PROBLEMS IN FORENSICS AND HOW TO IMPROVE

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ABSTRACT

Crimes typically leaves evidence that needs to be analyzed to uncover the happening of an event through the identification, individualization, association and reconstruction. There are many different types of evidence such as hair, fingerprints, blood, shoe impressions, bite identification and blood. There are many problems and limitations in forensics that has detrimental results to people and the criminal justice system such as wrongful convictions. To combat the problems, policies, procedures and methods will need to be reevaluated.

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Table of Contents

List of Tables

Problems in Forensic Science and How to Improve

INTRODUCTION

Crime takes place everywhere, at all hours of the day and night, and in all regions of the world. Sometimes, weapons such as a handgun, knife, or blunt object are used to commit the crime. Other times it is not a violent crime, but instead, the property is damaged or stolen, like when a burglary occurs. Nevertheless, there is usually a crime scene where evidence can be collected and used to aid in convictions when a crime occurs. The evidence gathered is analyzed and typically is used in forensic science, which seeks to uncover the happening of an event by identification, individualization, association, and reconstruction (Committer on Identifying the Needs of the Forensic Sciences Community [CINFSC], Committee on Science, Technology, and Law [CSTL], Policy and Global Affairs, Committee of Applied and Theoretical Statistics, Division on Engineering and Physical Sciences, National Research Council, 2012). Evidence left at the scene can include blood, semen, fingerprints, shoe impressions, bite marks, hair follicles, bullets, and tire tracks (Fisher, 2008).

There are a multitude of different crimes that happens everywhere and all hours of the days. Peterson et al. (2010), analyzed five different jurisdictions in 2003 specifically focusing on aggravated assault, burglary, homicide, rape and robbery. There were 859 aggravated assaults, of those aggravated assaults only about 30% of the cases had physical evidence and of that only 12% were submitted to a crime laboratory (Peterson et al., 2010). There were 1,263 burglaries and police collected physical evidence for about 19.6% of the cases. Latent fingerprints were 84% of the 19.6% and the crime lab

examined only 72% of those prints (Peterson et al., 2010). In the five jurisdictions, there were 400 homicides which had a very high percentage of physical evidence (97%) and 88.5% of the collected evidence was submitted for laboratory analyzation (Peterson et al., 2010). Of the 602 rapes, 64% had physical evidence but only 1.6% of the evidence was analyzed by laboratories. Lastly, there were 1,081 robberies which only had about 24.8% of physical evidence collected at the crime scene but only 9.9% could be examined (Peterson et al., 2010). It is implied and many people believe that the system relies heavily on forensic evidence for convictions but a small portion is actually analyzed due to the infrequent amount found at the scenes. The belief that the system relies on forensics is due to the CSI effect. There are many fictional and non-fictional based crime shows that focus on the understanding of forensics in the criminal justice system. The inaccurate information portrayed in the shows can result in affecting the public perception of the courtroom actors, court processes, trial procedures and police officers (Rhineberger-Dunn, et al., 2016). One example is police effectiveness. The public expects police officers to collect DNA and fingerprints for their case and that it will be solved the next day. If the case is not resolved by then it results in a negative perception of the police and the criminal justice system (Rhineberger-Dunn, et al., 2016).

Wrongful convictions can have a multitude of adverse effects on society and the individual. Forensic science is the second most common reason for wrongful convictions, about 45% of the wrongfully convicted cases was due to the misapplication of forensics (Innocence Project, n.d.-c). There are many different reasons that can define the misapplication of forensic science such as unreliable or invalid techniques. An example is bite mark identification because it cannot consistently produce accurate results

(Innocence Project, n.d.-c). Another reason is insufficient validation of the method used to produce consistent accurate results. For example, shoe print identification where it has produced results there is not a standard number of comparison points like fingerprint analysis (Innocence Project, n.d.-c). The last definition the Innocence Project uses is misleading testimonies and misconduct. Sometimes there is an over exaggeration or understatement of the significance of the evidence. Another example is fabricating evidence due to the pressure to apprehend the suspect (Innocence Project, n.d.-c).

The public assumes that exoneration involves an automatic compensation and support but in reality, it only guarantees release from prison. There are financial consequences to society for wrongfully convicting someone. For example, in 2003 Louisiana did not have any law that would compensate those who were exonerated. However, since then Louisiana Legislature has enacted a compensation of $15,000 to $150,000 per year for those who were wrongfully incarcerated (Innocence Project, 2010-b). Another example is Texas, it allows $80,000 per year to the wrongfully convicted. Florida allows $50,000 to $2 million annually for those who are wrongfully incarcerated (Innocence Project, 2009-a).

Those who have been wrongfully convicted will spend an extended amount of time in prisons before being exonerated. After their incarcerations, they will have many challenges ahead of them, such as "work and shelter, as well as reintegration back into the community" (Bang, 2019). Many have found that it is difficult to find employment as a significant gap in their work history. Also, with society constantly changing and advancing, it is difficult for an exonerated to adapt to these fast-paced changes (Bang, 2019). Another physical effect is health care. Many find that they have less medical

coverage than what they received in prison. Some find that even if they are eligible for government help there is paperwork and bureaucracy that prevents them from receiving it (Innocence Project, 2010-b). For example, one exoneree found out that he was dying of liver disease and was not eligible for an organ transplant while incarcerated but as a free man he has no health insurance at all (Innocence Project, 2010-b). The criminal justice system offers to aid ex-offenders and parolees in the transition period to return to society. However, these services are not available to those wrongfully incarcerated (Bang, 2019).

There is an emotional and psychological toll that affects the exoneree; for instance, some friends and family abandon the exoneree while they are incarcerated, leading to difficulty in reestablishing familiar bonds with the vast gap (Bang, 2019). Many will experience loss and grief of "what might have been" as many friends and family have continued on with their lives (Innocence Project, 2010-lb, p. 8). The violence that many experience in prison can lead to "social distancing, emotional aloofness, and a lack of positive social skills" (Innocence Project, 2010-b, p. 7). Some exonerees' return to society with Post-Traumatic Stress Disorder (PTSD) because of the violence they witness or experience during the time of their incarceration (Innocence Project, 2010-b).

According to Tyler and Huo (2002) there is a concern with how people perceive the law and legal authorities. Legitimacy is the belief that the law and legal authorities are granted the right to be obeyed and the people review their decisions (Tyler & Huo, 2002). Also, wrongful convictions can lead to a loss of legitimacy in the criminal justice system and police. As mentioned before the CSI effect can change the public's perception of how a case should be solved. For example, as long as DNA is collected many believe that their case can be solved most of the time. As a result, when their case is not solved the

public loses faith in the criminal justice system and the police to bring them justice. Prosecutorial power is included in leading to wrongful convictions because they pressure and control forensic laboratories by processing the evidence that is submitted by prosecution teams (Gianelli, 1998). Another result is that when there is a wrongful conviction it can lead to people to a decrease in legitimacy, obeying the law, cooperation, and seeking in assistance (Tyler, 2006).

Since legitimacy is a quality that is possessed by the authority, law or institution it leads others to feel obligated to obey the decisions voluntarily; a loss in this belief can cause concern. One affect when legitimacy is low, it can lead to the police using physical force more often and possible cause injury to the one being arrested (Tyler & Huo, 2002). As a result, the community loses respect to the police and the situation can escalate causing more conflict. In addition to the situation a police officer can create or dissuade an individual from believing that the authority police have is legit or not. For example, if a police officer who does not know the community responds to a call, and the community has a low perception of the police then it can result in more problems than solutions. However, this can change if there is a long-term relationship between the community and particular officers creating a personal legitimacy (Tyler & Huo, 2002).

Another characteristic in legitimacy is the institution and the trust and confidence in the law. Legitimacy can affect how the community complies and seeks help from legal authorities based on the trust they have. Tyler (as cited in Tyler & Huo, 2002) measured legitimacy and the affects it has on the community using a two-part approach. They were asked about how they feel about the law and the general trustworthiness of legal authorities specifically if they are willing to seek help from legal authorities. The results

from Tyler's (as cited in Tyler & Huo, 2002) study were, if people saw the system as legitimate, they were more likely to follow the law during their everyday lives. Another finding was that people were more likely to seek help from legal authorities in many situations that includes many legal concerns and problems. However, there is a cynicism about the law (Tyler & Huo, 2002). Some people believe that the law is an extension of power over other groups. The loss of legitimacy in the law results in people attempting to get around the law to preserve their own dignity and honor and advancing in their own self-interests (Tyler & Huo, 2002).

Although forensic science has aided in solving numerous crimes, there are still many problems, boundaries, and questions that need to be solved. Some prevalent difficulties are the validity and reliability of specific techniques and presented evidence in court (CINFSC et al., 2012). Is the proof validated? How does a glucose metabolism disorder affect post mortem analysis? Is deoxyribonucleic acid (DNA) research credible, and how do the limitations affect the analysis? Is there a more effective method to analyze bloodstains and fingerprints? Are there difficulties with a forensic science program's current education and training? These are questions that have been constantly scrutinized, and this thesis will attempt to offer some insight.

Forensic science is an essential tool to help solve crimes through the many techniques and methods in this subject. The primary role of forensic science is to identify physical crime scene evidence by comparing it to known samples obtained from either the suspect or an object related to the subject. A proposed principle is that the criminal leaves themselves or something associated at the scene while inadvertently taking something away from the scene (Fisher, 2008). This process involves the application of

hard science and technology in the investigation of the crime, during the stage of proving if the suspect is guilty or innocent, and the resolution of factual issues. Some examples of evidence include blood, fingerprints, shoe impressions, bite marks, hair follicles, bullets, and tire tracks (Fisher, 2008).

The purpose of this thesis is to give an introduction to the history of a few techniques that are applied in forensic science and the significance these developments had on the current methods. In addition to this, the thesis will focus on some of the problems and limitations of forensics with post-mortem, DNA, bloodstain, and fingerprint analysis. It will mention the issues in credibility, education, training, and methods. Also, it will discuss prosecutorial misconduct and how it affects forensics. Another purpose is, how forensics affects wrongful convictions and how it can impact society and the loss of legitimacy. Finally, this thesis will discuss how these problems can impact future studies toward a solution. It will mention and bring attention to the remaining questions that still are unanswered and some possible future studies that could be done.

HISTORY AND SIGNIFICANCE TO FORENSIC ANALYSIS

Post mortem studies began as early as the thirteenth century in China by Sung Tzu. He documented the first forensic entomology case. He observed a particular species of blowflies found in the blood and found that this specific type of insect lays its eggs about six hours post mortem. Tzu was the first to use insects as a tool to figure out the post mortem death intervals and mentioned that there should be regulations concerning autopsy and a need to protect the evidence during the examining process (Benecke,

2001). Later in the eighteenth and nineteenth centuries in France and Germany, the first modern forensic entomology case was reported with a post mortem interval or an estimated time of death. This case used fly pupae and larval moths and illustrated how early researchers in the field investigated the use of molds, mites, and plants as well as insects for post mortem analysis (Benecke, 2001). However, this report did not focus on forensic entomology to the court but concentrated on using this technique as a tool and other techniques (Benecke, 2001). Post mortem analysis is linked to forensic science because it explains the cause, nature, location, and time of death.

DNA analysis became more prominent in the late twentieth century, specifically in 1984. Sir Alec Jeffreys developed the DNA fingerprinting technique derived from a restriction fragment length polymorphism on variable number tandem repeat regions that are unique repeating regions of DNA (Dembinski, 2017). The restriction fragment length polymorphism is when a restriction enzyme is added to the sample of DNA, and the sequence is recognized by it. The enzymes cut the DNA molecules at a known location and mark certain strands. During the 1980s, Kary Mullis developed a polymerase chain reaction (PCR). This technique can amplify small amounts of DNA for analysis. It was followed shortly in 1995 with the short tandem repeats (STRs) method, which compares allele or gene repeats at a specific location in DNA between samples (Dembinski, 2017). These allele repeats can vary among individuals, effectively identifying suspects to an unknown sample. In 1998, the United States created the Combined DNA Index System (CODIS), which selected 13 alleles for the STRs technique, the core point for these DNA profiles in the system. This specific technique has become the standard for the current

analysis of DNA in forensic laboratories (Dembinski, 2017). DNA analysis has affected the criminal justice system by aiding in identifying suspects.

Fingerprint identification is an essential part of forensic science as well. In the early 1900s, Scotland Yard became the world's first law enforcement agency to fingerprint its arrestees. Fingerprint classification was founded by Edward Henry and is still being used by many fingerprint specialists today. Soon after Henry developed this method in 1904, St. Louis was the first United States police department to establish a fingerprint identification bureau. Then in 1911, the U.S. courts began to admit latent fingerprint evidence (Fisher, 2008). However, around the 1990s, there were many challenges to this technique and a lack of general acceptance of the identification process (Fisher, 2008). This has affected fingerprint analysis today and proves that analysts cannot simply rely on fingerprints themselves to convict a suspect.

Another necessary process that is analyzed is shoe print and foot morphology analysis. This is when a crime scene shoe print that had been left on a hard surface or an impression in dirt, mud, or snow is compared to a specific shoe. Many of the crime laboratories that work with fingerprints usually deal with identifying shoe prints and tire tracks. The process deals with less science and more human observation (Fisher, 2008). Three things are needed to identify the print: a good impression, the shoe, and a way to link the suspect to the footwear (Fisher, 2008, p. 140).

Bite mark identification was explored in the 1980s; however, it was recognized as a branch of forensic science in the 1970s (Fisher, 2008). The process analyzes abrasions or bruises, usually in the shape of two semi-circles or brackets that a particular set can

only make of teeth. It is based on the idea that no two people have the same two front teeth in thickness, shape, or wear patterns (Fisher, 2008).

Bloodstain pattern analysis was founded by Dr. Paul Leland Kirk and Dr. Herbert L. MacDonell. They were involved in the formation of circular bloodstains and identifying the size and orientation of bloodstains needed in the current analysis of the patterns as well as Hulse-Smith et al. researched the present mathematical formulas that are used to find the region of convergence (Banks & Larkin, 2012). This was the start of using bloodstains as evidence and is used in the stringing method. The technique has aided in many cases in helping interpret the bloodstains of the crime scene and recreate the actions that have caused the crime or bloodshed.

During the 1970s, there was a considerable impact on the criminal justice system. There was a change in dealing with criminals from a rehabilitative point of view to a more conservative mindset of incarceration and deterrence. During this era, the War on Drugs and "get tough on crime" policies became prevalent. The two theories of punishment became the basis of the criminal justice system. Deterrence is the idea that society can keep others from offending by punishing the criminal. Incapacitation is the mindset that locking up offenders can result in less crime because the offenders cannot physically commit the crime while being imprisoned. These theories believe judges are too soft on crime and have too much discretion. As a result, determinate sentencing became one of the policies. Also, prosecutors gained power from the influence. They were put in charge of areas outside their law enforcement responsibilities, including forensics and the labs (Barkow, 2019).

THE PROBLEMS IN FORENSIC SCIENCE

Bloodstain Pattern Analysis Issues

Bloodstain pattern analysis is a specific area in forensic science that involves examining and interpreting the bloodstains distributed at the crime scene that aids the investigators in concluding the crime. This technique can help investigators to determine the angle of impact, the area of convergence, and the region of origin of where the bloodstain is from (Acampora et al., 2016). Many mathematical equations can determine the location of intersection and area of origin. However, the identification of patterns is based on the expertise of forensic analysts (Acampora et al., 2016). The method used to determine a common point from where the bloodstain originated is the stringing method. This method starts with bloodstain pattern forensics recognizing a blood pattern that contains at least three bloodstain droplets. Once the pattern is identified, the analyst will take a string from the tip of the bloodstain ellipse, the end of a teardrop shape, and extend it back to attempt to draw the flightpaths. This will lead them to the point of convergence and the source of the bloodstains (Acampora et al., 2016). However, there is a significant problem with this method: optimization or standardization of bloodstain pattern analysis. There are possible errors to this method, which is human imprecision when evaluating the size and orientation of the bloodstains (Acompora et al., 2016). In addition, there is not a standard method for the investigators to follow, which means that each investigator has their discretion as to where the tip of the ellipse is located. This can lead to severe problems when needing to reconstruct the scene for the court or analysis purposes, as it will not be precisely the same as when the crime was committed.

Fingerprint Analysis Issues

Latent fingerprint identification is reliable, simple, and direct to place the suspect at a crime scene. Fingerprint analysis works on the theory that every ridge on the pad of a finger is a design that is distinct to each person and cannot be duplicated. As previously mentioned, there is a lack of acceptance of the validity and many challenges in fingerprint analysis (Fisher, 2008). Throughout the 1990s, many mistakes when identifying a suspect have created mistrust in using this evidence to convict someone. As well as the database for fingerprints and the Automatic Fingerprint Identification System (AFIS) has some challenges to overcome. The main problem is that many systems can come from multiple vendors and therefore cannot interoperate. Another problem is that due to the system being standalone, it means that technicians will need to enter the data numerous times, which can create room for error as one fingerprint might not be entered in a database the same way as it was entered in another database (CINFSC et al., 2012).

Another problem that arises with fingerprint identification is that it is up to the technician's discretion to decide if certain parts of a fingerprint are significant or not as well as the information that is considered not substantial due to the reason that many of the current instruments being used cannot analyze such a small amount of data (Neumann et al., 2011). Also, some low-quality finger impressions can be left at the scene, which has brought concern over the reliability, credibility, and efficiency of the techniques used to analyze them. (Neumann et al., 2011).

Pseudoscience

Shoe print and foot identification are similar to fingerprinting, but it requires more human observation. Size, brand, and model can identify a print from a crime scene. The issue is that there are as many as thousands of shoes being sold that are the same size, brand, and model (Fisher, 2008). Shoe prints are not detailed enough to match them to a specific shoe. There is not a required minimum number of similarity points. Instead, it depends on the examiner's training, experience, and objectivity, leading to wrongful convictions. As mentioned in history, a shoe identification requires a good impression, the shoe that made it, and a way to link the suspect to the footwear (Fisher, 2008). Some cases do not have the shoe that made the impression, but the suspect was still convicted because the expert who analyzed the print stated it was a match.

Another example where the expert wrongly convicted a suspect was analyzing a bare footprint of the suspect. The crime scene print lacked a ridge detail, yet the suspect was still found guilty because of the expert's testimony (Fisher, 2008). In both examples, the suspect was convicted based on objectivity and pseudoscience. Shoe print identification is helpful when the suspect does not match prints from the crime scene. However, it is not clear about the definitive answer when they are similar. It is an unreliable and subjective method (Garrett, 2011).

Another process of analysis that uses human observation is bite mark identification. The evidence is usually preserved by life-size photography, tooth tracings on transparent sheets, and dental casts. The suspect is usually asked to bite into a mold, and then a cast can be made (Fisher, 2008). Then, an expert will analyze details such as the shape or thickness of the teeth. Most of the time, experts will use the terms such as

"consistent" and "similar," which are very vague. Forensic odontology is a subject that does not have any objective criteria (Garrett, 2011). It is assumed that everyone has a distinct, different bite mark, but the assumption itself has not been tested yet. Not only has it not been tested, but the skin is not the best material for bite marks as it is dynamic, meaning it is challenging to decide if it came from a human or if it is due to decomposition or the attack (Garret, 2011). An example is the Kennedy Brewer Case, where there were 19 bite marks on the victim's body, and five of those were the suspect. However, it was later revealed that all of the 19 bite marks were insect bites, and the suspect's DNA did not match the DNA from the crime scene (Fisher, 2008).

Although DNA has come a significantly long way, hair follicles have been consistently used in cases against a suspect. Analysts will note the length, thickness, texture, curl, color and appearance. The hair follicle is not individualized, such as a fingerprint, meaning similarities between two or more different people across the board (Fisher, 2008). Hair cannot be used to identify a suspect without a follicle either. The follicle is where the DNA resides and, without DNA testing, cannot be used. When DNA analysis became a technique that could be used in court, it proved that hair identification through characteristics such as texture and length were unreliable (Fisher, 2008).

Glucose Metabolism Disorders

A glucose metabolism disorder is when the body cannot maintain an average blood glucose level called hypoglycemia or hyperglycemia. An example of which is well known is diabetes. A glucose metabolism disorder can affect the analysis of post mortem and toxicology tests because it is unreliable. This sort of analysis is then imprecise and complicated due to the missing forms of glucose. Multiple factors can affect glucose

levels, such as food intake or glycogen, and glucose can circulate through the victim's body during cardiopulmonary resuscitation. The time of death is unclear because the abnormal glucose levels have different degradation rates. Another problem with using glucose is that it cannot distinguish between hypoglycemia, euglycemia, and mild or moderate hyperglycemia (Hess et al., 2011a). Hypoglycemia is a glucose deficiency in the bloodstream, whereas euglycemia is the usual amount of glucose in the body. Mild and moderate hyperglycemia is an abundance of glucose in the body. If blood is used to measure the glucose level, this method has a complication. When taking a sample from different areas of the heart, there is a significant difference between these samples. For example, if a sample is taken from the right side of the heart, it has a higher concentration of glucose than the edge of the heart (Hess et al., 2011a).

DNA Analysis Issues

DNA is an element widely used in forensics to analyze and identify suspects and even witnesses from the scene. Many techniques are used in molecular biology and toxicology to determine the detection or quantification of DNA from body fluids. Some methods utilized are PCR, enzyme-linked immunosorbent assay (ELISA), agarose gel electrophoresis, and immunoelectrophoresis. The PCR technique allows scientists to make millions to billions of copies of a DNA sample which aids with crime scene analysis as usually only a tiny sample can be collected. ELISA is a sensitive technique that detects antibodies, antigens, proteins, and hormones and is commonly utilized by toxicologists for screening specific narcotics in the body. Agarose gel electrophoresis is a method that sorts DNA and generates a unique DNA fingerprint that helps distinguish one individual from another. Immunoelectrophoresis is the separation and identification

of proteins using electrical change and antibodies, and it aids in identifying how old a bloodstain is.

Although these methods are conventional and effective, there are still limitations to applying DNA identification in a case. One issue is the credibility of all the new techniques being created. It is questioned if they are reliable to use in court. As well as, there is a great deal of pressure on forensic scientists to confirm near matches which can lead to wrongful convictions (Machado & Granja, 2018).

As DNA analysis becomes more prominent, there is a growing need to create a database. Each nation that uses DNA analysis has made its database. However, the Council Decisions established a legal and technical standard for information exchange among those included in it. This step began a debate about ethical challenges concerning data protection, excessive surveillance of citizens, and potential threats to civil rights such as privacy, liberty, and presumption of innocence (Machado & Granja, 2018). The Science of Technology Studies contributed to creating and expanding the database. However, they have not addressed the transitional exchange of DNA data poses (Machado & Granja, 2018).

Another problem is that most samples from crime scenes are small and considered low quantities. The most typical technique is PCR which amplifies or magnifies that DNA, but there needs to be sufficient DNA to amplify it at least 28 times (Bukleton, 2009). Therefore, the samples obtained from crime scenes are usually not enough to be compared to a known sample using this technique. Other issues include the degradation of biological samples, affecting the investigation and possibly misleading the results. It limits PCR. When there is damaged DNA, it creates a nucleotide modification in the

strand, which can block standard DNA replication mechanisms and result in not amplifying and analyzing the strand (Shukla, 2017). Other challenges that arise are that silent alleles or mutations in DNA from damages can make it more complex than specific techniques are optimized to deal with (Dawid et al., 2006).

Problems with Credibility, Training, Education, and Methods in Forensics

There is increasing criticism of forensic scientists for relying on inadequate validation methods, overstated findings, and making insufficient efforts to avoid bias. Many are concerned that forensic examiners can be persuaded by contextual factors unrelated to the task that examiners are expected to perform. Significant amounts of literature show that human judgment can be manipulated and influenced by contextual facts, and forensics can be biased without being aware of it (Thompson & Scurich, 2019). Cognitive bias includes many different processes that can lead to inaccurate judgements or interpretations. It affects memory, decision making, and reasoning (Cooper & Meterko, 2019). An example is, unconsciously focusing one's attention on similarities instead of the dissimilarities due to other evidence in the case, like previous conclusion that another analyst made (Cooper & Meterko, 2019).

There is another definition that can be a problem, confirmation bias. This is when one seeks to find and interpret evidence to prove what they already know. Some forensic scientists will find evidence to confirm a hypothesis or expectation (Cooper & Meterko, 2019). In other words, they put the cart before the horse. Many have been questioning the need for a new procedure known as the blinding procedure, which is when the scientist is unaware of the conditions or the background of the evidence, such as if the known sample is from a suspect to compare to the unknown sample. Forensic scientists who

oppose the need to change the procedures state that they are not influenced by contextual information, creating bias. There has been a survey where 403 forensic science examiners lack the acceptance of this need to change procedures to minimize cognitive bias and a failure to recognize there is a susceptibility to bias (Cooper & Meterko, 2019). The problem is that a bias can affect forensic scientists beyond their scientific expertise. Therefore the conclusions they arrive at will not be based on the interpretation of the physical evidence presented to the court. Instead, they will be based on matters that do not include forensic science (Scurich & Thompson, 2019).

The final issue is with education, training, and methods for forensic science. There is a demand for more and better-skilled forensic scientists at the macro and the micro levels (CINFSC et al., 2012). However, most need at least a bachelor's degree in either natural or forensic science, leaving a lack of understanding of criminal justice (CINFSC et al., 2012).

Moreover, even with a science degree, there is still a lack of critical thinking regarding crime laboratories such as quality assurance, ethics, and expert testimony (CINFCS et al., 2012). Another issue is the crime laboratory administration, and many are managed by an administrator without a scientific background. For example, some laboratories have been managed by someone who has a history in law enforcement. An example is the St. Paul Police Crime Lab in Minnesota had a police sergeant as the lab manager (Turvey & Crowder, 2013).

Also, defense bolstering has been a major problem in the forensic science community. This is when they feel the need to defend their reputation by “bolstering” their character and expertise. An example of this is Dr. Louise Robbins, who claimed that

she could identify the wearer of the shoe based on the wear patterns when other analysts could not see this. However, it was later ruled that wear patterns would not hold in a court (Fisher, 2008). Dr. Robbins claimed to be an expert in foot wear analysis that she claimed that in the *Cruz v. Dupage County*, Rolando Cruz supposedly murdered and raped young Jeanine Nicarico and the evidence was that there was a boot print left at the crime scene but no boot (Fisher, 2008). Dr. Robbins testified that Cruz was the one who had worn the boot based on wear analysis of the boot. However, it was later proven that Cruz was not the one committed the crime due to DNA analysis and he was exonerated. This is not only an example of bolstering but also, confirmation bias. There were other pieces of evidence that collected based on Dr. Robbins analyzation including a coerced confession, and a jailhouse informant.

Another example of bolstering is Dr. Michael West who began testifying as an expert in bite mark identification claiming he could see things others could not in bite marks. His creditability was due to his dental degree, multiple publishing's, lecture appearances, and confident attitude. During the Kennedy Brewer case Dr. West claimed that Brewer was guilty of raping and strangling the victim because of the nineteen bite marks on the victim's body and five of them had been made by Brewer's upper teeth (Fisher, 2008). The jury believed Dr. West because of his creditability and that he looked and sounded confident in his conclusion. However, DNA analysis later proved that Brewer was innocent and that the marks were due to insect bites (Fisher, 2008). The jury believed Dr. West because of his bolstered creditability and reputation.

Another problem is the myths and definitions that surround forensic science. Hollywood has a significant role in creating myths and expectations for a person who

wants to pursue a forensic practitioner career which is known as the CSI effect. Many who want to start working as forensic scientists often expect to work in similar conditions that Hollywood has painted for them (CINFCS et al., 2009). As forensic science began to attract more attention from the media, it started to shape the view many had on this discipline.

An example is that many think forensic scientists go to the crime scene. While some departments do this, the more common practice is when a crime scene investigator goes to the location and is trained in smaller areas of forensics, such as fingerprint analysis. Usually, the sample is sent to a forensic lab for a more complicated test such as DNA analysis. Another myth is that many police operational managers and decision-makers at the political level believe that they understand forensic intelligence. This leads the forensic science community to favor solutions that are easier to accept in a media-shaped concept of discipline and most likely create poor decision making (Crispino et al., 2015). Many television shows and media show that forensic science solves severe cases by itself or contributes to the volume of crime reductions, leading to the public questioning the efficiency of forensics for policing (Crispino et al., 2015).

Forensic trace evidence is a significant part of forensic science in the criminal justice system. There are typically two approaches to analyzing trace evidence: a general practitioner and a specialist practitioner. Both of these styles have contributions and limitations in the forensic field (Bitzer, et al., 2015). The obstacles include required maintenance of machines at a high level of expertise, increasing probability of missed or misinterpreted evidence, variance with legal and scientific expectations favoring standardization and compartmentalization, restricted ranges, not having any adaptable

methods, and expertise can be narrowly defined (Stoney & Stoney, 2015). The technological advances and increased emphasis on scientific practices have reduced the effectiveness and viability of trace evidence and the technology itself (Stoney & Stoney, 2015). Many criticize that there is too much focus on the physical aspects of the traces themselves, meaning that there is too much emphasis on the elements of the crime itself and that the larger picture is ignored, such as the environment.

Prosecutorial Power

Prosecutors are involved in enforcement action and setting the border of criminal justice policies (Barkow, 2019). They participate in an area outside their responsibilities. For example, this includes forensics, corrections, clemency, and other criminal justice policies (Barkow, 2019). There is the "pro-prosecution" bias where the police control 80% of forensic labs, and most of the labs only process evidence submitted by the prosecution teams (Gianelli, 1998). Another problem is that prosecutors' discretionary actions hold significant power over someone claiming innocent at the post-conviction stage and are usually unwilling to participate in the post-conviction stage (Weintraub, 2020). Prosecutors' oppositions to post-conviction motions that could result in innocence are exceedingly difficult to overcome. The courts will trust the prosecutor's judgment about post-conviction movements, including DNA testing because they have prior knowledge of the cases. They usually resist DNA testing that could show the actual offender in about half of the nation's exoneration cases during the innocence project (Weintraub, 2020). A prosecutor’s power can affect forensics by barring them from specific tests to avoid being wrong.

SOLUTIONS AND ADVANCEMENTS IN FORENSICS

Blood Pattern Analysis

When attempting to lessen the issues with the stringing method, a formal representation was studied based on a genetic algorithm. Acampora et al. performed an experimental session by using a sponge of 3 cm^3 soaked with 3 mL of blood and striking it with a hammer in three different spots with the same elevation and space. It created eleven bloodstains, and an image was taken to be processed by a computer. Information was extracted, and the genetic algorithm was used to compute the critical activities of identifying the bloodstain patterns and calculating the regions of origin (2016). This created a standardization for this technique. Another solution to the problem is drones, used to log the crime scene and reconstruct the finer details such as bloodstain spots. Drones work by scanning the whole area and recreating the scene with an image. Then, with the picture taken, it can be analyzed through a program, and the region of origin can be calculated.

Fingerprint Analysis

One suggestion to navigate these challenges is getting multiple vendors to cooperate and ensure nationwide AFIS interoperability (CINFSC et al., 2012). In addition to this, there is a need to support the federal and state government policymakers to make the database interoperable (CINFSC et al., 2012). Some research was done by the British Forensic Science Service (FSS) with the Bureau of Criminal Apprehension (BCA) of Minnesota. The analysis was carried out in the field, starting with recovering the fingerprints, and then the research team examined the parts of the fingerprints that were

considered insignificant. Once they were examined, the evidence was quantified using a fingerprint statistical model developed by the FSS, the activity value was assessed (Neumann, 2011). The results showed that even the non-significant fingerprints could be used as evidence if they were given the correct resources and instruments. However, it would be necessary, valuable, and cost-efficient to improve specific protocols to maximize the amount of evidence (Neuman, 2011).

Pseudoscience

One suggestion mentioned is for judges to have the power to protect the juries from the pseudoscience by looking at the experts' qualifications. Another suggestion is to lessen the prosecutors' power in the laboratory, which draws inappropriate incriminating inferences (Fisher, 2008). Some tests mentioned could be used in courts if they were able to be validated and treated like fingerprint analysis, such as footprint analysis. Fingerprints have a minimum number of similarity points. Suppose an analyst could prove that a barefoot analysis is as unique as fingerprints and mention a minimum number of similarity points. In that case, it could be validated for use in a courtroom.

Glucose Metabolism Disorders

As previously discussed, using glucose in blood and urine is very unreliable and problematic. As a result, alternative tests have been suggested. One trial suggested is using glycated proteins, specifically glycated hemoglobin (HbA1c). A regular glucose test usually measures the amount of glucose currently in the body, whereas the HbA1c test can measure blood sugar for three months. This test has already been approved and used in a medical setting with diabetes mellitus to be applied to a forensic environment.

HbA1c is very stable and has a life span similar to red blood cells, making it adequate to assess stable glycemia. When using HbA1c, it is measured in whole blood, which means that there is little to no difference in the values when the samples are taken from different sites, unlike blood glucose. Also, many other HbA1c assay methods are currently in use due to the technique being used mainly in the medical field. For post mortem analysis, the HbA1c values show that it increases after death, and there is a minimal deviation between healthy subjects and those with a glucose deficiency (Hess et al., 2011b).

Using a fructosamine test is another alternative to a blood glucose test. This test is similar to the HbA1c test but can only measure glucose levels two to three weeks prior. It was shown that fructosamine values do not change significantly until after 72 hours of death. Much like the HbA1c test, it was revealed that there is little to no difference in the sample values when taking them from different testing sites. Subsequently, this specific protein can be stored at ambient temperatures for up to 24 hours, meaning that if the specimens were stored at colder temperatures such as -20 degrees Celsius, it could be kept for several months (Hess et al., 2011b).

Another alternative method mentioned is using ketone bodies to give death. It is a test that measures the number of ketones in the body. When the body does not have enough glucose, it will burn fat, producing ketones. When there is a high number of ketones, it can lead to ketoacidosis, which results in a coma or death. In ketone bodies, there is a part known as beta-hydroxybutyrate. The concentrations from this can provide more information about the severity of ketoacidosis (Hess et al., 2011b). Ketoacidosis is when these ketone bodies are abundant, and the body does not have enough insulin to balance the ketone bodies, which can lead to comas and many other medical problems.

The severity of the ketoacidosis can give more information about the problem was related to diabetes, alcohol, or starvation. For post mortem samples, the beta-hydroxybutyrate can be measured by taking the vitreous fluid of blood and in urine. This is significant as there is a strong relationship between blood and the vitreous ketone body levels found in alcoholic ketoacidosis. Much like the fructosamine test, ketone bodies can be stored at 4 degrees Celsius for 24 hours or prolonged periods of two days. In addition, it can be stored in a colder environment (Hess et al., 2011b).

DNA Analysis

When using DNA analysis, there are many limitations to the current techniques and specifically to PCR. As a result, to combat these limitations, new methods are constantly being made and applied. For example, laser microdissection, also known as LMD, is mainly used in biomedical applications and is relatively new to forensic applications. This technique is ideal for characterizing specific cells at the single-cell level. The method is applied similarly to PCR, with a sample being mixed with particular primers to lyse the DNA and prepare it for amplification. Then it can be analyzed by using a fluorescence technique to look for distinctive patterns that can be compared to a known sample (Leonov et al., 2011). Leonov et al. made a study looking into LMD for forensics by using a cigarette butt and comparing it to blood sample analysis. The results were viable, but it was also indicated that more than one individual left genetic material. Therefore the DNA could not be reliably identified (Leonov et al., 2011).

Another method mentioned is using short-tandem repeats, which compares genetic markers for DNA to another sample. A suggested study used skin cells for DNA from fingerprints offered by Ostojic et al. To test this idea, over 700 fingerprints were

collected and analyzed. Two extraction methods were used to amplify and analyze the DNA, where one of the two extraction methods showed significantly better results than the other. One swabbed the samples with water while the other used a tissue extraction mixture to swab with (Ostojic et al., 2014).

The last technique mentioned is single-cell gel electrophoresis or known as comet assay, which analyzes small amounts of DNA and analyzes degraded DNA of viable cells (Shukla, 2017). The principle is that once the sample has been taken, the cells should be encapsulated in low-melting-point agarose and placed on a microscope slide. The cells are then lysed or pulled apart to reveal the DNA, and then it is unwound during electrophoresis with a dye to show specific characteristics. Electrophoresis is when particles such as DNA fragments are separated under an electrical charge according to size. Each individual has different DNA, so no two separations between two other people will be the same. Finally, the sample can be analyzed and compared. Degradation in biological samples is a prevalent problem in forensics. This technique can be used as a preventative tool and screening method and assess the repair process and mechanisms in DNA, meaning there could be a procedure to reverse the damage done to the DNA (Shukla, 2017).

Credibility, Education, Training, and Methods Issues

There have been issues over credibility, mainly with inherent and subconscious bias. A solution mentioned is using blind procedures where information that does not pertain to the evidence is not given to the analyst. Thompson and Scurich did a study with 1000 samples to determine if a blind condition would be more credible than the ignored condition. There were four conditions mentioned in this experiment. The blind

condition applied to this test was when the examiner denied that he had been exposed to irrelevant information. The ignored condition was where the examiner had been exposed to the information and claimed that he ignored it. The used condition is when the examiner was exposed to the information. The last condition is the controlled variable, where the defense lawyer did not inquire if the examiner had been exposed to or used any irrelevant information (Thomson & Scurich, 2019). This experiment was measured using a two-way analysis of variance (ANOVA) with the experimental conditions as the independent variables. The participants' scientific credibility judgment was the dependent variable (Thompson & Scurich, 2019). The results were that the blind condition was considered more credible than the ignored and used. This emphasized that the jurors' perceptions of credibility and the willingness to convict a suspect will rest heavily on forensic evidence (Thompson & Scurich, 2019). A blind procedure would aid in the concerns over bias in the forensic sciences.

One of the many problems is miscommunication about forensic scientists' role in the process due to Hollywood, the media, and a lack of communication between the different areas in the criminal justice system. As mentioned, managers and administrators believe they understand forensics, which brings a more vital need for better integration between the police and forensic skills seen specifically in intelligence-led policing (Crispino et al., 2014). However, that can lead to problematic issues with the idea that scientists are unbiased experts. Although there should be better communication, a separation between law enforcement and laboratory analysts should be separated, especially in a management position (Turvey & Crowder, 2013). In regards to Hollywood and media, creating programs to allow the public to understand the role of forensics will

allow them some insight into seeing the processes. In addition, it has been suggested that there be more interaction between forensic science and medical examiner communities and the basic sciences, which will introduce new ideas and perspectives and allow some insight into the processes that forensics follow (CINFSC et al., 2012).

Regarding the problem with focusing on the physical aspects of the traces, any material that could be transferred at a crime scene, such as hair, rope, soil, and other evidence, it has been suggested to refocus criminal trace analysis on a more rounded emphasis on security problem-solving (Bitzer et al., 2015). This includes reestablishing parts of policing, crime investigation, criminology, and decision making in the core forensic science curriculum (Crispino et al., 2014). In addition to this, there are problems with the current education system lacking in criminal justice and critical thinking about crime laboratories. A solution to this issue would require teaching information processing skills and establishing new layers of technical abilities in the training programs (Crispino et al., 2014).

There is an urgency to develop new technical methods or provide advancements in forensic science to overcome limitations (CINFSC et al., 2012). There have been advancements in traces to lessen the current methods' issues when analyzing these traces. One of the prepositions is using particle traces. These traces can be an effective problem-solving tool because they are always present. They have the potential to address a wide range of questions that many forensics faces (Stoney & Stoney, 2015). The traces of the environment surrounding the crime scene, such as paint chips or soil around the area, can aid in the investigation. The methods used to analyze these particles tend to be readily available and straightforward (Stoney & Stoney, 2015).

Prosecutor Power

Prosecutors have much power in the criminal justice system that causes problems for many areas, including forensics. The solution is to remove the power by taking the decisions about places other than charging some instances out of their hands, so removing all but core prosecutorial decisions from their ability will help with better accurate forensics (Barkow, 2019). One way to release their power is by allowing legislatures to allow others to check the decisions prosecutors make. By eliminating mandatory minimum sentencing, it can return discretionary power to the judges and enable them to use their authority to correct prosecutors (Barkow, 2019). Another way is to stop judging if a prosecutor is "good" based on a tally system of convictions (Bang, 2019). Other solutions include prosecutors submitting their policies to the board that will review if the cost outweighs the benefits resulting in their decisions needing empirical evidence and not based on professional risk-averse preferences (Barkow, 2019). Finally, it has been suggested that there should be someone who monitors and audits unlawful or inappropriate activities and a better consequence to those who participate in misconduct (Barkow, 2019).

A summary of all the problems and solutions can be found in Table 1.

Table 1: Summary of Issues and Solutions

Subject	Issues	Solution
Blood Stain Analysis	• Optimization and standardization • Human imprecision	• Create a standard process using mathematics • Drones
Fingerprint Analysis	• Multiple databases • Entering data multiple times	• Creating one database

	• Objectivity of significance • Low-quality is used occasionally	• Support to make a database interoperable • Technology can be advanced to examine low-quality prints
Pseudoscience	• Shoe print analysis is objective, and no minimum requirement • Bite mark analysis is objective, and no standardization • Hair does not always have the follicle, and the characteristics do not narrow down to one person	• Judges protecting the juries • Lessen prosecutor power • Validation of tests • Standardize some tests
Glucose Analysis	• Imprecise • Disorders affect conclusions • Complicated • Different degradation rate • Differences in samples based on where it is taken from in the body	• Using different tests such as glycated hemoglobin, fructosamine test, and ketone body tests
DNA Analysis	• Credibility on new techniques • Wrongful convictions harm individuals and society • Small and low quantities • Degradation of samples • Damaged	• Using new techniques such as short-tandem repeats, laser microdissection, and single-cell gel electrophoresis • Standardizing the techniques with multiple trials before introducing them to courts
Credibility, Training, Education, and Methods	• Persuasion, manipulation, and bias	• Blind procedures • Communication between law

	• Lack of understanding in criminal justice • Lack of understanding in science • CSI effect • Emphasis on the elements and not the big picture • Lack of critical thinking	enforcement and scientists • Keeping law enforcement and scientists separate • Programs to the public to educate • Refocus training on a more rounded problem-solving and critical thinking curriculum
Prosecutorial Power	• Involved in areas outside the responsibilities • pro-prosecution bias in labs • Wrongful convictions	• Remove power outsider their jurisdiction • Check decisions • Eliminating mandatory minimum sentencing • Reviews • Monitoring unlawful and inappropriate activity

REMAINING QUESTIONS AND FUTURE STUDIES

Although bloodstain pattern analysis has come a very long way, problems still arise. This includes the fact that some distrust and concern with the new technology leads some to believe it is not credible in the court. In addition, with this new technology, a sufficient amount of resources are necessary to acquire and upkeep the maintenance of the technology.

Fingerprint analysis has come a long way with many advancements, but problems and questions still need to be answered. The study of fingerprints is still subjective currently. Although there is some push for vendors and policymakers to make the database more compatible with other databases, they have pushed against this. The

vendors see minimal incentive to redesign the systems to share information with competitors' strategies, similar to policymakers. They realize that remaking the designs would be costly and time-consuming. It would consist of repurchasing the system, maintaining it, training employees about the new system, operating and upgrading (CINFSC et al., 2012).

Even though there are alternatives to blood and urine glucose testing, these tests still have limitations. All of the tests still have specific time limits that the samples are considered viable, and if these samples are not analyzed any longer, they will not result in reliable answers. The HbA1c test had the most extended lifetime at six months, but if no preservative is added, the lifetime is only 40 days. In contrast, fructosamine must be stored within 24 hours and then analyzed within two weeks to be considered still viable (Hess et al., 2011b). Ketone bodies tend to only be stable for up to two days due to the unstable analyte (Hess et al., 2011b). The morphology and histology will need to be continuously investigated for future living people and autopsy (Hess et al., 2011b).

There are many new techniques to overcome the many limitations DNA analysis has. However, there are still many restraints. Although LMD aids with analyzing small samples of cells, it is still limited by the cell type and sample condition. This means that the technique will need to be adjusted as it will not analyze damaged DNA and certain types of cells (Leonov et al., 2011). The STR method can analyze small amounts of DNA and compare the samples. However, it was decided that fingerprints are a potentially unreliable source for DNA due to the quantity yielding little to no DNA (Ostojic et al., 2014). For future studies, if a different technique arose, it is possible to use fingerprints for a source of DNA, but it is currently not possible.

Single-cell gel electrophoresis, comet assay, is a well-known technique that can analyze small amounts of DNA, the only limitation is that the DNA cells must be possible, meaning the cells during their life cycle must be in time before apoptosis or cell death (Shukla, 2017). Comet assay can be limited by the number of samples per hour that can be analyzed, so if there are many samples, it might not be efficient. In addition, the interpretation of the sample is complicated because there is no simple relationship between the amount of DNA damage caused by certain chemicals possibly used in the process and the impact of this damage (Olive & Banath, 2006). Comet assay has advanced to overcome the limitations by combining this technique with fluorescence *in situ* hybridization, which will allow it to determine the sequence or gene-specific damage and repair (Spivak et al., 2009). This opens more opportunities to analyze chromosomes for forensics. However, future studies will need to be done to study the localization of chromosomal structures along the DNA fibers (Spivak, et al., 2009).

The credibility problems mainly focused on whether the forensic examiner's conclusion is biased or not. The solution suggested would be implementing blind procedures. However, it is met with much resistance. Many forensic scientists deny that being influenced by contextual information leads to bias. They believe it is acceptable for them to look beyond the physical evidence under the impression that they are looking at the bigger picture (Thompson & Scurich, 2019). The question remains that new methods and techniques are still not trusted in court.

The solutions to education and training are to implement new programs. However, most programs are met with resistance either by administrators, workers, or funding. The current budget is insufficient for developing programs at the bachelor's,

graduate, and even doctoral levels to train those who desire to become forensic scientists. Furthermore, there are not sufficient opportunities for someone in training to gain practical experience in this field (CINFSC et al., 2012). When new programs are implemented, the employees will need to be trained, which can be labor-intensive and expensive, thus resulting in resistance against implementing new programs (CINFSC et al., 2012).

There are still problems with prosecutors having too much power and participating in misconduct. Even though research over this problem has increased compared to other areas in the criminal justice system, prosecutorial misconduct has received little attention. Another problem is that there is not a lot of research on prosecutor power at the trial level. Most research is at the appellate level (Bang, 2019). Overall, there has not been much research over how they affect other areas such as forensics.

CONCLUSION

Forensic science has aided in solving numerous crimes, there are still many problems, boundaries, and questions that need to be solved. Some difficulties are the validity and reliability of specific techniques and presented evidence in court (CINFSC et al., 2012). There a many problems and limitations in postmortem, DNA, bloodstain, fingerprint, shoe print, and bite mark analysis including pseudoscience, validity, bias, bolstering and the processes. There are problems with prosecutor power and the affect it has on society, including those convicted. All of these reasons can affect the criminal justice system by causing disbelief in the legitimacy of the actors and government.

Efforts have been made to create new techniques and implement programs to combat forensics severely lacking. Some of these new techniques focus on post mortem, DNA, fingerprint analysis, and lessening the limitations. This includes creating new procedures to avoid bias, clearing the misunderstanding of forensic science, and lessening the control the prosecutor has.

However, more research still needs to be done to make these methods more effective. Some of the regulations in these techniques and even education are due to the resources. Many of the suggested changes are met with resistance from employees, administration, and policymakers because they believe that it is not cost or time efficient to implement programs or new instruments for analysis. Forensic science can overcome the problems and limitations it is constantly plagued with. Attitudes will need to be more accepting of the change required to improve.

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