

Recommendations of the Kinship and Data Analysis Panel (KADAP) to the Office of the Chief Medical Examiner of New York City During the World Trade Center DNA Identification Effort

The Kinship and Data Analysis Panel (KADAP), assembled to assist the Office of the Chief Medical Examiner of the city of New York (OCME) during the World Trade Center (WTC) DNA identification effort, prepared the following recommendations to help the OCME laboratory create policies and procedures specific to the WTC mass fatality incident. These recommendations provided a roadmap when it was necessary to depart from the laboratory's usual forensic casework protocols. The KADAP's recommendations also offered guidance for securing additional resources and provided assurance that sufficient peer review and expertise were available to support these new endeavors.

These recommendations appear here in their original form, without editing. *The annotations in italics offer an after-the-fact context for particular recommendations to the OCME. The KADAP's recommendations are included as appendix A to this report because of their historical significance, and because they may be helpful to laboratories that are developing a mass fatality incident DNA identification response plan. The recommendations and opinions represent a consensus of the KADAP members (referred to in the recommendations as "the Panel") who were present on the date indicated; not all members were present at every meeting.*

1st KADAP (October 18–20, 2001)

The following recommendation sought to inform officials beyond the OCME, New York City Police Department (NYPD), and New York State Police (NYSP) that deviations from protocols would be ongoing, that the local scientists were respected experts in their fields, and that the KADAP was involved in reviewing new protocol developments.

- The Panel recognizes the unprecedented complexity of identifying the victims from the World Trade Center attacks. They also recognize the expertise of the OCME, the New York City Police Department (NYPD), and the NYSP. Given the evolving nature of this task, the Panel stresses that these are their initial recommendations, and they may be modified by OCME, NYPD, or NYSP, as they deem necessary. The panel remains available to them for consultation upon request.

The use of multiple software programs presented numerous difficulties that had to be overcome in the face of the informatics needs of the WTC

DNA identification effort and the absence of existing software programs to address the issues. The following recommendations were developed after the KADAP considered the features of all available software programs.

- No single program currently exists that meets all of the analytical needs for resolution of the WTC victims. Therefore, we recommend for the short term:
 - WTC CODIS [Combined DNA Index System] be used:
 - At high stringency for direct matches. Likelihood ratio of 1×10^{10} is sufficient to report identity. A 13-locus match using the core CODIS loci is sufficient to report identity.
 - At low stringency to screen for potential first-degree relatives (parent/offspring and some sibs) in order to manually search case-specific data for cases with additional potential relatives.

- ❑ DNA•VIEW be used to assess the putative relationship. A minimum Probability of Relationship of 99.9% is sufficient to report identity by kinship analysis. The minimum prior probability is 1/5000, which can be increased to reflect case-specific issues (e.g., members of service).
- Commercially available pedigree programs should be incorporated for kinship review.
- Middleware should immediately be developed to facilitate use of existing programs.
- A customized program, developed in a modular manner following the proposed process flow, is needed. This package should be designed to analyze complex relationships in a way that integrates validated systems when possible. By October 26, 2001, the mechanism needed to commit resources to this program will be identified and established by NIJ [and reported back] to Inspector Mark Dale.

Because mitochondrial DNA mtDNA testing had received significant public attention in several forensic cases, stakeholder expectations for its use in the WTC response were high, and the OCME laboratory received many inquiries from officials regarding its use on the WTC samples. The KADAP was concerned that this early focus on mtDNA would dilute the effort to yield sufficient short tandem repeat (STR) loci in what were likely to be difficult samples. The Panel was concerned that this might hinder the identification process by adding less powerful methods of identification before all efforts to reveal unique identities had been exhausted.

- Mitochondrial DNA typing of victim samples should be used only as a last resort after additional test reanalysis and/or the use of additional forensically validated STR, Y-chromosome, or other nuclear markers have been used.
- If forensically validated systems, including mitochondrial data, are insufficient to resolve identity, research grade systems should be explored on a case-by-case basis.
- Mitochondrial DNA typing should be performed on all maternal lineage relative's appropriate samples (e.g., buccal swabs, blood) using a suitable validated system on the extracts as provided by NYSP, Myriad Genetics, or any other authorized agency.

- Mitochondrial DNA typing should not be performed on personal effect samples until other appropriate approaches have been considered.

These consensus recommendations represent a major step towards evaluating the complex data that will be generated from the World Trade Center terrorist attacks.

2nd KADAP (November 20, 2001)

With many competing agencies involved in the WTC effort, the KADAP offered recommendations about DNA-specific resource needs to reinforce their urgency with officials in charge of prioritization.

- This Panel determines that it is critical to the success of the WTC identification project that the OCME and NYSP share rapid access to the same data sets via immediate installation of a T1 line.
- The Panel recognizes that requests for prioritization of analyses of particular samples have significant implications for the overall process. Such requests will impede the overall progress of identification, increase the chances of analytical or interpretive errors, and increase costs. The Panel strongly urges those who make such requests to take all of these factors into account and minimize requests for prioritization.

The confirmation of identification by DNA was relied upon by the Chief Medical Examiner. The following recommendation aided in establishing baseline identity estimates.

- The Panel has recommended that likelihood ratios equal to or in excess of 1010 can be adopted as sufficient evidence of identity. However, this value should not be considered as a necessary criterion for identification in all cases, and that final recommendation of identification can properly be based on lower values depending on all available information, as determined by the Chief Medical Examiner.

3rd KADAP (February 21–22, 2002)

The following recommendations considered and addressed sample processing issues. The complexity of the process is shown in the graph

that appears on the last page of this appendix, "WTC Disaster Manhattan (DM) Identification Process."

Production:

- The Panel believes that collaboration and information sharing between the different groups and agencies involved in the DNA identification of the WTC victims is a critical component to maximum identification throughput.
- Numerous production choke points exist as obstacles in meeting the goal of maximum identification throughput. Information management and software integration are major issues that need to be supported to avoid obstacles. The existing software programs should continue to be supported and effective software integration should be developed with appropriate priorities. This requires additional resources, including but not limited to hardware, software, expert systems, and personnel.
- In order to eliminate the most immediate choke points, the Panel recommends that:
 - OCME and NYSP each hire/contract two (2) additional information technology FTEs so that present staff experienced in the current process can be solely dedicated to the WTC effort.
 - OCME and NYSP each hire/contract five (5) additional forensic analyst FTEs to be solely dedicated to the WTC effort.

Validation and Quality Control:

- Documented validation protocols should be developed and implemented for software programs and interfaces.
- Dedicated personnel and equipment should be made available for validation.
- Objective unbiased peer review is a useful process to implement valid systems.
- Appropriate test genetic data should be integrated into the WTC CODIS for efficient validation of all software.
- The current procedures to confirm matches (see attached flow chart) used by OCME and NYSP are appropriate.
- The probability of miscalling alleles that would lead to false inclusions is so small that it is not

necessary to review electropherograms previously reviewed by vendor laboratories for uncomplicated STR cases that meet previous recommendations for likelihood ratios.

Continued Testing:

- Successful DNA typing of all samples will not be possible due to conditions of the remains. The Panel recommends that testing of individual samples should be finite. Criteria for determining cessation of testing should be established. Development of a probative test should be investigated.

4th KADAP (April 24–25, 2002)

As the scope of the WTC effort evolved, and the complexities of data management and the number of partnerships increased, the KADAP recommended and implemented a mechanism to facilitate secure, rapid transfer of data and provided additional development of statistical approaches to kinship analyses.

Recommendations:

- In order to facilitate data flow, the Panel recommends that a mechanism of data synchronization should be created. NCBI [National Center for Biotechnology Information] should host the secure FTP resource. The Forensic Biology Unit of the OCME needs Internet access with adequate bandwidth and tools for secure access.
- Cases involving difficult kin interpretations, including such things as mutations, should be reviewed by members of the AABB Parentage Testing Community to recommend disposition to OCME.
- Kinship used to confirm a personal effect match should be accepted at a Probability of Relationship of 99.9% using a Prior Probability of 0.5.

In addition to making recommendations, the KADAP offered several statements to support the work of the OCME and the NYSP.

Statements:

- KADAP recognizes the desire of victims' relatives, public officials, and the concerned public for complete and accurate use of validated forensic methods for identification of those lost in the WTC attack.

- KADAP recognizes that elected officials and the public must balance the above goals with desire for expeditious reporting of results. These are competing goals which must be considered carefully.
- KADAP recognizes that ongoing scientific and administrative review of all data will be needed to assure the accuracy of victim identifications. KADAP has concerns that imposed time deadlines are not in the best interest of making accurate or complete identifications.
- KADAP fully supports and endorses the efforts to date of the NYC OCME and NYSP in the processing of DNA from victims, personal effects and family members. To date, over 900 identifications have been accomplished using a combination of traditional methods and modern DNA technology.
- KADAP also recognizes that many victims may not be identified despite great effort by all concerned. Similarly, incomplete DNA results on highly degraded samples are likely to preclude positive identification of many of the 19,000 remains from victims recovered to date.
- KADAP is fully committed to ongoing efforts to assist New York agencies in identification of victims and remains. KADAP recognizes that successful DNA typing of all samples will not be possible due to the condition of the remains.
- KADAP recommends that DNA testing of individual samples cannot continue indefinitely (i.e., beyond the limits of sample integrity and available technology).
- Statistical criteria should be reviewed and revised as appropriate for use in assignment of identity of remains yielding incomplete DNA profiles.

The following recommendation was made because results were obtained from fewer loci from later samples recovered from Ground Zero. At the same time, the estimate of the number of victims became more firm, allowing statistical approaches similar to that of a "closed" system to be considered.

Identification Rules:

- Compromised DM samples can be considered associated with samples that were previously

matched through DNA if the LR of shared loci [is] >108 . This is equivalent to one divided by the random match probability of the shared loci between the two profiles.

5th KADAP (July 15–16, 2002)

As data from fewer loci were recovered from more compromised samples, experimental methods were evaluated for application in the WTC effort. The following recommendations considered parameters for using single nucleotide polymorphism (SNP) methodology in this environment.

Commentary and Recommendations on Use of Linked SNPs for Forensic Kinship Analysis of WTC Samples:

- 1) Use of the CODIS STR loci is a well-established method for estimation of random match probability and for kinship studies.
- 2) Unlike the 13 CODIS STR loci, which are unlinked, the 70 SNP loci studied in the KADAP pilot project consist of multiple haplogroups. Many of these SNPs are closely linked with each other and with the CODIS STR loci.
- 3) While linkage of genetic markers, per se, may have no untoward effect on their use in match probability estimates, linkage between SNPs will alter the calculations used in certain kinship estimates.
- 4) Use of inherited SNPs is very promising as an adjunct or substitute for STR profiling. A KADAP subcommittee on SNPs met on 12 July 2002 in Washington, D.C. This subcommittee recognized the potential of the technique pending additional studies.
- 5) KADAP recommends that the OCME of NYC proceed with the pilot use of the ORCHID/Genescreen (Dallas, TX) SNP panels on WTC samples in appropriate situations.
- 6) Sample consumption issues must be appropriately addressed before SNP analysis proceeds.
- 7) KADAP also recommends the KADAP SNP subcommittee pursue further statistical analysis of existing SNP data.

6th KADAP (September 9–10, 2002)

As time passed, a more precise list of victims was established. The KADAP reassessed the character of the WTC site a year after the attack and the statistical approaches that could be used.

KADAP Recommendations Regarding Identification of WTC Victims Based on DNA Profiling:

- 1) For purposes of statistical analysis of genetic data, KADAP recommends that the OCME consider the WTC as a closed population at this time.
- 2) The size of the closed population is considered to be the number of persons reported missing (currently 2,802).
- 3) Therefore, KADAP recommends that prior probabilities used in match estimates be based on either the number of:
 - (a) RM [reported missing] and the gender ratio, OR
 - (b) nongenetically identified RM individuals (of appropriate gender) plus the number of genetically identified individuals who cannot be excluded from the DNA profile in question.

Operationally, KADAP recommends that the OCME use 3(a) above until such time as 3(b) is necessary to refine statistical estimates.

Based on the assumption of a closed population of WTC victims and on the reduced estimate of the number of missing persons (from 5,000 to 2,802), KADAP recommends reducing the threshold for direct matching of remains from a likelihood of 1×10^{10} to 4×10^9 .

Based on the gender ratio of the Reported Missing WTC victims (as of 9/10/02), the appropriate thresholds for direct matching of remains of known gender are 2×10^8 for females and 2×10^9 for males.

MtDNA Recommendations:

- KADAP recommends use of an mtDNA database that reflects, as closely as possible, the population mix of the WTC victims. The mtDNA from one maternal relative or positively identified personal item can serve as the

reference sample for the RM. Certain relatives, including spouses, can be used to constitute the mtDNA database. Thus, when multiple relatives of a victim are available, mtDNA profiles from different maternal lineages can be included.

- KADAP recommends that the upper bound of the frequency estimate of an observed mtDNA sequence in a population should, at this time, be reported as:

$$X/N + 1.96 \div (p(1-p)/N),$$

where $p = X/N$, and where

$X = \#$ of "matching" mtDNA sequences in a database of size N .

If $X = 0$, then the upper bound of the frequency estimate = $1 - \alpha(1/N)$, where $\alpha = 0.05$

Additional recommendations were made as the SNP technology was assessed.

SNP Recommendation (December, 2002)

Based on the UHT [ultra-high throughput] SNP validation data provided by Orchid Biosciences in Dallas, Texas, the KADAP recommends that this technology may be used by the OCME for WTC specimens as a potentially useful, but research grade, identification technology. The KADAP recommends going forward with limited testing of WTC specimens for investigational purposes, proceeding in a staged approach, with continuous evaluation of the utility and validity of this technology.

7th KADAP (January 21–22, 2003)

As the identification effort progressed, review of collection issues highlighted the need to adopt new methods of data collection for future mass fatality situations. The following recommendations were made after dialogues with those responsible for data collection from the Disaster Mortuary Operational Response Teams (DMORT).

KADAP Recommendations to DMORT

The KADAP recognizes the importance of the Victim Identification Program (VIP) as a vehicle for collecting the critical data relied upon for making precise identifications in mass fatality incidents. The VIP can be made more useful to DNA Laboratories by including additional genetic information. Therefore, KADAP respectfully offers the following recommendations:

- 1) Amend the VIP form to include more comprehensive fields to assist in DNA-based identifications. The KADAP would be pleased to assist the DMORT committee in revision of existing forms.
- 2) DMORT should consider adding one or more DNA identification specialists to the Family Assistance Center (FAC) teams to allow for timely onsite collection of kinship data and personal effects needed for DNA extraction/profiling.

8th KADAP (July 7–8, 2003)

Nearly 2 years after the attack, the KADAP assessed the capabilities of existing technologies for the remaining and most challenging samples. This recommendation was made to help families and other stakeholders understand the limitations of existing technologies for identifying these remains.

KADAP recognizes that DNA testing will not be successful for many samples and therefore some of the WTC victims will not be positively identified by STR, mtDNA or SNP testing.

KADAP further recognizes that OCME has exhausted appropriate contemporary methods of DNA extraction and genotyping on recovered WTC biological samples. While it cannot be ruled out that future scientific advances may reopen promise for additional testing, KADAP recommends that completion of ongoing work with current technologies be viewed as a stopping point in the identification process.

World Trade Center Identification Process 2/21/02

This dataflow scheme presumes that M-FISys will be regularly updated with MLI status on all DM#s

If OCME is communicating with NYSP, we will not get any new SP or family profiles for identified DMs (accounting for time lag with processing)

