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Forensic genealogy, bioethics and the Golden State Killer case

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ABSTRACT

A case study will be used to examine specific issues of bioethics and forensic science that occur in forensic investigative genealogical searching, which include genetic privacy, discrimination and public safety concerns. The forensic investigative process and various investigative DNA tools will also be described. The Golden State Killer Case (1) will be examined to highlight and discuss forensic ethical issues to develop an ethical framework, as well as provide recommended solutions to pressing public safety and privacy issues facing crime laboratories and criminal investigators. Use of the ethical concept of proportionality (2) will be utilized to contrast and balance competing ethical concerns.

1. Background

Investigators turn to forensic genealogy when DNA has been obtained at a crime scene, a suspect match has not been obtained in the National DNA Index System (NDIS), and investigative leads have not identified viable suspects. In forensic genealogical searching, the DNA profile found at the scene of the crime is searched against DNA profiles from individuals known not to be the perpetrator for genetic similarities consistent with originating from a related family member. NDIS is the acronym used to refer to the criminal justice DNA database program administered by the FBI. The acronym CODIS (Combined DNA Index System) is frequently used synonymously with NDIS, but is usually used to refer to the software that runs the system, the type of forensic DNA profile as in "CODIS profile", or the crime scene and DNA offender indices within NDIS [3]. The acronym CODIS as utilized herein refers specifically to the 20-locus autosomal DNA profile that is developed at crime scenes and compared against suspects, known offenders and arrestees.

The crime scene DNA can be further analyzed with new technology by labs outside the existing forensic service spectrum of CODIS loci by using large panels of approximately 850,000 single nucleotide polymorphisms (SNPs), which are commonly used for direct to consumer genealogy [4]. Searching publicly available databases containing DNA information from individuals who have placed their DNA in the database for the purpose of finding missing relatives, can provide investigative information to solve a previously unsolved crime. Beginning with candidates that are identified in a database search, a family tree or multiple family trees are developed to create a pool of potential suspects. Traditional and genealogical investigative methods then narrow the potential suspect pool of relatives using data such as location, sex, age, access to the crime scene and other factors. As relatives will be frequently located from each side of the crime scene profile owner's family tree, a critical finding is where the family trees join. This indicates that DNA from both maternal and paternal sides of the family are represented in one individual or a single family, thereby

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pinpointing specific candidates for sampling. This information is particularly powerful when a suspect is linked to a location near the crime scene, along with case specific investigative information which can further include or further eliminate an individual. Once specific potential candidates are developed, known reference samples can be obtained and compared directly against the crime scene profile for a direct inclusion or exclusion.

While innocent individuals are examined and eliminated on a routine basis through traditional investigation, the use of databases and genetic data represents a unique situation of exposure of specific personal information. Searching individuals via traditional investigation often requires a form of reasonable suspicion, where there is normally a presumption of innocence. This causative barrier is frequently in place, to prevent legal and procedural violations, discrimination and provides respect for privacy. Hand in hand with the presumption of innocence comes an expectation of freedom from unreasonable search and seizure, providing a balance between competing interests of individual rights to privacy versus personal and public safety.

Individuals who commit violent crimes inflict tremendous grievous emotional and physical harm on their victims and their families, expressing individualism and autonomy while infringing on the rights of others, practicing recidivism. Recidivism is the commission of repetitious and frequently increasingly violent infractions on new victims. To illustrate this cost, the damage to the individual in a case of sexual assault is estimated at over $111,000 [5]. The societal return on investment from the testing of all sexual assault kits ranges from 9874% to 64,529% [6]. The existing cycle of recidivism represents a growing opportunity for disruption of a criminal career earlier in its cycle, which can prevent future victimization and associated costs to both the individual and society. This opportunity warrants an examination of the ethical balance between the individual right to privacy and autonomy, versus the public's right to personal safety and integrity, not to have harm inflicted on them by an individual.

2. Case history: Golden State Serial Killer

The Golden State Serial Killer is a burglar, stalker, peeper, rapist and killer known to have murdered 12 victims and raped over 50 others in California from 1974 through 1986 [1]. The case, which remained unsolved for decades, was broken with the arrest and charging of Joseph James DeAngelo in Orange County on April 24, 2018 [7]. DeAngelo began as a burglar, known as the Visalia Ransacker in 1974–1975, operating in Visalia, California, between Fresno and Bakersfield. The severity of his crimes escalated to sexual assault as the East Area Rapist from 1976 to 1979, committing sexual assaults in the Sacramento area. He then graduated to murder, as the Original Night Stalker from late 1979 to 1986, committing homicides in Orange County and Santa Barbara [7–16].

DeAngelo shows the classic features of recidivism, with his crimes beginning as a burglar, demonstrating not only repeated offenses, but escalating to cases of greater and greater severity including sexual assault and homicides. His experience as a police officer in two jurisdictions is thought to have increased his knowledge base to elude capture, but also to become emboldened to seek greater and greater excitement through escalating severe and violent cases. A note sent to the Sacramento newspaper and media outlets [1,16] provides a view into the psychology of the criminal, including building impulsive desire, uncontrollable urges, excitement seeking, feelings of superiority combined with self-esteem issues, and a need for dominance, achievement and recognition not fulfilled within societally accepted norms.

Unsolved serial crimes have become the subject of various cold case task forces, many of which have achieved remarkable success. Forensic tools unavailable when crimes were original committed have shed new light on previously unsolved offenses, permitting investigators to connect cases to establish previously unseen trends and combine intelligence. In the Golden State Killer Case, DNA evidence linked various crimes to combine what was originally thought to be unconnected offenses in different areas, to be the crimes of a single individual. Despite the development of single source DNA profiles at multiple crime scenes, there was no match made to a suspect, and no matching profile found in NDIS. The Golden State Killer case remained unsolved for over 40 years from the commission of the original crimes.

The break in the Golden State Serial Killer case came when DNA from the crime scene deposited by the assailant was further analyzed and compared to an open source genealogical website, GEDMatch [8–16]. Presumably GEDMatch was used in favor of other ancestry and genealogical websites as other providers had more restrictive policies on law enforcement access and GEDMatch aggregated data from these other providers, with participants moving their data to GEDMatch specifically to search for relatives. On the website, individuals affirm a privacy statement acknowledging their genetic DNA information will be available for searching for the purposes of being located. Upon learning of the Golden State Killer case, GEDMatch updated their confidentiality statement to include information that genetic information can be searched by law enforcement [17,18]. Police investigators, with the assistance of a genealogist, reconstructed the family tree that included the crime scene profile, which matched to a probable 4th cousin [4]. It took approximately 4 months of family tree construction and investigative legwork to narrow potential suspects in the tree to males of the age and geography that could have committed the crimes. Among candidates developed as investigative leads, there will be those who may fit the profile, whose DNA does not match a direct comparison to the crime scene profile. Such was the case for a 73-year-old male at an Oregon nursing home who had his DNA sampled and was eliminated from suspicion [19]. While police had obtained a court order signed by a judge compelling provision of a reference sample, the man allegedly provided a sample with consent once investigators informed him of the purpose. The man's daughter was notified after the elimination and worked with police to help them rule-out additional people who could conceivably be the killer.

Eventually investigators narrowed their search for male relatives fitting the age and description to Joseph James DeAngelo. Placing him under surveillance, discarded DNA samples were obtained without the suspect's knowledge, including a discarded tissue and a swab taken from the handle of a car door. Once these samples were found to directly match those from the crime scene, DeAngelo was arrested and charged.

3. History of forensic DNA typing

Forensic DNA typing began in 1985 with a discovery by Sir Alec Jeffreys that DNA patterns could be obtained from unknown biological samples. These ‘DNA fingerprints’ were apparently inherited characteristics, which in turn could be used for relationship analysis, with the first application being an immigration case [20]. Further development of the technique with the Forensic Science Service's Peter Gill enabled the comparison of DNA patterns developed from crime scenes to samples from known individuals to establish a likely identity [21,22]. The first criminal case was the murder of two young girls from Leicestershire, where the technique exonerated Ricard Buckland, who confessed to killing one of the girls. The DNA patterns from both crime scenes indicated a single perpetrator. After a large investigation involving collection and comparison of many reference samples, Colin Pitchfork was

subsequently matched to the crime scenes, admitting he had sexually assaulted and murdered both victims [23]. Serological comparisons had been in use in forensic laboratories for decades prior, however lacked the level of specificity and relative stability that DNA could provide. The protein variations detected using serology have the disadvantage of being shared by more people than DNA variants, and were also more labile, leaving them more susceptible to breakdown by heat, microbial and environmental factors, rendering specimens unusable. The Polymerase Chain Reaction developed by Cary Mullis, who was awarded the Nobel Prize for his ground-breaking work, enabled additional targeted copies of DNA to be generated from crime scene and suspect samples, dramatically increasing sensitivity [24]. With the discovery of trimeric and tetrameric tandem repeats and the development of use of fluorescently labelled PCR primers for detection of PCR products [25–28], the sensitivity of forensic DNA typing went from 250 ng to less than a single nanogram to develop a useable profile. One nanogram is one billionth of a gram of purified DNA, which is virtually invisible to the naked eye. The DNA contained in a spot of blood the size of a head of a pin is more than sufficient to develop a complete CODIS DNA profile using modern forensic profiling methods. This increase in sensitivity opened the potential of specimens beyond those from traditional sources of blood, semen and saliva, to include trace or touch DNA, which is DNA transferred by contact with skin and hands [29,30].

Biological material containing DNA is frequently left behind at a crime scene by offenders. This is abandoned crime scene material is generally considered discarded akin to trash; therefore, an individual is generally considered to have no right to privacy for this sample [31,32]. However, given the ever-increasing level of specific information that is available with DNA, there is rationale for debate depending on use [33]. Crime laboratories analyze this crime scene evidence and provide investigative leads, including or eliminating individuals submitted for comparison. Known samples may be for elimination, such as people who are expected to be there, like the owner of a car when their car is stolen. A sample is also taken from potential suspects. There are privacy concerns over the handling of these reference samples, particularly restricting the use of known samples from victims and elimination of individuals only to the case at hand. Crime labs participating in NDIS have a Local DNA Index System (LDIS), which provides for more discretionary uses of DNA profiles, which frequently include staff indices used to detect instances of contamination. LDIS may be used by crime labs to compare their own cases among themselves for case to case hits prior to upload to state or national indices. All laboratories who have access to the NDIS must be accredited, and therefore abide by all requirements of the DNA Identification Act, protecting privacy and dictating compliance with extensive quality assurance measures.

Prior to the advent of DNA databases in the days of forensic serology pre-1995, when types of blood were very common relative to the rarity of different DNA types, a known suspect was required for a direct comparison to the crime scene to further an investigation. Databases of known individuals had not yet become a reality to permit the development of suspects as investigative leads. NDIS was created by the DNA Identification Act of 1994 [34]. The act establishes strict requirements for use of data, confidentiality, penalties for breach of confidentiality, proficiency testing, personnel qualifications and quality assurance. It is a felony for anyone to misuse NDIS information [34]. The short tandem repeat (STR) markers included in NDIS are non-coding regions of DNA [3]. The gender marker, Amelogenin is a single gene found in males and females with a short length difference which is used to determine gender. This restriction of genetic markers to non-coding regions protects genetic privacy of individuals housed in the database. The regions are repeats of short DNA sequences and therefore do not encode protein and hence do not confer a visible or measurable trait. It is notable that the non-coding regions used in forensic DNA typing short tandem repeats (STRs) can be used for identification and relationship information [35,36]. These short DNA sequences consist of repeating regions of 4 or 5 base pair sequences, where the number of repeats vary between individuals. The number of repeats creates allele designations that can be characterized by length, which enables the assigning of lengths to alleles, thereby generating a DNA profile. These DNA profiles can in turn be stored as a series of numbers and compared to other profiles [37].

Inclusion in the NDIS investigative database of known individuals is restricted to those convicted or arrested for designated offenses. There is also a missing persons database, however these data are fully segregated from the investigative database, ensuring no inappropriate use of individuals' information. As a result of this structure, the risk to society's privacy is balanced against public safety by providing limited exposure to personal genetic information. There is a threshold to entry into the investigative database by a form of just cause, which is the commission or arrest of a designated crime. The US Supreme Court weighed in on the admissibility of arrestee DNA in Maryland versus King, resulting in a 5-4 decision in favor of permitting the practice in those 39 states that have chosen to utilize arrestee samples [38].

When the case does not have a viable suspect, or does not get a hit on the database, it may grow cold. Crime laboratories continue to search unsolved cases on a weekly basis, however at some point, such as in the case of the Golden State Killer, the suspect is not in the database and the investigators turn to more innovative methods. These methods include forensic phenotyping, partial matching, familial searching, ancestry and forensic genealogical searching.

4. Forensic phenotyping

Forensic phenotyping is an attempt to determine visible physical features from the DNA left at a crime scene. Features began with racial determination and skin color, however now include eye color, hair color and facial features. It was first used in the case of the South Louisiana Serial Killer in 2002, who was determined to be Derrick Todd Lee [39]. DNA from the crime scene was sent to a now defunct company, DNA Print, for a determination of racial origin. From eye witness accounts the suspect was a light skinned male, however various other factors pointed to an African American suspect. The DNA Print results indicated an individual of African ancestry [40]. Prior to the ancestry results some investigators had not been collecting DNA samples from African American suspects. They subsequently began sampling all individuals to ensure a suspect would not be inadvertently missed. The case was eventually solved when a trace DNA profile was recovered from a victim who survived and who provided an accurate description of her assailant. This description was used to create a composite sketch of the attacker. When the foreign component of the mixed DNA profile developed from trace DNA on the front of the victim's garment included the suspect, the composite profile was released. Subsequently a DNA hit was obtained to a sample provided earlier by Derrick Todd Lee. As the DNA analyzed was discarded at the crime scene, there is no presumed right to privacy, therefore full interrogation of information from the DNA was performed without ethical or legal issue. Forensic phenotyping is therefore considered ethical and does not breach any right to privacy concerns when it is performed on discarded crime scene samples.

Characteristics of a potential suspect have been derived from crime scenes for decades to provide direction to investigations. Examples include shoe size from shoe-prints and hair length, color,

treatment and ethnicity from items left behind by suspects. A great challenge with forensic phenotyping is the variation seen in the human population, the variability of assignment of features and the absence of a reliable database for comparison to known individuals to develop specific leads. As a result, forensic phenotyping is of limited use in developing suspects, and marginally useful to compare crime scene evidence against existing suspects as unless there are gross differences, eliminations cannot be made conclusively. The pivotal point is when a CODIS profile exists, the direct comparison of a suspect reference profile to a crime scene profile provides much more reliable evidence. Therefore, the utility of forensic phenotyping is limited in unsolved cases and found human remains to circumstances that assist in canvassing eyewitnesses to provide investigative leads, where follow up includes the direct CODIS comparison.

5. Ancestry and ethnicity

Ancestry or ethnicity can be inferred by DNA testing, where physical characteristics of the individual can be projected. Populations cluster by broad geographic regions, however race is a social construct that is an inadequate descriptor of genetic variation found in quasi-continuous clinical patterns related to geography [41]. The term "quasi-continuous clinical patterns related to geography" refers to the significant shared areas of DNA among people originating from the same area of the world. Progress has been made in developing common panels for ancestry inference despite these limitations of racial descriptors [42]. As in Forensic Phenotyping, there are distinct challenges where no databases exist to narrow the suspect population to individual identities. Ancestry and ethnicity databases frequently rely on those populating a database to self-report their own background information. As the ancestry results provided are general in nature, and members of any population numerous, investigative leads are not individualizing and potentially prone to error [43]. Further, as there is considerable admixing of races and variable penetration of genes, there are considerable differences in appearance of individuals with common ethnic and cultural backgrounds [44]. Likewise, where a CODIS profile or other identifying evidence exists, such as a fingerprint, the direct comparison of the reference sample to the crime scene sample is a far more reliable means of identification. Both ethnicity and phenotyping may be of application in cases of unidentified human remains or assistance in canvassing witnesses for investigative leads, where a missing loved one or suspect may be recognized. Once again, value lies in generating leads which can provide the direct CODIS profile comparison.

6. Partial matching

Partial matching is the term used in situations where there are large number of alleles in common between two DNA profiles, such that the level of similarity may be due to a genetic relatedness rather than coincidence. Partial matching is conducted by policy approved by the California Department of Justice, the Commission on Forensic Science in the state of New York and informally by chance in other crime laboratories across the nation and internationally [45–47]. When a DNA profile is come across in the daily work of forensic scientists where that profile is very, very similar to another profile, yet not identical, it is known to have a higher potential to come from a related individual due to the increased sharing of DNA by immediate family members. In 2008, the California Department of Justice adopted partial matching policy which required 15 alleles out of a possible 26 alleles must be in common between profiles, as well as concordant Y-STR profiles [47]. The New York Commission on Forensic Science approved partial matching in 2009, which provides a framework for examining and reporting DNA profiles that differ at a single locus (position in the genome) [45]. This partial match policy requires two DNA profiles to be identical at 12 out of 13 STR loci of the original FBI CODIS core loci for the partial match between them to be investigated as potentially related individuals. These target profiles are examined statistically (based on STR frequencies in relevant populations) and if meeting specific criteria released as an investigative lead, provided law enforcement and district attorneys formally agree to follow up on investigations and charges [48]. Forensic scientists typically do not actively search among cases for profiles that exhibit a high degree of allele sharing, however recognize when profiles share sufficient alleles in common that the profiles may be from relatives. In these cases where partial matching is found, scientists effectively do not "look away," but rather follow up in the event to see if there is a potential familial relationship. A serial killer case in Suffolk County, NY, was solved through the use of partial matching. DNA samples submitted by the brother of the perpetrator following a misdemeanor conviction for violating an order of protection closely matched that of Timothy Bittrolff [49]. Once a sample was taken from Bittrolff, it directly matched DNA recovered from the bodies of two deceased homicide victims. It must be noted that as the FBI has expanded the core loci from 13 to 20 loci in 2017, and the New York partial matching policy permits only a single locus mismatch. As the likelihood of 2 profiles having 19 out of 20 identical loci is diminishing small, the utility of partial matching is very low in randomly detecting genetic relationships in the state of New York.

7. Familial searching

Familial searching is conducted on a case by case basis in 12 states, including the more recent addition of in New York in 2017 [36,46]. The term familial searching is limited to using an offender State DNA Index system within NDIS to compare against a crime scene profile, to develop a potential investigative lead by using a kinship calculation [50,51]. Partial matching is similar to familial searching in that both define sharing alleles by decent rather than through random sharing and use statistical methods to evaluate the potential for kinship. The difference between the two is that partial matching frequently occurs by accident whether as recognized by an analyst or by a quality assurance measure searching for clerical errors; whereas familial searching is a deliberate database search for family members to generate investigative leads.

When reasonable investigative efforts have failed to solve a case where a database search has not provided an investigative lead through a direct match, application is made in major cases of crime against the person for consideration to search the offender/arrestee database for similar profiles. As DNA is inherited, there is a statistical ratio known as a likelihood ratio used to evaluate how closely related the profiles in the database are to the crime scene samples. The likelihood ratio can also be applied to assess partial match candidates discovered randomly rather than in an organized database search. High scoring candidates are then typically typed with additional discriminating markers such as Y-STRs and if they are still included as potential relatives, the investigative lead is released after education is provided to investigators. Training is given to ensure investigators know that investigative leads may not be the true perpetrator but rather any one of a number of potential close relatives. Therefore, known samples must be collected with permission or in a manner not infringing on the rights of the family members nor raising false suspicion. For example, investigators showing up at a candidate's workplace in uniform would be actively discouraged in favor of plainclothes officers making contact or inviting the individual to visit the office. Alternatively,

surreptitious discard samples may be collected from trash or discarded items. Samples which do not match will yield valuable investigative information in terms of additional kinship statistics, besides ruling out a candidate. As there will be ramifications for family members sampled for DNA where a close family member is suspected of a major crime, sensitivity is required in making contact, obtaining a sample and conveying results. Even if samples are taken without suspicion in a surreptitious collection, there is bound to be a shock if a match to a suspect is made. Notification of social support networks, provision of contact information and supplying pertinent information to support workers could provide a valuable service to families.

Concerns have been raised regarding the higher representation in the offender databases of minorities, the violation of rights of suspected family members, the use of the profiles for means not originally proposed when offender databases were originated, and rights issues of those housed in the database itself as their family members are indirectly implicated [50–53]. A critically noteworthy point is that if the investigation identifies the true perpetrator, the known sample is compared directly to the crime scene profile in a one to one comparison rather than a database search. If it does not match, the person is eliminated. If it does match, the case is provided a pivotal investigative lead. The entire national NDIS investigative databases are not currently searched in familial searching, however US states have autonomy to apply familial searching to offender data they have developed within their state, specifically their State DNA Index System. Each state determines the criteria for inclusion into NDIS within their state. Therefore, states have the potential to authorize use of their offender data including conducting familial searching, notwithstanding concerns over the expanded application for criminal investigations. Only Maryland and the District of Columbia have familial searching laws, with both states prohibiting its use [54]. The 12 states currently conducting familial searching utilize policy to guide familial searching [36,55] rather than state law. These policies typically involve generation of full suspect CODIS profiles from probative samples in cases of major crimes against the person, no matches in NDIS, and exhaustive case investigation not solving the case. Inherent limitations of the discrimination of the number of CODIS loci restricts familial relationships to immediate family members, as those with more distant relationships cannot be discerned [36].

8. Genealogical searching

Once traditional investigative measures have failed to provide a viable suspect, expanded use of DNA analysis and application of databases may be considered. Genealogical searching is an extremely rare and new application that is gaining notoriety as it is being applied to help solve an increasing number of major cases [4,56]. The convicted offender and arrestee database housed in NDIS may be used for direct comparison to a crime scene profile, or as in familial searching, examined for closely matching profiles to locate potentially related individuals. Where no DNA matches have been found and sufficient crime scene sample is remaining, an expanded panel of SNP DNA markers can be generated for potential comparison to publicly accessible genealogy databases. An overview of the Forensic Genealogical Searching process is provided in Fig. 1. Crime laboratories currently focus on STRs and do not currently type SNPs, therefore a sample of purified crime scene DNA must be sent to an outside laboratory for additional processing to develop the SNP profile. As genealogy databases are designed to search for biological relatives, once a crime scene SNP profile is obtained, the search mechanism is the same as for any other relative. If leads are generated though this expanded search that appear related to the donor of the crime scene profile, police work begins anew to develop and then narrow the candidate pool. Family trees are developed for individuals as close or closer than 3rd or 4th cousins, with an eye to where disparate branches of the family trees cross, indicating a family where both paternal and maternal lines combine in a single family. Coupled with data, such as location, age and other information specific to the crime, the next step is to carefully sample individual candidates for evaluation. In order to prevent potential negative side effects from arousing suspicion, frequently a discarded sample is collected. At this critical point, which bears repeating, is that this new known sample from a suspect is provided for direct comparison to the crime scene profile. There is either a match or an elimination. Incredible levels of investigative work distill down to this big moment of the direct comparison of the crime scene profile to the known suspect profile.

9. Paternal lineage

A component of forensic genealogical searching is paternal lineage, as all males in the same family line share the same Y chromosome, with the exception of some very small areas of DNA found at each end of the chromosome. Y STRs are inherited along paternal family lines and are static aside from mutations, which can be included in calculations to assess matches and near matches [57,58]. Y STRs can also be used to deduce surnames as well as to include or exclude branches of constructed family trees from relatedness to the crime scene profile [59]. Providing the potential surname of a suspect, along with data such as the relative age and sex of the suspect and geography of the crime, can be very valuable investigative information. Used in combination with a CODIS profile and potential leads from a genealogical search, results can be used to triangulate towards an individual, narrowing the suspect pool to save tremendous investigative resources. Again, the confirmation of a direct comparison of a suspect's DNA with the crime scene profile is the most reliable evidence, therefore the goal is to arrive at individuals that can be sampled to make this comparison.

10. Elimination samples

Experience as a police officer provides a variety of advantages if an individual committing crime chooses to use the intelligence gained to evade detection, as was evidenced by Golden State Killer Joseph James DeAngelo [14] as well as serial rapist Randy Comeaux in Louisiana [60]. Knowledge of police communications allows the perpetrator to monitor emergency calls and responses, thereby permitting selection of escape routes and times. Experience with gaining surreptitious entry, habits of patrols and area policing, evidence collection and analysis, and methods used by other perpetrators to elude capture, all add to the arsenal of knowledge used by a police officer. This knowledge is particularly problematic if an officer should use this privileged information to commit crimes. This specialized education, training and ability places the police officer and police personnel in a special arena of trust. Safeguards against this misuse include providing known samples of DNA and fingerprints for comparison to crime scene samples should the need exist. While best practices dictate provision of an elimination sample by crime lab and crime scene attendees [61], education is needed that an elimination sample will not be used against the provider's interests and potentially keeps their profile from appearing in an investigative database if it is found as a contaminant in a crime scene sample. While additional effort is required to search each crime scene profile against a staff database, locating profiles from personal provides the opportunity to improve contamination prevention procedures. Furthermore, in many cases the detection of a foreign profile results in the cessation of

additional forensic analysis, as effort shifts to reliance upon database searches to develop investigative leads and forensic scientists and investigators move on to the next case. Identifying foreign profiles as contamination ensures analysis continues to identify the true perpetrator. It should be noted that many police agencies and forensic laboratories do not mandate provision of elimination DNA and fingerprints. This policy should be reconsidered, given the nature of special information and practices that in turn provide more risk should they be used in the commission of a crime.

11. Genealogical searching ethical issues

Ethical dilemmas occur when there are two competing interests, each of which has rights that will be denied if the course is ceded to the other side. Ethical dilemmas frequently lie at the margins, far from the easy choices where a single interest lacks conflict with another individual's rights. Here, the Aristotelian concept of the excellent mean between the two extremes aptly applies, striking a balance between competing interests [62]. Examples of Aristotelian extremes on one side are full state privilege, public safety at the expense of individual rights, and parens patriae, which is government or other authority having responsibility to protect the masses and those unable to protect themselves. The opposing competing interests are the rights of the individual to privacy, ability to express full autonomy, and anarchy, which is the complete absence of government in favor of total freedom of the individual.

The translation of this philosophical dilemma to our current topic begets the following question: to what extent can the rights of the innocent general public and relatives of the committer of a crime be infringed upon by interrogating their genetic data to identify the crime perpetrator and thereby prevent future crimes and improve public safety? On one extreme is maximized public safety through full genetic surveillance to apprehend perpetrators who have left genetic material behind at crime scenes. As of May 2019, there are 944,750 forensic (crime scene) profiles in the FBI National DNA Index System (see Table 1) [63]. This represents a very large number of crime scenes where the offender has left a profile that can be reasonably attributed to the crime or a “person of interest” in the investigation. There have been 468,156 hits to those crime scene profiles [63], which very roughly translates into more than 476,000 additional crimes (approximately 944,750 - 468,156) that could be solved if everyone was included in the known sample collection to which these unsolved crimes were compared. This position also obviously infringes to the maximum extent on individuals’ rights to genetic privacy.

The competing extreme is full respect of individuals’ freedom, right to privacy and autonomy, where none of their genetic data were subject to search against these unsolved crimes. This position would not only negate the crime solving and public safety potential of the unsolved crimes, but also of the 468,156 hits and 457,450 investigations aided (see Table 1) by this investigative information through the current use of NDIS [63].

Clearly a middle ground is sought where there can be a balance between use of genetic information to provide investigative leads in pursuit of public safety while limiting the threat to personal privacy by restricting NDIS entry to those committing or being arrested for criminal offenses. The ethical concept of proportionality has been discussed as a balance to the principle of autonomy to find the optimal balance between individual and public rights [2].

Table 1
CODIS — NDIS statistics (as of May 2019).

Offender profiles	13,823,140
Arrestee profiles	3,568,200
Forensic profiles (crime scenes)	944,750
Hits	468,156
Investigations aided	457,450

Source: FBI Laboratory Services [63].

Principles that provide the foundation for medical bioethics include autonomy, beneficence, non-maleficence and justice [64]. As applied to forensic science, autonomy provides that decisions are made for best interests of the case by its surrogates, the investigator, the prosecutor and the forensic scientist [2]. Beneficence requires the value of evidence is maximized for each case [2]. Non-maleficence dictates the evidence is preserved and protected from deleterious change; no harm comes to the case [2]. Justice supports that each case is treated fairly through use of best practices and receives proper scientific and timely analysis [2]. Further, the concepts of objectivity and proportionality have been introduced as concepts unique to the forensic context, as in an adversarial justice system the forensic scientist must be true to independent data driven scientific decisions and weigh the greater proportion of good when confronted with competing interests [2]. Use of proportionality permits a reasoned response to debate pros and cons of challenging issues, particularly those where individuals' rights conflict with each other and the greater public.

12. The concept of proportionality applied to genealogical searching

The principle of proportionality dictates that there should be a common sense reasonable balance between choices and their consequences, such that the balance between the good achieved is maximized with as little harm as possible occurring as a result [65]. The doctrine of double effect is an example of proportionality, where if doing something ethically good has resultant bad side effect, the original act is deemed ethically acceptable provided the bad side effect was not intended, even if it was foreseen [66]. Palliative care situations in which a patient's life may inadvertently be shortened while pain is managed falls within the doctrine of double effect, where the proportion of good resulting from pain management outweighs the negative value of shortening of life span.

The principle of proportionality has been discussed as a guide in decision making, however it is context dependent, requiring the conditions of importance of objective, relevance of means and most favorable option as starting points [67,68]. Proportionality is applicable when there are two competing interests with significant overlap, therefore there must be a measure between the two to balance the level or proportion of positive versus negative outcomes to achieve an optimal outcome.

There is a balance to be struck between public safety, society's rights and individuals' rights. The cost of violent crime to victims and their families is enormous. Besides the high cost to crime victims, the cost of investigations in these cases is extremely high, with investigators working years on large unsolved cases. If investigators are allowed access, individuals placing their genetic data in private and public databases are giving up rights to privacy. A looming question in cases such as this is to what level should that data be available for investigators for use to provide leads to solve major crimes? If investigators are enabled access to specific data to solve major crimes, there is the issue of informed consent for those individuals populating databases that are subject to search. What rights or disclosure is needed for those individuals who have populated the DNA database, enabling individuals to seek them out as relatives, however not for the kind of news they had originally intended? Ideally a full disclosure is provided to support informed consent, as the individual then decides with full knowledge of

options and consequences, where they can express their autonomy in choosing to enable or deny having their profile searched.

13. Privacy

There is currently no additional US Federal genetic privacy legislation beyond GINA and HIPAA [69,70]. Approximately half of American states have laws that protect genetic privacy. There is no level of consistency between state protections attempting to balance access yet at the same time protect personal genetic information. As soon as there is access, that individual is likely their own worst enemy regarding dissemination of their own information, often permitting very wide access beyond what they imagine the true range of use may be. There is so much fine print in cell phone plans, credit card plans and numerous other similar disclosures that the public may have become desensitized to disclaimers regarding use of personal information.

A high level of structured policy and protection is placed on use of criminal justice databases, such that this could provide needed framework to genealogical searching rather than the laissez faire approach apparent in the direct to consumer marketplace. Potential safeguards include restricting access to specific authorized individuals, providing sufficient checks and balances for access, and strict use of the data that is accessed. Data should only be shared in a very controlled manner to provide investigative leads. There should be penalties for misuse to safeguard data. It is preferable to not re-invent the wheel, but rather adapt another functioning wheel to the specific needs of genealogical searching.

The 4th Amendment of the US Constitution enshrines the right of the individual to be protected from unreasonable searches and seizures [71]. In Maryland vs. King, the Supreme Court determined that arrestee DNA profiles can be included in NDIS, despite 4th Amendment concerns over the comparison of fingerprints to the non-coding regions examined by NDIS [38]. In the rationale of the Justices, this examination of DNA profiles was considered analogous to fingerprints, which can be taken legally upon arrest. Notably, there is significant dissenting opinion. Fingerprints are used upon arrest and are compared to thousands of open crimes, crimes for which that individual is not a suspect. There is no basis for the fingerprint comparison in terms of reasonable suspicion for any of the individuals whose prints are being searched against, however it is done routinely without issue to provide investigative assistance. The same analogy is true for searching addresses, names, or any other database information, in the hopes of finding the correct address or individual being searched. The barrier to search is entry into the database itself and the nature of the information being provided.

The vast majority of forensic laboratories are governmental. As public servants, forensic scientists frequently leave major policy decisions up to either elected officials or those who are in board positions who are formally granted this decision-making capability. As noted earlier, eligibility for NDIS entry is determined by the DNA Identification Act and individual state's laws [34,72]. Reasonable search and seizure is balanced by the nature of why an individual's DNA is included in the database. Convicted and arrested individuals have had rights removed or suspended based on applicable state or federal law, either due to reasonable suspicion or to the magnitude of the criminal cases. Familial searching is currently performed on a limited subset of criminal cases, with significant layers of approval, including being limited to major crimes against the person when traditional leads have run out [36,46,51].

Using the Golden State Killer as an example, searching those individuals in a database could be considered a violation of their 4th amendment rights, however the weight of issue on the public and their safety is very large. In these major unsolved serial offender cases, the context of the situation is very important and therefore use of genealogical searching could be reserved for these types of serious public safety threats. The State of New York has included specific wording permitting familial searching of “crime presenting a significant public safety threat” [55] to enable flexibility of application to a variety of cases, despite the potential for disagreement on what specific crimes and circumstances would apply. The limited application for cases of major crime is supported by public opinion as evidenced by a survey conducted by bioethicists where 79% of 1587 individuals polled supported use in major crimes against the person of homicide and rape [73]. Respondents were 80% in favor of these activities applied to violent crime, versus 39% in cases of property crime [73]. While intuitively there is a significant difference in public safety threats posed by violent crime versus property crime, this difference is supported by the bioethicists study of public opinion.

An interesting legal point was made by Don Shelton in his Jurisprudence Section presentation at the AAFS Annual Meeting in Baltimore, Maryland, on February 21, 2019, stating that a suspect who takes issue with forensic genealogy database searching does not have legal standing to argue on behalf of his relatives. Only the relatives themselves are in a position to dispute the use of their profiles, as they have autonomy to permit their profiles to be used to uncover a potential criminal. For those individuals whose DNA profiles are housed in NDIS, those convicted or arrested of crimes have given up some rights. In the case of the publicly accessible genealogy database, people have voluntarily agreed to have their DNA searched to find people. They have had their DNA analyzed by one genealogy provider, then obtained their profile and moved it to another provider to find relatives, including affirming a disclaimer statement that they acknowledge they are interested in being located. Informed consent requires acknowledgment of an individual's right to have opinions, to make choices, and to take actions based on personal goals and values [64]. Autonomous choices have three central characteristics: they are adequately informed, they are voluntary instead of coerced, and they are rational [64]. Individuals have the right to make an autonomous choice to place their DNA in a databank with informed consent to permit a search to develop investigative leads. Once again, the critical point is that the crime scene profile will in turn be included or eliminated in a subsequent comparison to a suspect.

An individual not in genealogy databases who are developed as persons of interest would not have their DNA compared to the Golden State Killer profile without just cause. This just cause encompasses inclusion in a family tree that matches data from the crime, which could not be excluded by subsequent Y-STR testing at the forensic laboratory to further eliminate false leads. In most of these cases, discarded samples are collected, in hopes that the individual will never know they were under suspicion, however also to prevent inadvertent negative consequences from an obvious intrusion by law enforcement into their lives, potentially witnessed by co-workers, friends or neighbors. The case of the Oregon man in the nursing home, presumably as his discard samples were more difficult to obtain as he was residing in a group setting, provides rationale as to why a court order was obtained. With these considerations, the encroachment on individual's rights can be reduced while keeping investigative options open for major crimes with public safety concerns.

Concerns raised regarding familial searching include privacy and increased focus on minorities that disproportionately populate NDIS [51–53]. Privacy concerns are for those individuals in the NDIS database as it interrogates their families, who are innocent as the crime scene DNA does not match them. A counter argument to the disproportionate representation of minority suspects in NDIS is that cases also represent minority victims, where the majority of

crimes are committed within the same racial and socioeconomic community [74]. Therefore, not pursuing these cases because of race would negatively impact minority victims, their families and communities. The efficacy of familial searching has so far demonstrated that concerns have not been borne out in results. Of the approximately 300 familial searches conducted nationwide, 37 names have been released. Thirty-five of these have been found to originate from a related individual, leading to a direct match with the perpetrator [36]. This represents an effectiveness of over 94.5%.

14. Issues and options summary

The ethical issues that arise in genealogical searching are similar to those of familial searching, which include privacy, protection from wrongful incrimination, confidentiality and potential misuse of genetic information [51–53]. The STRs that are used in NDIS do not code and hence do not produce proteins or confer traits. STRs are not used in genealogical searching. SNPs throughout the genome provide the variation between individuals and inheritance to be used in genealogy. The map unit for measuring genetic linkage is a centimorgan [75], which is used to determine the level of relatedness between potential SNP profiles [4,76].

While SNPs and STRs generally do not provide any direct information on traits, their increased use and the expansion of testing to the entire genome may uncover connections to genetic sequences that confer traits, or conversely permit deduction of the identity or connection to other databank samples [35,77]. While some of these inferred traits used in phenotyping have been harnessed by commercial interests for use in investigations potentially identifying persons of interest, in practical application using GEDMatch there is limited opportunity for disclosure of health information due to the reporting of very general relatedness centimorgan data [18]. Information regarding potential health issues such as cancer and genetic diseases are of theoretical assistance in narrowing a suspect population, however health information is generally far too general to be of practical use in investigations where near individualization is required for court proceedings. Nevertheless, once traits can be connected to DNA which is examined in forensic genealogical searching, access and use of information could be misused in applications including and beyond crime solving and prevention. This potential for misuse has implications at the crime scene, with respect to elimination samples and for database application issues. Potential for misuse must be balanced against public safety issues. The level of privacy afforded to individuals placing their genetic information into databases that are searched against profiles generated at the crime scene must be determined and individuals informed.

Crime scene profiles are obtained from discarded DNA and hence perpetrators of crime do not have an expectation of privacy. Other individuals besides the perpetrator may also have DNA at the crime scene, including the victim and other individuals, therefore there should be consideration for their privacy concerns. Depending on the deposition of that biological material, it may be mixed with other individual's DNA bearing material and develop a mixed profile. Specific case circumstances dictate the context of the profile, therefore the identification of the probable donor of DNA may have limitations regarding interpretation of source, sub source and activity level propositions regarding its interpretation [78–80]. There may be instances where the DNA profile originated from an individual who did not perpetrate the crime, however their DNA is present. Examples of this occur where a potential victim had consensual sexual relations with a partner prior to an assault. Another example would be when a law enforcement officer or crime scene technician inadvertently contaminated the evidence at the crime scene with their own DNA by coughing or sneezing.

In cases where there may be another person's DNA present, elimination samples may be requested to ensure the focus is kept on a perpetrator's DNA. Elimination samples are provided by individuals who are not suspects but will be used to eliminate their profile from suspicion and for use in DNA mixture interpretation. A foreign profile found at a crime scene that originates from a law enforcement officer or crime scene technician that is not eliminated from suspicion by provision of an elimination sample may cause the expenditure of resources looking for a non-probative match rather than the real suspect. The probative value of DNA mixtures is generally much less than a single source DNA profile and often much more difficult to interpret without an elimination sample. Therefore, it is recommended that elimination samples are obtained from everyone in law enforcement and crime laboratories subject to handling evidence, to remove their DNA from suspicion, to have that DNA treated with full confidentiality and not entered into suspect DNA databases.

Individuals must be provided protection from false incrimination. There is danger in unsolved cases that the wrong individual is incriminated or prosecuted, thereby accuracy of searching and confidentiality of information must be protected. In the “forklift approach” used in some states to process a large number of backlogged cases, every case is processed rather than eliminate those that have been through the justice system or deemed solved. In New York City, a case processed through a backlog reduction project exonerated an individual who had falsely confessed to the crime and been in prison for 12 years when the DNA did not match [81]. Conducting forensic analysis on all cases of homicide and sexual assault protects against wrongful conviction, rather than attempting to exonerate individuals through post-conviction testing. Certainly, both approaches can and should be used, however better to prevent the wrongful conviction than deal with it after it has occurred. The best wrongful conviction is one which has not happened.

Individuals placed in offender and arrestee DNA databases have forfeited some right to privacy. However, their information must be protected from misuse. NDIS legislation has safeguards against misuse of data including significant penalties [34]. NDIS currently has not had an issue with misuse of data since its inception and has over 457,450 investigations aided by this information [63]. Given this successful track record, no change to existing NDIS searching is recommended. Searching has shown to be effective by using non-coding regions, therefore no further interrogation of the genetic nature of profiles included in NDIS is warranted. The current system has proven effective in providing investigative leads while not revealing any sensitive genetic information.

Given the potential for invasion of privacy of family members not guilty of a crime examined through genealogical searching, there should be case selection criterial established prior to undergoing the search. Using the ethical principle of proportionality, the benefit of the search in terms of solving otherwise unsolvable cases involving threats to public safety must outweigh the corresponding breach of privacy [2,82]. A balance of autonomy and safety based on proportionality finds a median where individual rights to freedom from unreasonable search and seizure are weighed against emerging public safety issues in specific cases which warrant the special measures of genealogical searching. Therefore, to balance public safety against privacy concerns, genealogical searching cases should be selected based on a high level of proportionality, limited to major crimes against the person with a public safety threat. Cases should be vetted to ensure traditional means of investigation have not succeeded. To qualify for genealogical searching, there must also be no match made to a suspect profile in NDIS, and sufficient DNA for testing to yield an accurate search against public databases.

By requiring a NDIS qualifying profile and search of offender

databases prior to familial searching and forensic genealogy, this guarantees that the profile has been generated by an accredited lab. With accreditation there comes a corresponding cascade of requisite requirements, including but not limited to ongoing audits, proficiency testing, independent technical review, training, security and quality protection measures, as well adhering to the FBI Quality Assurance Standards [72]. The level of work which has gone into many major cases of crimes against the person should not be underestimated. Once a DNA sample has been placed into NDIS, this means the crime scene was investigated, in the case of sexual assault the victim consented and provided a sexual assault kit via a medical provider, probative samples were collected, examined by an accredited crime laboratory, biological material found, analyzed and a single source or deduced suspect profile obtained. While there are a large number of unsolved cases where crime scene profiles remain unsolved, these rank among the most mature of cases where significant investigative and forensic resources have been expended in their investigation. Coupled with a signed memorandum of understanding from those responsible for investigation and prosecution prior to undergoing forensic genealogical testing, this ensures the weight of case severity as well as committed resources and follow through is in place prior to enacting the forensic genealogical search process (see Fig. 1).

Individuals placing their DNA in public databases such as

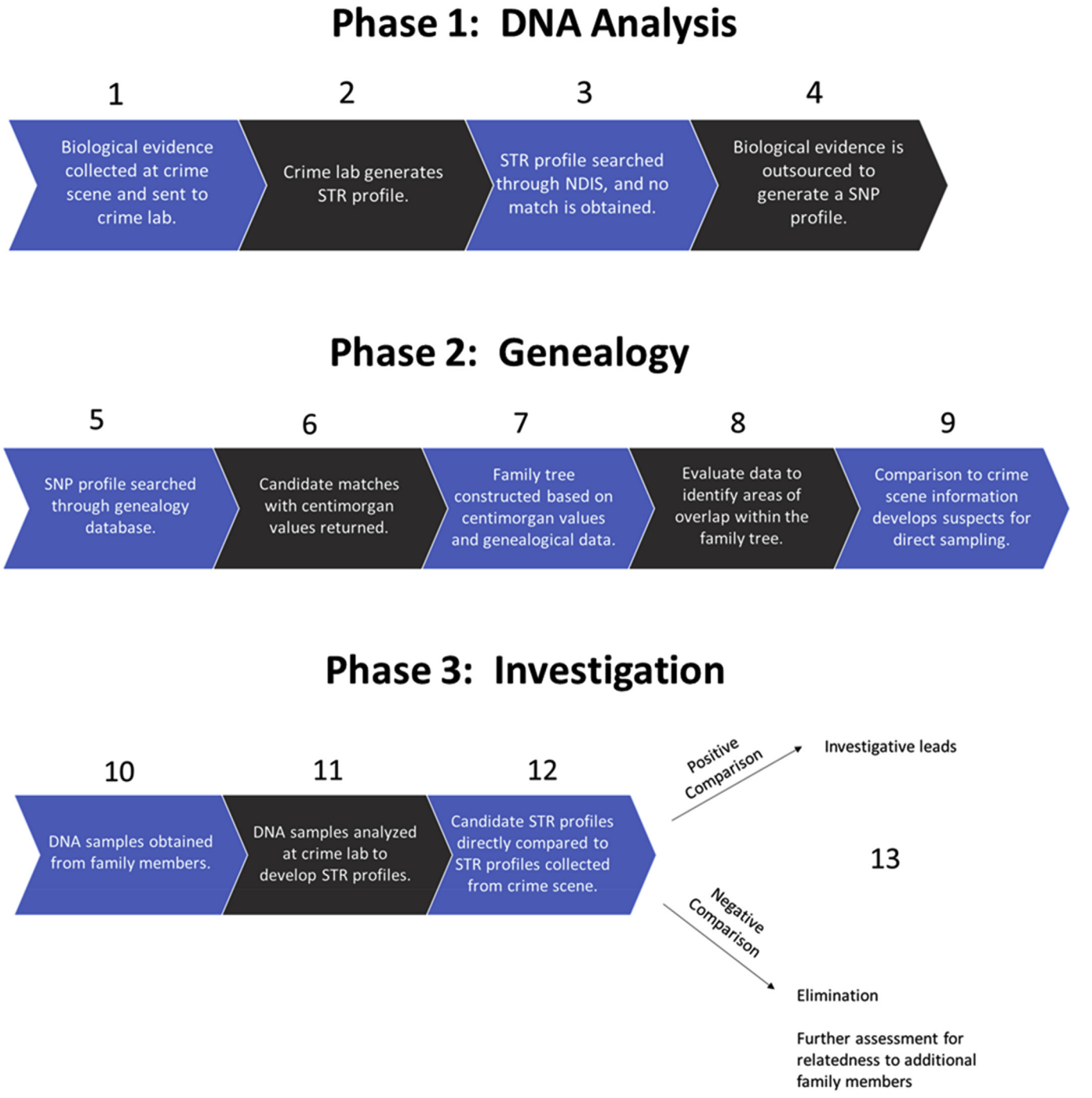

Fig. 1. Forensic genealogy casework flow.

GEDMatch currently acknowledge a consent waiver permitting their DNA to be searched to locate missing relatives [18]. The difference between a search by many anonymous individuals looking for lost relatives and law enforcement looking for a perpetrator of a major crime lies in the proverbial knock on the door when the nature of the relationship is revealed. As opposed to getting a warm hug from a missing relative, a DNA donor many get a thank-you for helping solve a major cold case. Individuals providing their DNA profiles should be informed of all potential uses of their DNA in databases, including the potential for designated forensic genealogical searches. This informed consent would be provided such that the individual affirms understanding their DNA could be searched to provide investigative leads to law enforcement [18], which will be followed up with a direct comparison of the suspected individuals' DNA directly to the crime scene profile.

Investigative leads provided by genealogical searching may mean an individual is the perpetrator, a relative, or a coincidental inclusion as a potential relative. Education of law enforcement must be provided to ensure no miscarriages of justice potentially occur, to ensure that samples are taken for elimination with respect and dignity provided to the individual. While highlighted individuals may not be the perpetrator, they may be a related person and further assist the investigation. Direct comparisons of the known sample DNA profile to the crime scene profile are the only indication of probative evidence that an individual may have committed a crime. Therefore, where possible samples from potential relatives or suspects should be taken without arousing suspicion of guilt or any negative consequences until a match is made, to protect the privacy and integrity of the sampled person. At that point, a second sample can be taken for a confirmatory analysis to provide an extra measure of confidence in a positive association.

There must be a process to ensure genealogical searching is conducted properly scientifically and from a public policy perspective. There should be transparency of policies, procedures and documentation to guide and demonstrate appropriate use [82]. Collection of statistics can demonstrate the outcome of cases, to provide objective evidence to support or deny the efficacy of forensic genealogical searching to inform decisions on its most appropriate use. Forensic genealogical searching, like many new forensic and genetic techniques, has tremendous opportunity to do good, while any potential harms should be identified and managed appropriately. Prudent application will ensure that the risks are managed to provide the maximum benefit, thereby meeting the ethical principle of proportionality while balancing autonomy, beneficence, non-maleficence, justice, objectivity and right to privacy.

Forensic laboratory and law enforcement's duty is to maximize the value of evidence. If probative DNA is left behind at the crime scene, if it can be ethically and legally examined further to solve and prevent crime, should it be? Is there a public safety obligation to proceed? The author submits, given the cost of the investigation and the potential of future harm to innocents, there is a duty to apply the best techniques to solve those crimes, however to also do so in a transparent, ethical and legal manner.

15. Conclusion

Key components of an ethical framework for forensic genealogical searching include respect for privacy of victims and persons of investigative interest. Victim and elimination reference samples should be held separately from databases and only used for the instant case. Persons of investigative interest should be approached with care and confidentiality as they may be not guilty of any offense, however may be related to a suspect. Elimination samples should be mandated for crime scene and forensic personnel to limit the negative impact of contamination and maintain case integrity. Training should be provided for law enforcement and forensic scientists to ensure persons of investigative interests are treated appropriately and data is properly safeguarded. Access to case and database information should be strictly controlled and subject to strong protection against misuse.

Evidence left at a crime scene can be fully interrogated as there is no right to privacy for discarded samples. Forensic laboratories and law enforcement have a duty to maximize the value of evidence. As genealogical searching is an intrusion into the rights of innocent persons of investigative interest, cases should be limited to major cases of crimes against the person, where probative crime scene samples are present to permit reliable analysis. Individuals placing their genetic information into searchable databases should be provided informed consent regarding the potential use of their information, including potential for forensic genealogical searching. The process for case application, acceptance, analysis, reporting and investigator training should be transparent, to gain and maintain the public trust and ensure the appropriate balance is struck between privacy and public safety. Finally, the keeping of statistics and publicly available annual summary reports demonstrate both the cost and value of the greater scientific and investigative measures used to uncover major offenders.

The ethical principle of proportionality provides guidance in dilemmas where rights are overlapping, to find the optimal balanced solution while respecting the rights of each party. Where the potential damage to society is high, such as in the commission of crimes against the person of homicide and sexual assault, there is weight to counter the negative impact on individual rights to autonomy and privacy. Steps must be taken including establishing a robust set of procedures to ensure that right to privacy is respected as much as possible to ensure trust is maintained within a forensic investigative genealogical searching system that provides the greatest benefit for all citizens.

Conflict of interest

Author declare no conflict of interest.

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