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APR 22 1992

Dr. Richard S. Laymon
Program Manager, DNA Programs
National Institute of Justice
633 Indiana Ave., NW
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Dear Dick:

Re: Grant 87-IJ-CX-0041 and Grant 87-IJ-CX-0041 (S-1)

As I recently promised, I am pleased to transmit herewith our Final Report on the above-referenced grants. Sometime back in 1990, we transmitted a "final report" of a similar nature to Dick Rau that had primarily to do with the 1988-1990 grant period (i.e., with 87-IJ-CX-0041). This project had mainly to do with ABO typing. The supplemental grant, 87-IJ-CX-0041 (S-1), had mainly to do with DNA analysis. The enclosed was prepared to be appropriate for NIJ Reports, and was written with a broad, general readership in mind. The one we previously sent Dick Rau was not published to my knowledge, and it would be more appropriate to use this present one if you decide to use it for NIJ Reports, since it covers both the ABO and the DNA aspects.

I believe that this submission completes and fulfills all the formal reporting requirements for these two grant projects.

In our minds, the projects have been succesful, and have resulted in a number of papers in the refereed literature, as well as in a number of presentations and workshops. I have shared reprints of the published work, wherever possible, with Dick Rau. A summary of the principal outcomes of the projects is presented below.

Papers in the refereed literature:

M.E. Lewis, R.E. Kouri, D. Latorra, K.M. Berka, H.C. Lee and R.E. Gaensslen. 1990. Restriction Fragment Length Polymorphism DNA Analysis by the FBI Laboratory Protocol using a Simple, Convenient Hardware System, *J. Forensic Sci.* **35**, No. 5, September: 1186-1190

R.E. Gaensslen and H.C. Lee. 1990. Genetic Markers in Human Bone Tissue, *Forensic Sci. Rev.* **2**, No. 5, December: 125-146

H.C. Lee, E.M. Pagliaro, K.M. Berka, N.L. Folk, D.T. Anderson, G. Ruano, T. Keith, P. Phipps, G.N. Herrin, D.D. Garner and R.E. Gaensslen. 1991. Genetic Markers in Human Bone. I. DNA Typing, *J. Forensic Sci.* **36**, No.2, March: 320-330

H.C. Lee, K.M. Berka, N.L. Folk, E.M. Pagliaro, J. Carroll-Reho, T.L. Brubaker and R.E. Gaensslen. 1991. Genetic Markers in Human Bone. II. Studies on ABO (and IGH) Grouping, *J. Forensic Sci.*, **36**, No. 3, May: 639-655

R.E. Gaensslen, K.M. Berka, D.A. Grosso, G. Ruano, E.M. Pagliaro, D. Messina and H.C. Lee. 1992. A Polymerase Chain Reaction (PCR) Method for Sex and Species Determination with Novel Controls for Deoxyribonucleic Acid (DNA) Template Length, *J. Forensic Sci.*, **37**, No. 1, Jan: 6-20

Presentations and Published Abstracts / Extended Abstracts:

M.E. Lewis, R.E. Kouri, D. Latorra, K.M. Berka, H.C. Lee and R.E. Gaensslen, "VNTR Polymorphism Analysis by the FBI Laboratory Protocol Using the Bios Timeframe System," International Symposium on Human Identification - DNA Data Acquisition and Statistical Analysis for DNA Typing Laboratories," Promega Corp., Madison, WI, November, 1989

R.E. Gaensslen, H.C. Lee, K.M. Berka, E.M. Pagliaro and J. Carroll-Reho, "Human Bone Grouping: ABH Typing of Human Bone Tissue in Varying Environments over Varying Time Periods," 41st Annual Meeting, Am. Acad. Forensic Sciences, Cincinnati, OH, February, 1990

H.C. Lee and R.E. Gaensslen, "ABH Grouping in Human Bone: Practical Applications in Forensic Casework," 41st Annual Meeting, Am. Acad. Forensic Sciences, Cincinnati, OH, February, 1990

R.E. Gaensslen, H.C. Lee, K.M. Berka, E.M. Pagliaro, J. Carroll-Reho, G. Ruano, G.L. Herrin and D.D. Garner, "Genetic Marker Analysis in Human Bone -- A Potential Aid in the Forensic Identification of Human Remains," International Symposium on the Forensic Aspects of Mass Disasters and Crime Scene Reconstruction, FBI Laboratory and Investigation Divisions, FSRTC, FBI Academy, Quantico, VA, June 23-29, 1990

Invited Speaker, "Forensic Applications of DNA Typing by Polymerase Chain Reaction Technology," Forensic Applications of PCR Workshop, Georgia Bureau of Investigation, Decatur, GA, July, 1990

Invited Speaker, "Genetic Markers in Human Bone - A Potential Aid in the Identification of Human Remains," 2nd International Homicide Investigation Symposium, Kansas City, MO, October, 1990

H.C. Lee, R.E. Gaensslen, E.M. Pagliaro, K.M. Berka, T.P. Keith, G.N. Herrin and D.D. Garner, "DNA Analysis in Human Bone Tissue - RFLP Typing," 12th Triennial Meeting, Int. Assn. of Forensic Sciences, Adelaide, October, 1990

H.C. Lee, R.E. Gaensslen, G. Ruano and E.M. Pagliaro, "DNA Analysis in Human Bone and Other Materials of Forensic Interest - PCR Typing and Testing," 12th Triennial Meeting, Int. Assn. of Forensic Sciences, Adelaide, October, 1990

H.C. Lee, R.E. Gaensslen, K.M. Berka, E.M. Pagliaro, J. Carroll-Reho and T. Brubaker, "Development of a Reliable Procedure for the ABO Typing of Human Bone," 12th Triennial Meeting, Int. Assn. of Forensic Sciences, Adelaide, October, 1990

H.C. Lee, E.M. Pagliaro, R.E. Gaensslen, K.M. Berka, T.P. Keith, G.N. Herrin and D.D. Garner. 1991. DNA Analysis in Human Bone Tissue: RFLP Typing, *J. Forensic Sci. Soc.* **31**, No. 2, Apr/Jun: 209-212 [Ext. Abstr.]

H.C. Lee, G. Ruano, E.M. Pagliaro, K.M. Berka and R.E. Gaensslen. 1991. DNA Analysis in Human Bone and Other Specimens of Forensic Interest: PCR Typing and Testing. *J. Forensic Sci. Soc.* **31**, No. 2, Apr/Jun: 213-216 [Ext. Abstr.]

P.A. Fish, C.T. Comey and R.E. Gaensslen, "The Effects of Induced Biological Contamination on the Polymerase Chain Reaction Amplification of the HLA-DQα Gene, Annual Meeting, Midwest Assn. of Forensic Scientists, October, 1990

E.M. Pagliaro, T. Schwartz, H.W. Carver, R.E. Gaensslen and H.C. Lee, "Analysis of DNA from Different Body Tissues and Organs using the Polymerase Chain Reaction," 43rd Annual Meeting, Am. Acad. Forensic Sci., Anaheim, CA, Feb., 1991 [Abstr B68]

G. Ruano, D. Messina, E.M. Pagliaro, K.M. Berka, R.E. Gaensslen and H.C. Lee, "Determination of Sex of Origin of Bloodstains by PCR DNA Analysis," 43rd Annual Meeting, Am. Acad. Forensic Sci., Anaheim, CA, Feb., 1991 [Abstr B73]

C.T. Comey, P.A. Fish and R.E. Gaensslen, "Effects of DNA Contamination by Sample Handling on PCR/DQ-Alpha Typing," 43rd Annual Meeting, Am. Acad. Forensic Sci., Anaheim, CA, Feb., 1991 [Abstr B74]

R.E. Gaensslen , K.M. Berka, D.A. Grosso, G. Ruano, E.M. Pagliaro, D. Messina and H.C. Lee, "Amplification of X, Y, and Monomorphic 'Control' Sequences in DNA from Blood, Bone and Other Tissues --- Determination of Sex (and Species) by PCR," International Seminar on the Forensic Applications of PCR Technology, Laboratory Division, Federal Bureau of Investigation, FBI Academy, Quantico, VA, May, 1991

R.E. Gaensslen, K.M. Berka, G. Ruano, E.M. Pagliaro and H.C. Lee. 1991. PCR Amplification of X and Y Chromosome and Single- and Mutiple-Copy Control Sequences in DNA from Blood, Bone and other Tissues -- PCR Determination of Sex and Species and Useful Controls for PCR Reactions in Forensic Tests, *FBI Crime Laboratory Digest*, Vol. 18, No. 4, Oct: 198 [Abstr]

H.C. Lee and R.E. Gaensslen. 1991. Analysis of Human Bone DNA by PCR, *FBI Crime Laboratory Digest*, Vol. 18, No. 4, Oct: 156-159 [Extd Abstr]

In addition, we conducted a three day Course/Workshop on Bone Grouping at the University of New Haven in July, 1989, according to the plan in our original proposal. This workshop was well attended and succesful. Dr. Rau was a guest here during this activity.

We are currently working on one additional paper having to do with bone DNA analysis, and expect to submit it for publication in a special edition of *Analytica Chimica Acta* within 30 days. We have one more interesting piece of data concerning the amplification by PCR of a 123-bp homeobox sequence in DNA isolated from a 125-year-old bone specimen from a dig in New Mexico. The experimental work is finished, but this work has to be written up. We plan to send this off as a Letter to *Nature*, although there is no guarantee that they will take it. If they don't, we will send it to another journal.

In view of this summary, Henry Lee and I share the view that both our ABO and DNA projects have been successful, and that they have yielded some good and valuable information on the subject.

I trust you will find this report in order, and I look forward to working with you in the future. Let me know if there is anything else we need to do. I hope you will be able to join us on May 15th.

Kindest regards and best wishes,

Bob Gaensslen

R.E. Gaensslen, Ph.D.
Professor / Director
Forensic Sciences

IDENTIFYING HUMAN REMAINS: BLOOD AND DNA TYPING IN BONE

Henry C. Lee* and R.E. Gaensslen**

Forensic Identification of Human Remains

Our society considers the unequivocal identification of deceased persons essential for both personal and legal reasons. Next of kin must be notified so that they may provide the deceased an appropriate burial. In addition, there are a variety of legal matters that can be properly settled only after the appropriate authorities have issued a death certificate for an individual. In cases involving foul play, positive identification is required in order to help establish *corpus delicti*, and to initiate a criminal investigation.

A variety of methods are used to identify human remains depending on the case circumstances and the condition of the remains (see Inset Table 1). The most commonly used of these include: (1) Identification by a living person who knew the decedent by direct facial recognition, identification of special features, or less directly, by recognition of individualizing scars or marks (such as tatoos); (2) The matching of fingerprints, provided pre-mortem inked prints are available; and (3) The matching of dentition by a forensic odontologist (dentist), provided representative pre-mortem dental x-rays are available. In many situations, these methods cannot be used either because of extensive putrefaction or destruction of the remains, because appropriate pre-mortem records are unavailable or cannot be located, or because the remains lack identifying features or markings due to natural or intentional destruction.

Under these circumstances, other less direct methods must be used to assist in the identification. These include: (1) The use of clothing and belongings;

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(2) Findings at autopsy that yield information about the medical history; (3) The analysis of skeletal remains by forensic anthropologists to estimate sex, age, time since death, race, and stature; (4) Attempted reconstructions of facial features from skulls by physical anthropologists or forensic sculptors; (5) Hair comparisons in cases where pre-mortem hair exemplars can be obtained; and (6) Blood type.

In those cases where the remains are solely skeletal, or where only small fragments of bone are found, no information is generally available from clothing or belongings. The ability of forensic pathologists, anthropologists or odontologists to make or assist in making an identification depends in great part on whether the skull is recovered, whether it contains teeth, what other bones or fragments of bone are recovered and available for analysis, and the size and condition of the skeletal fragments. In some of these situations, blood typing can become the only tool in assisting in identifications as well as in excluding possible identities.

Situations that Require Forensic Identifications

Forensic specialists are called upon to attempt to identify human skeletal remains in a variety of situations (see Inset Table 2). These include: (1) Mass disasters due to natural phenomena (such as earthquakes and storms); (2) Civilian and military air crashes or explosions, including those resulting from acts of terrorism; (3) Identifications of the human skeletal remains of U.S. military personnel recovered from wartime theaters (such as the returned remains of alleged Vietnam era military personnel); (4) Cases involving the finding of human skeletal remains thought to belong to a person previously reported missing; (5) Cases involving the identification of human skeletal remains following extensive fires or explosions; (6) Cases involving the identification of skeletal remains in criminal matters where mutilation or significant destruction of the body accompanied or followed the homicidal death;

(7) Cases involving the identification of human remains following essentially complete putrefaction of the body; and (8) Cases in which fragments of human bones are recovered.

A number of recent cases have dramatically illustrated the potential values of a reliable method for blood typing bone fragments. In one case, bone fragments alleged to be those of a Vietnam era MIA were "identified" anthropologically, but the identification was challenged, and a second anthropologist was not in agreement with the first. A second case, the so-called "MOVE" case in the city of Philadelphia, resulted in the recovery of a number of skeletal remains. Questions arose as to whether these remains belonged to "MOVE" members or to innocent victims of the incident. The typing of these bones at the Connecticut State Police Forensic Science Laboratory helped in the investigation. In a third case, a few small bones were found in the woods. Typing tests in the forensic laboratory helped to establish that the remains belonged to a person who had been reported missing five years earlier. A fourth illustrative case occurred in Connecticut several years ago. A man murdered his wife, and then disposed of her body by cutting it into pieces and putting at least some of them through a diesel-powered wood chipper. The few bone fragments recovered in the debris that resulted from this action were of little value for identification. Determination of the blood type from the bone fragments, however, assisted in including the victim as a possible source of the bones. A fifth case involved a body recovered near a major interstate highway in New England. Badly burned by an intentionally set fire, the body's hands and feet had been completely removed and all the teeth knocked out by force. Anthropological examination determined that the body was that of an adult Negro female.Blood typing of portions of the skeletal remains, however, provided the only assistance to an identification in this case. A sixth case involved the finding of burned human bone fragments in the fireplace of a private home. The house had been occupied by an old woman and her mentally defective son.

The matter came to police attention when neighbors reported that the woman had not been seen for quite a while. Investigation showed that the woman had apparently died, and the son, incapable of handling the situation in a normal way, had disposed of the remains in various ways including the apparent cannibalization of part of them. Identification of the recovered remains was necessary to determine whether or not they were from a single individual or whether multiple victims were involved. Blood typing of bone fragments recovered from the fireplace constituted an important component of the identification. In a seventh case, a small airplane crashed and an accompanying explosion caused the victims to be burned beyond recognition. Many small pieces of body parts were recovered, and blood typing results on the tissues and bones helped in identifying the sources of the remains.

These apparently very different cases have in common that they underscore the potential value of a procedure for determining genetic types for identification purposes from otherwise uninformative fragments of human bone. There are many similar cases reported every year all over the country. In addition, bones and small pieces of bone fragments have been found in yards, parks, fields and even in homes every year. Because there have been no fairly simple, routine methods available to forensic labs for genetic typing in bone to assist in identification of these fragments, however, the cases are often closed without further analysis.

ABO Blood Types from Human Bone

Although many studies have been conducted in this area over several decades, a reliable procedure has not emerged. Two groups of scientists have taken an interest in blood typing in bones: physical anthropologists, and forensic specialists.

The anthropologists have concentrated their attention on old or ancient human skeletal remains recovered from burial sites decades to centuries old.

Determining the blood types of these remains can give scientists information about the types of people who lived in various places in older times, and possibly about the relationships of these groups of people to one another and to groups of modern human inhabitants. Usually, the bones of a whole group of people are typed in these situations, and the anthropologists are more interested in the distribution of blood types in the particular population than in the type of any one individual. It is important to understand, too, that although typing tests can be conducted on these older specimens, and results obtained, there is no way to know whether the individual typing results are correct because no independent information is available about the blood types of people in older civilizations.

Forensic scientists approach the bone typing problem a little differently. In a forensic identification case, skeletal remains from only one or a few people are being tested. And it is essential that any typing tests used give reliable results. Otherwise, the information is of no identification value. As a result, most of the studies by forensic scientists have concentrated on typing bone from individuals whose blood type could be independently determined. This type of study allows us to evaluate the reliability of the typing tests being used.

Most bone typing studies have concentrated on trying to get ABO blood types from bone tissue. The properties of the ABO blood group system, first described in human blood in 1901, are well known. People can readily be classified into one of four blood groups, A, B, AB and O by the typing of their blood. A person's blood type is important in transfusion medicine, and it is typically determined when the person donates blood for transfusion, or when he or she requires a blood transfusion. Because of the clinical importance of ABO groups, the blood group can be an important identifying feature because it is an invariant genetic property, and because there are hospital, military, blood bank and other records of the blood types of a large number of people.

These pre-mortem records can be compared with grouping results obtained on the skeletal remains, and used as an aid in identification. In addition, even if no pre-mortem blood group record is available, information about the blood type may be obtainable through the blood typing of a victim's family members.

It has long been known that the antigens which characterize the ABO blood group system occur not only on the red blood cells but are widely distributed throughout human tissues. This knowledge has been exploited for forensic identification purposes for many years, primarily using procedures that were originally devised for ABO typing in bloodstains. The application of bloodstain typing techniques to bone tissue has yielded mixed results, particularly when aged bones or bones subjected to putrefactive processes are analyzed. Earlier investigators used a technique (called inhibition) that was once widely used for bloodstain typing, but is now used primarily for ABO typing in body fluids, such as saliva and semen (in rape cases, for example). More recently, a newer bloodstain typing technique (called elution) has been used almost exclusively in attempts to determine ABO type from bones. A number of studies have been done on bone fragments taken from individuals whose blood types were known, in order to determine the accuracy and validity of the methods being used. The percentage of incorrect results in these studies has been so high, however, that the procedure could not and still cannot be regarded as very reliable. Technical modification of the techniques by a number of investigators have more recently resulted in greater but still limited success.

For a procedure to be really useful in the determination of ABO groups from bones, it should not give incorrect results. In real casework, sample specimens often give no results at all, or results that are inconclusive (that is, a blood group cannot be assigned to the specimen based upon the test results).

If a method or procedure is to find widespread use in forensic science laboratories, it must also be simple enough for routine use, without the need for any additional costly equipment or analyst training. And, a procedure will be easier to set up, validate and use if it is based on other techniques and procedures with which most forensic blood analysts are already familiar. Results should be easy to interpret, and be reproducible and reliable. The proportion of tested samples that yield a conclusive typing result is an important consideration in devising a method, but we think that the paramount issue is that the results be correct when they are conclusive. It is important, therefore, for there to be checks built into the method, so that the analyst has some objective way of knowing when to regard the results as conclusive.

We have devised a procedure for ABO typing of bone that involves the combination of both previously used methods (inhibition and elution). Because of the sensitivity required, we found that the only inhibition method of value in this overall procedure was our recently devised two-dimensional inhibition method. With some modifications, these procedures are the same as those applied to the blood and physiological fluid stain specimens commonly tested in forensic laboratories.

Extremely important to the results of this combination procedure is the technique used to prepare the bone tissue for analysis. The critical effect of bone specimen preparation on the results obtained has been noticed by previous investigators. It is well known that adverse environmental factors and conditions can have deleterious or destructive effects on blood types, and that contamination of specimens like bones with various microorganisms can lead to false positive ABO results under some conditions. Procedures used to prepare bone tissue for typing must have several objectives: to clean up the material, freeing it from other tissues and ridding it of contaminants;

and to accomplish the preparation using techniques that are not themselves deleterious to subsequent typing. By using a combination of two different typing methods, one applicable to the bone fragment itself and the other applicable to an extract of the bone fragment, we have tried to avoid interference by possible contaminants. Those contaminants that might survive the preparative steps in the bone itself are not expected to be extracted in soluble form under our conditions. This may help to explain why the reliability of our combination procedure approach is significantly better than that of other investigations that have relied exclusively on the elution technique.

Another key to the success of the combination procedure is the interpretation of the results. The ABO type of questioned (unknown) specimens is not conclusively diagnosed unless the results of both component techniques (elution and inhibition) are consistent with one another.

We have studied bone fragments from individuals of all four ABO blood types before and after exposure to different temperatures under both dry and humid conditions, and in some cases, being buried in the ground in and out of doors. Specimens were recovered and tested after periods of time ranging from one to nine months. Separate elution and inhibition tests do yield incorrect grouping results in some specimens, but the combination procedure provides a check on the results obtained by either testing method alone. In tests on more than 1500 bone specimens, we correctly typed 32% of them, but most significantly, only 0.6% were incorrect. The remainder of the specimens gave inconclusive results. If the specimens kept in moist soil are excluded, 38% were typed correctly and only 0.2% were wrong. The percentage of conclusive results decreases significantly in specimens kept at higher temperatures, especially under humid conditions, and in specimens buried in the ground. As noted above, however, this is far less important than obtaining the correct group when the results are considered conclusive.

DNA Types From Human Bone

The most exciting recent development in forensic biology came from advances in molecular biology and so-called genetic engineering. Deoxyribonucleic acid or DNA, the genetic material itself, can be extracted from the cells of human blood, bloodstains, seminal stains, and other tissues, and analyzed. There are two major methods of DNA analysis at present, called RFLP (for "restriction fragment length polymorphism") and PCR (for "polymerase chain reaction").

Analysis by RFLP involves the use of DNA probes specifically prepared for the purpose. Results with this DNA analysis method indicate that a much greater degree of individualization of human blood, physiological fluids that contain nucleated cells, and tissues, is possible than has been achievable with blood typing and other genetic markers. The prospect of "effective" individualization has led some scientists and the popular press to refer to the technique as "DNA fingerprinting."

Application of the procedure to any tissue requires the ability to isolate DNA from the tissue in a sufficiently intact form to be amenable to analysis using the probes. As part of this project, we have isolated DNA from bone and several soft tissues in a form suitable for such analysis. The DNA from any tissue of the same individual should be identical, and as such, should give the same DNA typing results. We have shown that DNA from the bone and from the blood of the same individual demonstrated the same individualizing types when tested with human DNA probes. Thus, DNA analysis can be applied to bone and soft tissues, at least when the specimens are comparatively fresh.

Since DNA analysis is a new procedure, and the DNA types that are detected have no clinical importance, there will not be any pre-mortem records of the types at the present time. However, DNA typing could be used to match different bones belonging to the same person from sites where skeletal remains of more than one person are commingled.

In addition, DNA typing is a sufficiently powerful individualizing tool that it can sometimes be used to show that a specimen of human remains must have originated from the offspring of particular parents, or that the DNA pattern is consistent with another set of members of the family. In this last application, DNA typing is used in a parentage testing context, but for the purpose of helping to identify a person rather than for the purpose of establishing the parentage of a child.

The second major DNA analysis method is called polymerase chain reaction or "PCR." This technique is especially useful in circumstances where the quantity of specimen is very limited or where the quantity of intact DNA in the specimen is insufficient for RFLP analysis. With PCR, a small, defined specific segment of the DNA can be faithfully replicated up to a million or more times in a short period of time. Thus, even though little DNA may be available because of the size or condition of the evidence specimen, the DNA segment of interest can be copied, or "amplified," to yield a quantity suitable for typing analysis.

The PCR technique can be used to analyze two different kinds of DNA variation (technically called length and sequence polymorphism). In addition, the sex of origin can be determined by analyzing DNA segments from the sex-specific chromosomes.

We have demonstrated that PCR analysis works effectively in DNA isolated from bone and some soft tissues. Both length and sequence polymorphic types can be detected, and the sex of origin can be determined.

Studies of bone fragments aged at different temperatures and under different environmental conditions show that the DNA is often very degraded. The RFLP technique requires a certain quantity of DNA that is not too degraded. Thus, these specimens are often unsuitable for RFLP analysis. The PCR technique, however, sometimes yields results in specimens unsuitable for RFLP analysis.

There is little doubt that bone is one of the best sources of DNA among the different human body tissues.

This fact should be helpful to forensic identification specialists in handling specimens of human remains in which soft tissues are often putrefied or missing altogether.

Interestingly, the genes responsible for ABO blood types have recently been described in detail. This basic knowledge makes it possible to devise methods for determining ABO types by DNA analysis, and such methods have already been used in fresh blood specimens. Further developmental work may make it possible to get ABO types in DNA from bone or soft tissue specimens. This analysis might get around some of the problems associated with conventional ABO typing methods, and enable the identification specialist to take advantage of any pre-mortem blood typing records available.

Recently, there has been discussion about establishing national and state DNA typing data bases. Should such data bases become a reality, DNA profiles from unknown bone fragments could be used to search missing persons or other files. This capability could provide an excellent investigative tool for criminal justice and identification specialists in both the civilian and military communities for the positive identification of human remains.

Type / Condition of Remains	Identification Method(s)	Information Obtainable Using the Method
fresh intact body	direct recognition by relative or acquaintance	positive identification
unrecognizable body but with recognizable items or belongings or identifiable markings	• fingerprint comparison with premortem records • odontology - dental comparison with premortem records • personal belongings • scars, marks, tatoos	• positive identification possible if premortem records available • must have putative identification information to select premortem reords for comparison
skeletal remains intact	• odontology - dental comparison with premortem records • radiology - comparison of premortem x-rays with x-rays of remains	• positive identification possible if premortem records available • must have putative identification information to select premortem reords for comparison
skeletal, intact but no premortem dental records or skeletal, dentition not intact	• anthropology • bone grouping	• estimates of gender, age, stature, race, time since death, and possible information about premortem injury or medical history • blood group
skeletal, not intact, bones missing, dentition not intact	• anthropology • forensic hair comparison • bone grouping	• information depends on which bones are recovered • inclusion or exclusion based on comparison with known hairs • blood group
skeletal, not intact; bone fragments and pieces; no hairs	• bone grouping	• blood group

Situations Requiring Bone Grouping

to Assist in Identification

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Mass Disasters

Air or Railroad Disasters

Fires

Explosions

Military KIA and MIA in Wartime Theaters

Missing Persons

Homicide Victims

Unidentified Skeletal Remains

Civil Matters

Archaeological Investigations

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