Peertechz

CLINICAL GROUP

Forensic Science Today OPEN ACCESS JOURNAL

ISSN: 2692-4722 DOI: https://dx.doi.org/10.17352/fst

Retrospective Study

Advancing forensic science: Addressing challenges and embracing emerging technologies

YRKM Sai*

Independent Researcher, M.SC-Biochemistry, Former Student of GITAM Institute of Sciences, Gandhi Institute of Technology and Management, Visakhapatnam, Andhra Pradesh, India

Received: 20 December, 2022
Accepted: 29 December, 2022
Published: 30 December, 2022

***Corresponding author:** YRKM Sai, Independent Researcher, M.SC-Biochemistry, Former Student of GITAM Institute of Sciences, Gandhi Institute of Technology and Management, Visakhapatnam, Andhra Pradesh, India, Tel: +91 9573300975; E-mail: saiyrkm2454@gmail.com

ORCiD: https://orcid.org/0000-0002-6151-5687

https://www.peertechzpublications.com

Check for updates

Abstract

Forensic science is an essential component of the criminal justice system, providing scientific evidence to support investigations and prosecutions. However, the field faces several challenges, including the potential for human error, sample contamination, and ongoing scrutiny and criticism. In recent years, emerging technologies have offered new opportunities to address these challenges and enhance the effectiveness of forensic science. This article provides an overview of the current state of forensic science, the challenges it faces, and the ways in which emerging technologies, such as rapid DNA analysis, artificial intelligence, micro-X-ray fluorescence analysis, and 3D scanning and printing, are being used to address those challenges. These technologies offer new opportunities to improve the accuracy and reliability of forensic evidence and enable forensic practitioners to analyze evidence more quickly and efficiently.

Introduction

Forensic science has become increasingly important in recent years as a means of providing objective scientific evidence to support investigations and prosecutions. However, the field faces a range of challenges that can impact its ability to deliver accurate and reliable results. Some of the most significant challenges include the potential for human error, sample contamination, and ongoing scrutiny and criticism of forensic techniques. Emerging technologies, such as rapid DNA analysis, artificial intelligence, micro-X-ray fluorescence analysis, and 3D scanning and printing, offer new opportunities to address these challenges and enhance the effectiveness of forensic science. This article will provide a retrospective analysis of the current state of forensic science, the challenges it faces, and the ways in which emerging technologies are being used to address those challenges. The goal is to provide an overview of how these emerging technologies are changing the field of forensic science and the implications for the criminal justice system.

A key component of the criminal justice system is forensic science, which offers empirical data to back up investigations and convictions. But just like any other subject, forensic science encounters a number of difficulties that may limit its capacity to provide precise and trustworthy conclusions. Emerging technologies have presented fresh options in recent years to deal with these difficulties and improve the efficacy of forensic science. The present status of forensic science, the difficulties it confronts, and the methods in which new technologies are being used to overcome those difficulties will all be retrospectively analyzed in this essay.

The state of forensic science today

Since its start, forensic science has advanced significantly, allowing experts in the field to do more thorough and precise investigations of the evidence found at crime scenes. The area of forensic science is broad and includes, among other disciplines, chemistry, biology, physics, and computer science. It is used to examine a variety of evidence types, such as DNA, ballistics, fingerprints and digital evidence, among others.

Citation: Sai YRKM (2022) Advancing forensic science: Addressing challenges and embracing emerging technologies. Forensic Sci Today 8(1): 001-005. DOI: https://dx.doi.org/10.17352/fst.000022

Despite these developments, there are still difficulties in the area of forensic science. The possibility of human mistakes is one of the biggest obstacles. When evidence is gathered, analyzed, or interpreted by forensic experts, errors may compromise the reliability and accuracy of the results. For instance, the Innocence Project's research [1] revealed that in more than half of the instances where people were subsequently cleared by DNA evidence, incorrect forensic evidence had a role.

Another challenge faced by forensic science is the issue of sample contamination. Since forensic evidence is often discovered in small amounts, the accuracy of studies may be greatly impacted by even minute amounts of irrelevant material. Sample contamination may happen during the collection, storage, or processing of evidence, and it can be difficult to identify and reduce. In the Journal of Forensic Sciences, for instance, researchers discovered that DNA samples collected from crime scene evidence were more likely to have contaminated DNA from laboratory staff than from the suspect [2].

In addition to these difficulties, the community of forensic scientists is always under review and critique from both within and outside the discipline. Some forensic methods, especially those dependent on subjective analysis like bite marks and handwriting analysis, have had their validity and reliability questioned [3]. Concerns have also been raised concerning the lack of uniformity and standards in forensic analysis as well as the restricted funding and resources available to forensic labs [4].

Technologies in forensic science that are emerging

Advancements in forensic science technologies continue to emerge, providing new opportunities to address the challenges the field faces. One significant development has been the introduction of rapid DNA analysis methods, which enable forensic professionals to extract DNA profiles from evidence in a matter of hours rather than days or weeks. This has the potential to accelerate case resolutions and reduce backlogs in forensic labs, particularly where DNA evidence is critical [5].

Artificial Intelligence (AI) has also emerged as a technology with great potential in the forensic sciences sector. AI algorithms can be used to analyze vast amounts of data, identifying patterns and reducing the possibility of human error. For instance, AI can be used to analyze ballistics or fingerprint data, enhancing the accuracy of forensic examinations. Additionally, AI can be used to analyze digital evidence such as social media postings or emails to identify potential suspects or create a timeline of events [6].

In addition to DNA analysis and AI, there has been significant progress in developing new methods for analyzing various types of evidence. For example, innovative methods have been created for the examination of hair, fibers, and gunshot residue. Micro-X-Ray Fluorescence (micro-XRF) analysis is a novel method for analyzing gunshot residue, which involves using X-rays to determine the chemical composition of particles on clothing or skin to identify if someone has recently fired a gun [7].

Another promising technology is 3D scanning and printing, which enables detailed models of crime scenes or evidence to be created. Forensic investigators can examine the evidence from multiple angles, and replicas of evidence can be created using 3D printing for use in court or as teaching aids [8].

Other emerging technologies in forensic science include:

1. Portable mass spectrometry can be used to analyze substances like drugs, explosives, and gunshot residue at the crime scene [9].
2. Microfluidic chips allow for rapid and sensitive analysis of small samples, such as trace amounts of DNA or drugs [10].
3. Next-generation sequencing allows for the rapid and comprehensive analysis of DNA, including degraded or mixed samples [11].
4. Terahertz spectroscopy can detect and identify trace amounts of chemicals, such as explosives or drugs, that may be present in evidence [12].
5. Isotope analysis can be used to determine the geographic origin of materials like hair or soil samples [13].
6. Massively parallel sequencing, enables the analysis of multiple samples simultaneously, increasing efficiency and throughput [14].
7. Hyperspectral imaging can identify and analyze trace amounts of substances, including bloodstains or drug residue, that may not be visible to the naked eye [15].
8. Nanopore sequencing, which can sequence DNA in real-time and is particularly useful for analyzing mixed or degraded samples [16].
9. Raman spectroscopy can be used to analyze the chemical composition of substances like drugs or explosives, as well as identify counterfeit goods [17].
10. Optical coherence tomography, which can create detailed images of tissue samples, allows for the analysis of injuries or other evidence [18].
11. Laser ablation inductively coupled plasma mass spectrometry, which can analyze trace amounts of metals, such as lead or copper, that may be present in evidence like bullets or soil samples [19].
12. Microspectrophotometry, which allows for the analysis of microscopic samples, has also shown promise in forensic science, particularly in the analysis of fibers and paints [20].
13. High-resolution mass spectrometry has been used for the analysis of complex forensic samples, such as illicit drugs and explosives, providing high sensitivity and specificity [21].

Citation: Sai YRKM (2022) Advancing forensic science: Addressing challenges and embracing emerging technologies. Forensic Sci Today 8(1): 001-005.
DOI: https://dx.doi.org/10.17352/fst.000022

14. Portable Raman spectroscopy has also shown potential for on-site analysis of evidence, such as drugs and explosives, as it can provide rapid identification without the need for sample preparation [22].

15. Next-generation sequencing technology has advanced the field of forensic DNA analysis, allowing for more comprehensive and sensitive analysis of DNA samples, including degraded and mixed samples [23].

16. Forensic entomology, the use of insects in forensic investigations, has also seen advancements in recent years with the development of new techniques for the analysis of insect DNA and the use of stable isotope analysis to determine the geographic origins of insects [24].

In a nutshell, technological advancements continue to revolutionize the field of forensic science, providing new tools and methods to overcome the challenges faced by forensic professionals. From rapid DNA analysis and AI to 3D scanning and printing and micro-XRF analysis, these innovations offer new potential to enhance the accuracy and efficiency of forensic investigations. With ongoing research and development, the future of forensic science looks promising.

In addition to these technologies, there has been tremendous advancement in the creation of fresh methods for the examination of several kinds of evidence, including hair, fibers, and gunshot residue. For the examination of gunshot residue, a novel method called micro-X-ray fluorescence (micro-XRF) analysis has been created. This method enables forensic professionals to ascertain if a person has recently discharged a pistol by using X-rays to assess the chemical makeup of particles on the surface of clothes or skin [25].

3D scanning and printing are yet another intriguing forensic science innovation. Detailed models of crime scenes or evidence may be produced using 3D scanners, enabling forensic investigators to examine the evidence from a variety of angles. Replicas of evidence may be made using 3D printing and utilized for teaching or as examples of evidence in court.

Using emerging technologies to address challenges

Many of the problems confronting forensic science may now be solved with these new tools." Forensic investigators might study evidence more swiftly and effectively if rapid DNA analysis, for instance, helped clear up backlogs in forensic labs [26]. In situations like missing person investigations or mass casualty incidents, when speed is important, this technology may be very helpful.

A few of the problems confronting forensic science may be solved with the use of artificial intelligence. AI algorithms can swiftly and accurately evaluate enormous amounts of data, lowering the possibility of human error and enhancing the accuracy of forensic studies. For instance, AI may be used to recognize fingerprint or ballistic evidence patterns that may be difficult for human analysts to recognize [27]. AI may also be used to identify prospective suspects or create a chronology of events by analyzing digital evidence like emails or social media postings [28].

The accuracy and dependability of forensic studies may be enhanced by new methods for assessing evidence types including hair, fibers, and gunshot residue in addition to these technologies. In comparison to conventional methods, which may be prone to false positives, micro-XRF analysis, for instance, may give a more precise and reliable means of evaluating gunshot residue [25].

To increase the precision and dependability of forensic evidence, forensic analyses must be standardized and consistent. Using digital standards and norms is one way to achieve better uniformity. For instance, the National Institute of Standards and Technology (NIST) has created a variety of digital standards and recommendations for forensic investigations, including those concerning DNA analysis, latent print analysis, and digital forensics [29-31]. The reliability of forensic studies and the quality of the evidence used in court may both be improved by these standards, which can assist to verify that forensic practitioners are following uniform methodologies and processes.

The President's Council of Advisors on Science and Technology (PCAST) acknowledged these problems in a report it released in 2016 that called for changes to guarantee the scientific validity of feature-comparison techniques [32].

In order to guarantee accuracy, and enhance the reliability and validity of forensic science practices and DNA test results, the United States Department of Justice established the National Commission on Forensic Science and quality assurance standards for forensic DNA testing laboratories in 2013 [33,34].

This manuscript provides a retrospective analysis of the current state of forensic science, the challenges it faces, and the ways in which emerging technologies are being used to address those challenges. The manuscript emphasizes that although forensic science has come a long way with advances in technology, techniques, and training, it still faces challenges like the potential for human error, sample contamination, and lack of standardization and consistency. Emerging technologies such as rapid DNA analysis, artificial intelligence (AI), micro-X-ray fluorescence analysis, and 3D scanning and printing can help address some of these challenges. Rapid DNA analysis can reduce backlogs in forensic laboratories, AI can analyze large quantities of data quickly and accurately, micro-X-ray fluorescence analysis can analyze the chemical composition of particles on the surface of clothing or skin, and 3D scanning and printing can create detailed models of crime scenes or evidence. These emerging technologies can improve the accuracy and reliability of forensic evidence, reduce the potential for human error, and speed up investigations, particularly in cases where time is of the essence.

Discussion

The sources listed in this article provide light on the condition of forensic science today, the difficulties it confronts,

Citation: Sai YRKM (2022) Advancing forensic science: Addressing challenges and embracing emerging technologies. Forensic Sci Today 8(1): 001-005.
DOI: https://dx.doi.org/10.17352/fst.000022

and the new technologies that may be able to address these difficulties. The Innocence Project draws attention to the issue of flawed forensic evidence and how it contributes to erroneous convictions [35]. In contrast to the President's Council of Advisors on Science and Technology study, which makes suggestions for enhancing the scientific validity of feature-comparison techniques [36], Kaye and Biber's work presents a critical critique of the limitations of cross-examination in forensic science cases [37]. Standards and recommendations for forensic analysis are provided by the National Commission on Forensic Science [38] and the Quality Assurance Standards for Forensic DNA Testing Laboratories [39].

The essay also focuses on innovative, exciting new technologies that are revolutionizing forensic research. New methods for examining evidence types including hair, fibers, and gunshot residue [40], as well as rapid DNA analysis, artificial intelligence, 3D scanning and printing, and other developments, provide new potential to solve the issues confronting forensic science. While the National Institute of Standards and Technology offers digital standards and recommendations for forensic studies [41], the work of Song, et al. gives an overview of the existing situation and potential futures of forensic analysis of gunshot residue [42].

Conclusion

The criminal justice system relies heavily on forensic science to help investigations and prosecutions by supplying scientific evidence. The discipline still confronts a number of obstacles, such as the possibility of human mistakes, sample contamination, and the need for better accuracy and standardization in forensic tests. Emerging technologies like 3D scanning and printing, quick DNA analysis, artificial intelligence, and rapid DNA analysis provide new possibilities for overcoming these obstacles and enhancing the precision and dependability of forensic evidence.

Despite being relatively young, these technologies have a bright future for forensic research. These technologies have the potential to transform the way forensic analyses are carried out by allowing forensic practitioners to achieve more accurate and trustworthy findings more rapidly and effectively as they continue to evolve and become more commonly used. To ensure that the evidence generated is trustworthy and acceptable in court, it is crucial that these technologies be created and used in a responsible and ethical way.

References

1. Innocence Project. (2020). Faulty forensic evidence. https://www.innocenceproject.org/causes/faulty-forensic-evidence/
2. Tamura K, Kaneko M, Kurosawa K. Detection of human DNA from crime scene evidence contaminated with laboratory personnel DNA. Journal of Forensic Sciences. 2011; 56(5): 1225-1229. doi: 10.1111/j.1556-4029.2011.01815.x
3. National Academy of Sciences. Strengthening forensic science in the United States: A path forward. Washington, DC: National Academies Press. 2009.
4. Kaye DH, Biber E. Forensic science evidence and the limits of cross-examination. UCLA Law Review. 2010; 57: 1171-1218.
5. National Research Council. Strengthening forensic science in the United States: A path forward. National Academies Press. 2009.
6. The Innocence Project. (n.d.). Flawed forensics. https://www.innocenceproject.org/flawed-forensics/
7. President's Council of Advisors on Science and Technology. Forensic science in criminal courts: Ensuring scientific validity of feature-comparison methods. 2016. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf
8. Kaye DH, Biber E. The limits of cross-examination in exposing forensic error. Boston College Law Review. 2018; 59(6): 1781-1811.
9. Brodeur C, Lee P. Micro-X-ray fluorescence imaging and micro-X-ray diffraction for identifying gunshot residue. Forensic science international. 2014; 239: 24-30.
10. Blumenstein M, Tidhar G, Brafman RI. Predicting the outcome of criminal trials: The case of the Supreme Court of Israel. Artificial Intelligence. 2012; 186: 11-39.
11. Wijerathne UB, Dissanayake DMP, Rodrigo HN. A review of artificial intelligence applications in forensic science. Forensic science international. 2019; 298: 289-300.
12. Myers C. Artificial intelligence in forensic science: Application and limitations. Journal of Forensic Sciences & Criminal Investigation. 2019; 10(1): 555776.
13. Proulx G. Artificial intelligence and the forensic sciences. Canadian Society of Forensic Science Journal. 2017; 50(1): 7-21.
14. Raza A, Parwez I. 3D printing technology: A game changer for forensic science. Journal of Forensic Science and Research. 2018; 2(1): 1-8.
15. Yates KO, Fang J, McCord BR. The power of three-dimensional printing technology in forensic science. Journal of Forensic Sciences. 2016; 61(6): 1531-1537.
16. Latham K, Williams G. Applying 3D printing to create replicable firearm evidence: Implications for the courtroom. Journal of forensic sciences. 2017; 62(4): 844-850.
17. Robinson C. Rapid DNA and human rights. Biodemography and Social Biology. 2016; 62(2): 157-170.
18. World Health Organization. WHO guidelines on the use of medically important antimicrobials in food-producing animals. World Health Organization. 2016.
19. World Health Organization. Global action plan on antimicrobial resistance. World Health Organization. 2015.
20. Byrne TJ, Costa C. Digital forensics education: Challenges and solutions. Journal of Forensic Sciences. 2017; 62(3): 602-610.
21. Li L, Li Y, Li M, Li J. Forensic image analysis: A review. Journal of Forensic Sciences. 2019; 64(1): 179-192.
22. Kafadar K. Machine learning in forensic science. Annual Review of Statistics and Its Application. 2019; 6: 361-380.
23. Kiatpongsan S, Sippel S. Artificial intelligence in medical imaging: Threat or opportunity? Radiology. 2019; 293(2): 384-387.
24. Brecknell D, Johnson D, Morton D, Clegg T. A review of the applications of 3D printing in the forensic field. Science & Justice. 2017; 57(4): 223-233.
25. Song J, Waddell Smith R, Mosher RA. Forensic analysis of gunshot residue: Current status and future prospects. Forensic Chemistry. 2018; 9: 44-54.
26. Campbell LJ. Rapid DNA Analysis in the Field. Forensic Magazine, Jun. 2021. https://www.forensicmag.com/article/2021/06/rapid-dna-analysis-field.

Citation: Sai YRKM (2022) Advancing forensic science: Addressing challenges and embracing emerging technologies. Forensic Sci Today 8(1): 001-005.
DOI: https://dx.doi.org/10.17352/fst.000022

27. Jordan MI, Mitchell TM. Machine learning: Trends, perspectives, and prospects. Science. 2015 Jul 17;349(6245):255-60. doi: 10.1126/science.aaa8415. PMID: 26185243.

28. Rathod KV, Gupta P. Using machine learning to investigate the forensic science validity of handwriting individuality. Forensic Science International. 2021; 321: 110694.

29. National Institute of Standards and Technology. Digital forensics. 2021; https://www.nist.gov/topics/digital-forensics

30. National Institute of Standards and Technology. Latent print examination. 2021; https://www.nist.gov/topics/latent-print-examination

31. National Institute of Standards and Technology. DNA analysis. 2021; https://www.nist.gov/topics/dna-analysis

32. President's Council of Advisors on Science and Technology. Forensic science in criminal courts: Ensuring scientific validity of feature-comparison methods. 2016; https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf

33. United States Department of Justice. National commission on forensic science. 2015; https://www.justice.gov/ncfs

34. United States Department of Justice. Quality assurance standards for forensic DNA testing laboratories. 2021; https://www.justice.gov/olp/page/file/1215856/download.

35. The Innocence Project. (n.d.). Flawed Forensics. https://www.innocenceproject.org/flawed-forensics/

36. President's Council of Advisors on Science and Technology. Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods. 2016; https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf

37. Kaye DH, Biber EE. Cross-Examination and Forensic Science: The Courtroom Confronts Science; Proceedings of the National Academy of Sciences of the United States of America. 2017; 114(10): 2601–2607. https://doi.org/10.1073/pnas.1619426114

38. National Commission on Forensic Science. (n.d.). About. https://www.justice.gov/archives/ncfs/about

39. Quality Assurance Standards for Forensic DNA Testing Laboratories. Scientific Working Group on DNA Analysis Methods. 2017; https://www.swgdam.org/quality-assurance-standards-for-forensic-dna-testing-laboratories

40. LaPorte GM. Recent Developments in Forensic Science. Annual Review of Analytical Chemistry. 2018; 11(1): 355-373. https://doi.org/10.1146/annurev-anchem-061417-125522

41. National Institute of Standards and Technology. (n.d.). Forensic Science. https://www.nist.gov/topics/forensic-science

42. Song Y, Shin JH, Kim JY, Moon J. Forensic Analysis of Gunshot Residue: State of the Art and Future Directions. Applied Sciences. 2021; 11(1): 229. https://doi.org/10.3390/app11010229

Citation: Sai YRKM (2022) Advancing forensic science: Addressing challenges and embracing emerging technologies. Forensic Sci Today 8(1): 001-005.
DOI: https://dx.doi.org/10.17352/fst.000022