) match.

A hypothesis was constructed that, if searches were accomplished for fragments with a minimum number of *mismatches,* the correct matches would appear higher in the rank order. Six antemortem records (that had all dental information) were sorted against one hundred and twelve postmortem fragmented records. The resulting report was reordered so that records were listed by *minimum number of mismatches.* There was significant improvement in rank placement for all of the records. Thus it was accepted that in the situation of highly fragmented remains a different sorting based on the number of mismatches is indicated. Programming changes to make this option available have been implemented in the new version of CAPMI.

KEYWORDS: odontology, computers, human identification, computer identification, forensic dentistry

The views of the authors do not purport to reflect the position of the Department of the Army or the Department of Defense. (Para. 4-3, AR 360-5). Commercial materials and equipment are identified in this report to specify the investigative procedure. Such identification does not imply recommendation or endorsement, or that the materials and equipment are necessarily the best available for the purpose. Furthermore, the opinion expressed herein are those of the authors and are not to be construed as those of the U.S. Army Medical Department. Received for publication 27 July 1988; accepted for publication 15 Aug. 1988.

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Computers have penetrated virtually every aspect of our society. In mass disaster management they have emerged as crucial supports to forensic odontologists in the matching of antemortem and postmortem data.

Identification in a mass disaster is not simply the verification of the identity of many single remains. It is much more of a puzzle, involving the management and arranging of large amounts of information. To organize this effort, it must be understood as a succession of distinct processes, each of which can be optimized for the greatest efficiency. The processes are the gathering of data, the comparison of antemortem and postmortem data, the selection of small target sets for complete analysis, and the final verification of identity matches. When the data handling, comparison, and sorting is automated, a system emerges in which virtually thousands of simple decisions are made, tracked, and completed in a short period of time without the potential for human errors. The important issue is that computers are certainly more efficient than people at some tasks, but those tasks and their solutions must be definable by the human minds behind the computer algorithms. When a computer program is not efficient it is almost always the human intellect behind the program that has failed to understand the problem completely. We have lately encountered a new mass disaster scenario which required us to rethink, and add to, the basic sorting concepts of our computer system.

In using the Computer-Assisted Postmortem Identification (CAPMI) software, the antemortem data base is created using preexisting dental records and X-rays of the victims.

The subsequent comparisons of postmortem and antemortem records will result in one of three possible outcomes for any tooth-to-tooth comparison—a "match," a "possible," or a "mismatch." A match exists when the condition of the tooth is the same for both the postmortem and the antemortem state. For example, tooth number nineteen, the lower left first molar, has a mesio-occluso-distal (dental terms that refer to specific surfaces of a tooth) restoration present in both the antemortem and the postmortem charts. A "possible" match occurs when the condition of the tooth in the postmortem could have evolved from the condition of the tooth in the antemortem. An example of this is when a virgin (unrestored) tooth in the antemortem charting is indicated as restored with a mesio-occlusal restoration in the postmortem charting—a "possible" change in state. Finally, a "mismatch" occurs when the condition of the tooth in the postmortem is not the same as the antemortem, and the "possible" prospect does not exist, in other words, when the postmortem condition could not have evolved from the antemortem condition. Clearly it is impossible for an antemortem tooth restored with a mesio-occluso-distal restoration to evolve into a postmortem virgin tooth.

In previous mass disasters, CAPMI software was usually employed to compare postmortem remains against an *antemortem* database. The antemortem records were then listed by maximum number of matches and by minimum number of mismatches. For example, the first record on the list would theoretically have 32 matches, 0 mismatches, and 0 possibles. The second would have 31 matches, 0 mismatches, 1 possible, the third 31 matches, 1 mismatch, and 0 possibles. Other techniques for reordering of the data base to improve the selectivity of rank order listings have been simulated and will be detailed in a future publication.

Recently a situation presented itself where the database was composed of a great number of fragmented postmortem remains. This situation developed out of the disaster which took place in Warsaw, Poland, 9 May 1987. A Soviet constructed IL-62 Polish airliner departed Warsaw Airport on a transcontinental flight to New York. It developed mechanical problems, crashed, exploded, and burned in a wooded area outside of Warsaw. The U.S. State Department directed a dental identifications team from the Armed Forces Institute of Pathology to aid in the identification of the victims of the disaster.

The remains in this disaster were fragmented from the force of the crash and subsequent explosion. There were only 14 antemortem dental records; the database was composed of and 112 postmortem records made of various fragmented remains. The normal sorting algorithm did not work well in this occasion, providing too many ties for "first" in the rank order list of possible matches. Although we were certain at the time that this was due primarily to the fragmentation of the database, we were not certain about the underlying computational reasons, nor the solution. The lack of specificity of the sort under these conditions prompted a reevaluation of the protocol by which the sort is performed.

A new reordering concept was introduced that ordered the database by the minimum number of mismatches and, within each category, the maximum number of matches. The specificity of this ordering method was tested in the following way.

Methods

The antemortem records of 6 victims, whose remains were identified on the basis of dental means alone, were chosen to test the new sorting algorithm. This small number of test records reflected, not the lack of initiative of the investigators, but rather the paucity of *complete* antemortem records. Each of these 6 records was sorted in the conventional manner against 112 postmortem records. The records were also sorted using the minimum number of mismatches hypothesis against the same 112 postmortem record database.

Results

The rank of the correct match in the most probables list (as confirmed by visual matching of X-rays) using the computer sort is shown for both the original and new methods in Table 1. In each of these cases, the rank of the correct match was better using the new hypothesis than in the original sorting procedure.

Discussion

Figure 1 demonstrates the concepts behind the new hypothesis. When the database is composed of complete records, the number of comparisons is always 32 for any postmortem record/antemortem record comparison.

That is, the maximum number of matches is 32 since a complete postmortem remains will match a perfectly recorded current antemortem record. When there are fewer points of information, such as when the database to be searched is a fragmentary postmortem set and the antemortem record is complete, the number of possible matches for each comparison *changes* with each different postmortem record considered.

In the first case the maximum number of matches is *set* by the single record to be compared to the database. Thus each record in the database is tested against the same criterion set by this single record. In the second case the maximum number of matches varies with the fragmentation of the postmortem remains in the database and thus the maximum score for

TABLE 1—*Rank in list of correct identity match.*

	Ordered by Maximum Matches	Ordered by Minimum Mismatches
Individual 1	1	1
Individual 2	75	50
Individual 3	21	7
Individual 4	61	13
Individual 5	12	3
Individual 6	21	5

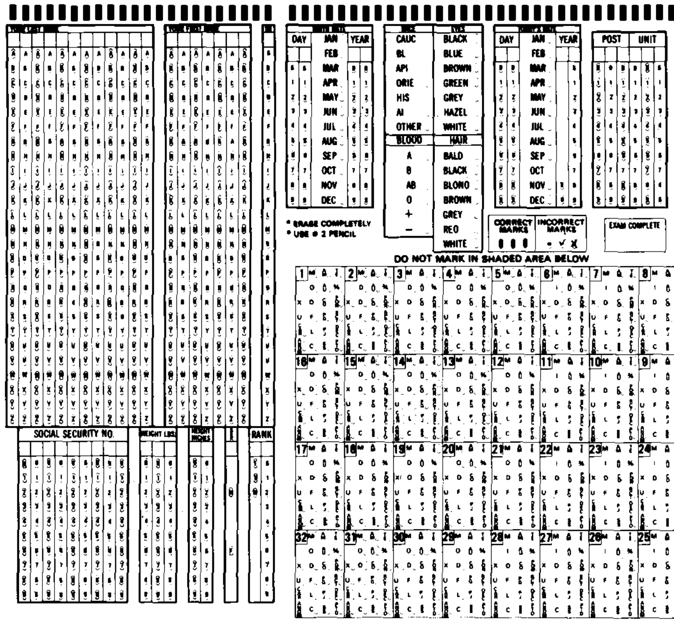


FIG. 1—*Comparison of postmortem record against antemortem database. Number of matches fixed by size of single postmortem record.*

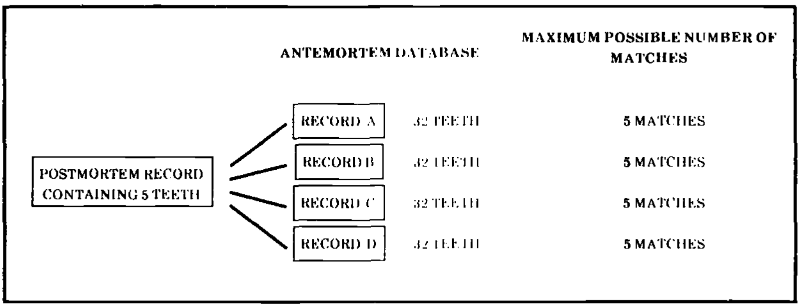
each comparison varies. Thus the score of each comparison cannot be readily compared to other comparisons to list the most probables first. The potential for number of matches is altered by the number of comparisons available and the eventual sorted order is suspect. It has been our experience that a good many of these matches will be on virgin teeth, a relatively nonimportant concurrence.

An example of this second case—an antemortem record with a single crown and 27 virgin teeth is sorted against a database resulting from postmortem examinations. In Fig. 2, the correct match is a record of only a single tooth, that is, the crown has been found as a single piece of a fragmented remains. In this not-so-far-fetched example, all of the records with more than one match, even of just virgin teeth, against the antemortem record will rank higher than the correct single crown fragment because they have information for more, albeit trivial, matches. This problem can easily be generalized to other situations where the database is composed of *incomplete* records, as from fragmented remains.

Although, in this case, the problem can be solved simply by sorting only for significant characteristics from the antemortem records, this is not a logistically sound way of dealing with all fragmented remains problems.

If, however, the list of most probables is derived from those records with least mismatches first, the effect of a great number of trivial matches will be obviated to a large extent. The sorting approach that emphasizes the minimum number of mismatches as the prime criterion in establishing a rank order of possible matches seems to have merit for cases in which fragmentary remains prevail.

The new version of the CAPMI software will give the user the option of ranking by minimum mismatches, maximum matches, and minimum possibles (new hypothesis) or by maximum matches, minimum mismatches, and minimum possibles (original method). The software allows rearrangement *after the actual comparisons are completed.* The new version of



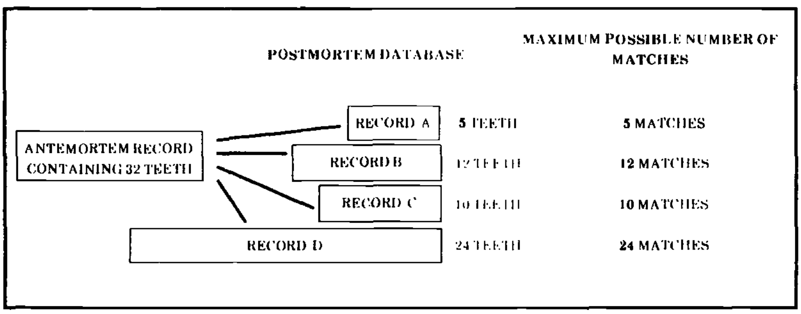


FIG. 2—*Comparison of antemortem record against postmortem database. Number of matches varies with size of postmortem records.*

CAPMI will compare and return lists on databases of 10 000 records in <12 s, thus making real-time iterative searches on dental or physical characteristics readily available. These 2 sorting options will provide forensic odontologists with a variety of options to assist them in coping with different mass disaster scenarios.

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