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Review Article

Emerging Trends and Applications of Forensic Medicine in Modern Healthcare and Criminal Investigation: A Narrative Review

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A B S T R A C T

Background: In Medical Science, we are very much better with everything we have in the last many years from a technology point of view and how we can use medical science to investigate crimes especially using autopsies and medical legal things.

Aim: We wish to examine the innovations in forensic medicine — what is working and what is not, so it alters our approach to helping persons who are injured/ill as well with how we prosecute cases.

Methods: Data were retrieved from studies published between 2000 to 2025 using databases of PubMed and Google Scholar as well as reports on World Health Organization and journals about forensic medicine. We selected articles that dealt with closely related topics, such as pathology and DNA profiling.

Results: Techniques such as DNA sequencing and forensic imaging represent some of the most transformative advances in medicine today. These technologies have been extremely valuable in solving crimes, correctly identifying victims and more efficiently tracking medical legal matters. Forensic medicine — which is vital, for example by caring for people while discovering in the cases of crimes victims of disasters and for assuring the correct functioning of the legal system. We need to ensure that we have established centres of forensic medicine which train individuals well and use the latest technology ensuring that the medical legal system works better behind our justice delivery.

Keywords: Forensic Medicine, Forensic Pathology, DNA Profiling, Toxicology, Medico-Legal Investigation, Digital Autopsy

Introduction

Forensics is a field of medical science. It applies the knowledge in both legal problems and the administration of justice. Forensic scientists assist law enforcement and courts with determining how and why someone died or been injured. They are called in for instances of rapes, poisoning and unidentified individuals as well. Over time, medicine has witnessed enormous growth. This is attributed to enhanced methods of practices such as DNA examination, imaging the body and searching for poisons. Now, things like DNA profiling and computer analysis have worked their way into modern forensic investigations to help with crime-solving. You see crimes, accidents and abuse happening globally in every media outlet. It means forensic services are crucial. Forensic medicine plays an integral role for many such forensic investigation and helps not only in detection, availing justices to victims but also deterrent effect of nature i.e. even leaves a warning signs which prohibits committing crimes like murder/ suicide and sexual assault etc.

There is also forensic medicine behind car accidents, abuses and when doctors make mistakes. Forensic experts are called upon to assist in legal investigations related to homicide, suicide, custodial deaths, sexual offenses, mass disasters and cases of clinical negligence. Medico-legal sciences also involve forensic medicine.

Forensic scientists assist in the process of identifying patterns of injuries, cause of death, working out whether a person has been sexually molested and also investigating instances of poisoning alongside estimating an age category and discovering burial customs in unknown remains. The discipline deals with the investigation of crimes, civil litigation, identification of human remains in mass disasters and public health surveillance. Forensic medicine is the branch of medicine that applies science and logic to legal matters and justice. Forensic medicine, an important medical science component

DNA profiling has changed forensic science by providing definitive identification of suspects, missing persons and victims from cadavers in disasters.[4] Forensic toxicology is also an important area, dealing with the determination of drug, alcohol, poisons and chemical substances which are related to suspicious deaths and criminal investigations.

The advancement of some digital technologies (e.g. virtual autopsy, postmortem computed tomography and magnetic resonance imaging) introduces non-invasive forensic examination and documentation system.[5] The innovations bring better precision, evidence preservation and lower risk of work-related injuries. Forensic medicine also plays an important role in preventive healthcare by recognizing trends such as injuries, occupational hazards, patterns of poisoning, and threats to public health. Medico-legal data derived from forensic investigations can inform policy development as well as preventive interventions.

Several unresolved issues still exist in forensic healthcare systems in many developing countries, including shortage of trained forensic experts, lack of laboratory infrastructure, delayed reporting and limited technological resources — although some progress has been made since 2016.[6] The current review highlights the key uses, trends in developments, innovations, hurdles and outlooks of forensic medicine and toxicology.

Objectives of the Review

This review intends to give a comprehensive insight into the prospective development of forensic medicine as an increasingly significant field in contemporary healthcare systems and criminal investigations. Forensic medicine connects medical science with law as it helps in the identification, analysis and interpretation of evidence, injury, causes of deaths and medico-legal cases. The review provided insight on both the current and upcoming aspects in forensic sciences, which correlate with justice delivery as well as public health.

- To understand the application of forensic medicine in health care and its role in crime investigation, medico-legal examination, cause-of-death determination, injury assessment, and providing legal documentation.
- To talk about advancements in forensic sciences over recent years especially related to digital forensics, artificial intelligence, imaging technologies, molecular diagnostics and automated analytical systems which have improved the accuracy and efficiency of forensic investigations.
- To assess forensically a criminal case, DNA profiling, and forensic toxicology in determining the identity of victims, suspect, or individual evidence and detection of toxins in life or postmortem samples as well.
- Identifying barriers to implementing forensic healthcare systems, such as shortage of trained professionals, delayed forensic reports, inadequacies in infrastructure and technology, ethical concerns and issues with evidence collection and standardization.
- Explore future directions in forensic medicine, with an emphasis on technological developments, interdisciplinary collaboration, refinement of laboratory works, and incremental changes provide new opportunities to improve the field of forensic healthcare via positive advancements in various policies to enhance the field, thereby improving the quality of value-added service for both victim care as well as protections through criminal justice systems.

Methods

A narrative review of articles published between 2000 and 2025 were conducted to report the recent progress and flexible usages of forensic. Data and information related to COVID-19 was collected from electronic databases: PubMed, Scopus, Google Scholar, World Health Organization, other peer reviewed journals of forensic medicine. Relevant studies, literature reviews and scientific publications on forensic healthcare and criminal investigation were retrieved using keywords such as: [forensics health care], [forensic medicine], [forensic pathology] AND (or) else DNA profiling), [(or) else forensics toxicology], ([digital autopsy]), ([medico-legal investigation]).

Major Branches of Forensic Medicine

Forensic Pathology

The forensic pathology is the main field of the forensic medicine related to establishing cause, manner, and time of death through examination (autopsy) and laboratory testing. The specific type of forensic examination is focused on case-specific repair, injury analysis, tissue pathology, and medico-legal evidence synthesis to provide important information as relevant for the criminal investigation or legal proceedings (Table 1).

Forensic Toxicology

Forensic toxicology involves the detection, identification, and quantification of drugs, alcohols, poisons or other toxic chemicals in biological specimens such as blood [and/or] urine and tissues7. This is a vital part of the investigation into an overdose, poisoning, death by substance abuse or from an unknown cause.

DNA Profiling

One of the most sophisticated techniques in forensic sciences is DNA profiling and it has high implementation for criminal identifications, paternity testing and disaster victim's identification.[4] This supplies extremely reliable genetic evidence that helps connect suspects to crime scenes and identify unidentified individuals.

Forensic Anthropology

Forensic anthropology is the aligning of skeletal remains to different characteristics that can help identify remains by estimating age, sex, stature and ancestry. This branch of forensic science is well-suited to use in the case of dissected, charred, or unidentified human skeletal remains.

Cyber Forensics

Definition Of Cyber Forensics Digital forensics or cyber forensics is the investigation of digital crimes and electronic evidence. This involves the rehabilitation and examination of data from computers, mobile devices, and digital networks to access cybercrime, fraudulence, hacking as well as electronic offenses.

Role of DNA Profiling in Forensic Investigation

DNA profiling has transformed forensic investigations due to its high accuracy and reliability. Biological samples including blood, saliva, hair, semen, and bone can be analyzed for genetic identification.[4]

Applications include (Figure 1):

- Criminal investigation
- Paternity disputes
- Identification of missing persons
- Disaster victim identification
- Sexual assault investigations

Table 1.Major Branches and Applications of Forensic Medicine

Branch	Major Application
Forensic Pathology	Cause of death investigation
Forensic Toxicology	Poison detection
DNA Profiling	Criminal identification
Forensic Anthropology	Skeletal identification
Cyber Forensics	Digital crime investigation
Forensic Psychiatry	Mental health evaluation in legal cases

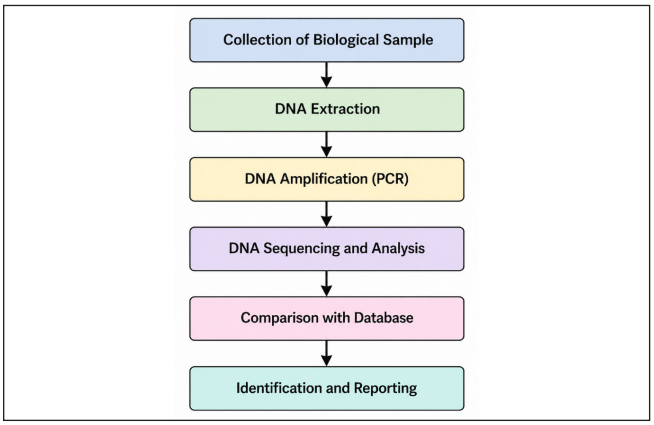

Figure 1.Flow Diagram of DNA Profiling Process

Recent Advances in Forensic Medicine

Digital Autopsy

Virtual autopsy using CT and MRI imaging provides non-invasive postmortem examination and improved forensic documentation.[5]

Artificial Intelligence

AI-assisted forensic systems improve facial recognition, fingerprint analysis, and pattern identification (Table 2 and Figure 2).

Forensic Odontology

Dental identification plays a major role in mass disaster victim identification and age estimation.

Toxicological Advancements

Advanced chromatographic and spectrometric methods have improved poison detection accuracy.

Table 2.Recent Technological Advances in Forensic Medicine

Technology	Application
DNA Sequencing	Human identification
Digital Autopsy	Non-invasive postmortem imaging
AI-Based Analysis	Pattern recognition
Mass Spectrometry	Toxicological analysis
3D Facial Reconstruction	Victim identification
Cyber Forensic Software	Digital evidence recovery

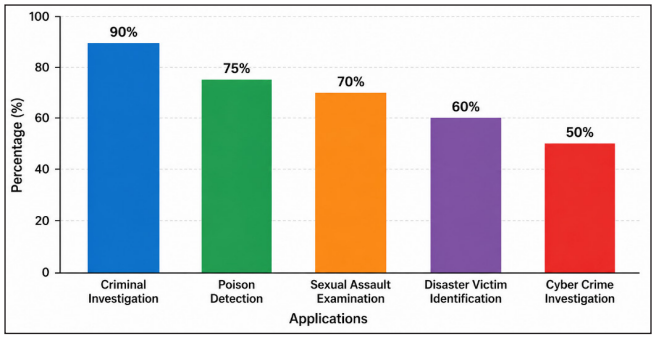

Figure 2.Applications of Forensic Medicine

Discussion

Forensic medicine is an emerging area of interdisciplinary research that integrates principles and knowledge from the fields of medicine, pathology, toxicology, (bio) genetics, anthropology, radiology and law to assist with the dispensation of justice and the promotion of public safety. This review describes the increasing significance of forensic medicine in identifying health-related aspects in criminal investigations, disaster situations and legal medicine practice.

DNA profiling, which makes use of our unique genetic make-up to identify individuals or help track down criminals, is one major medical revolution. People can be identified from blood, saliva they leave behind and bits of semen left on a shoe or hair on clothing or bones found in the ground and no other science is as specific, sensitive or reliable as DNA analysis has proved to be. DNA fingerprinting has increased the accuracy of investigations, paternity tests and identification of disaster victims. DNA profiling is an important type of forensic evidence and forms a critical part of many legal cases particularly in the case of assault, murder, missing people and large disasters. In such cases forensic medicine and DNA profiling play a vital role.

Forensic medicine has many utilizations in several domains such as health systems and this domain is gaining its significance every coming day. We are using forensic medicine and DNA analysis to help solve crimes and keep people safe. The introduction of short tandem repeat (STR) analysis with polymerase chain reaction (PCR)-based amplifications has greatly improved the effectiveness and accuracy of genetic forensic research. Many countries, along with their ability to identify a suspect or solve a crime much more easily through the development of national DNA databases. But persistent ethical issues surrounding privacy, the potential for abuse of genetic information, and continued storage of confidential databases have not been irrelevant concerning careful legal regulation.

Virtopsy or digital autopsy is another development in forensic medicine. Conventional postmortem autopsy is associated with an invasive procedure, but recently non-invasive imaging techniques (i.e., computed tomography (CT) and magnetic resonance imaging (MRI), especially 3D reconstruction) have developed as useful complementing tools.[5] These technologies have improved the visualization of skeletal injuries, internal haemorrhage, foreign bodies, and trauma patterns while maintaining normal anatomy.

Infectious disease outbreaks, highly decomposed remains, culturally sensitive populations and scenarios where informed consent for the autopsy via the traditional approach is unobtainable makes virtual autopsy especially valuable. Furthermore, digital imaging provides permanent documentation of findings, can be analysed multiple times and is compatible with medico-legal presentation in trials.

Forensic toxicology is still critical in determining poisoning, alcohol intoxication, substance abuse, and drug-related death.[7] The growing industrialization of the world, increasing availability of toxic substances and rising drug abuse have raised the number of toxicological challenges around the globe. In many cases, poison detection has become extremely sensitive and accurate due to advanced analytical techniques like gas chromatography, liquid chromatography and mass spectrometry.

Toxicologic studies are important in the cases of accidental poisoning, suicidal death, homicidal poisoning, occupational exposure and loss of life due to substance abuse. Toxicological screening at an early stage along with a medic-legal interpretation as soon as possible leads to better inputs not only for criminal investigations but also helps in public health surveillance.

The review also discusses the growing importance of forensic odontology in identifying individuals and

managing disaster victims. Because of their resistance to decomposition, heat and environmental damage, dental tissues have been recognized as useful tools for forensic identification.[8] Forensic-identical dentists also play a role in mass fatalities, burns and unknown-even physique situations with age estimate, biting mark evaluation and dental similar comparison.

Introduction Cyber forensics is a new emerging field of forensic science as cybercrime, digital fraud, identity theft, online harassment and electronic data manipulation have now become very common. The emergence of the new digital domain has added an important dimension to modern forensic practice with respect to investigation of electronic communication records, cyber evidence and investigation of digital devices. The recovery and analysis of digital evidence is an expert skill that needs special technological infrastructure.

The forensic investigations are increasingly utilizing the artificial intelligence (AI) and machine learning technologies. AI can help automation systems use fingerprint analysis, facial recognition, handwriting analysis, crime pattern identification and even predictive analytics. The automation of forensic data analysis has the potential to improve efficiency, relieve human error, and increase investigative precision in future forensic practice.

Forensic medicine also plays a substantial role in the fields of preventive healthcare and public health policy forming. Medico-legal investigations are a rich source of demographic information and epidemiological data related to: road traffic accidents, poisoning trends, domestic violence/violence against women / occupational injuries, firearm related deaths and suicide. This information can help the public health authorities to detect risk (or protective) factors and thus develop prevention measures.

In India and deceased especially in developing countries, HDS SULL represent a major med1co-legal burden. Related Content Forensic investigations have the ability to answer questions surrounding cause of death, mechanisms of injury, fatal alcohol intoxication and other justifications for negligence in fatal accidents. Likewise forensic investigation of occupational injuries and industrial poisoning forms basis for workplace safety regulations and occupational health policies.

The specialty is also essential in the management of sexual assault cases. Like this: Aspects such as the successful forensic examination of crime scenes, evidence collection and documentation of injuries are crucial in ensuring that justice is delivered to victims The introduction of standardized sexual assault examination protocols and multidisciplinary victim support services have greatly improved the medico-legal management of these cases.

Disaster victim identification (DVI) is a concept that has been gaining prominence with the increasing occurrence of natural disasters, terrorist attacks, Air-crash accidents and mass casualty incidents. Forensic analysts can identify common forms of victim identification, including but not limited to DNA, fingerprinting, dental records, radiological exam (x-rays), and anthropological examination. DVI systems are important for humanitarian assistance and documenting events that occurred during a disaster.

While there have been strides in forensic healthcare systems in developing countries, challenges remain. A trained forensic expert, proper laboratory infrastructure, timely reporting, preservation of evidence, and technological assistance is still a major barrier to effective medico-legal services.[6] This also faces a lot of difficult questions in most of the healthcare institutions as well related to overcrowding, inadequate funding and lack of forensic equipment among others.

Poor medico-legal reporting can compromise both police investigations and judicial processes. Poorly trained health care professionals in terms of medico-legal documentation and evidence preservation may also affect the quality of these investigations. Therefore, some reinforcement of undergraduate and postgraduate forensic upskilling is required.

Another key challenge is ethical and legal problems regarding conducting forensic investigations. Strict legal and professional guidelines are essential for privacy issues, consent complexities, genetic data misuse and human remains ethically being handled. To ensure that forensic findings are reliable in court, chain of custody and appropriate evidence handling protocols must be maintained.

Strengthening forensic infrastructure, improving laboratory facilities, expanding digital forensic capability and increasingly integrating advanced technologies to support their routine forensic practice are the needs bore out in the review. If regional forensic science laboratories and modernised medico-legal systems are established, investigations may be carried out with ease and healthcare delivery may improve.

Advancement of forensic medicine demands regular training program, work on interdisciplinary collaboration, research needed and public awareness about medico-legal procedures. The inter-profession collaboration can enhance the quality of medico-legal services and subsequent administration of justice involving healthcare professionals, law enforcement agencies, forensic scientists and judicial authorities.

In summary, forensic medicine is still an integral part of modern health and justice systems. Innovative

technological development, multidisciplinary integration and strengthening of forensic infrastructure is expected to accelerate the role of forensic medicine in crime scene investigation, public health, disaster management and justice delivery systems around the globe.

Challenges in Forensic Medicine

- Shortage of trained forensic specialists
- Delayed medico-legal reporting
- Inadequate laboratory infrastructure
- Limited access to advanced technologies
- Poor preservation of forensic evidence
- Increasing burden of cybercrime and digital offenses

Recommendations

- Strengthening forensic laboratory infrastructure.
- Improving medico-legal training among healthcare professionals.
- Integration of AI and digital technologies into forensic practice.
- Establishment of advanced regional forensic centers.
- Enhancement of disaster victim identification systems.
- Promotion of research in forensic medicine and toxicology.

Conclusion

Forensic medicine is an essential component of medical care, investigative procedures in criminal matters, and aspects of public safety and administration of justice. Recent developments in technologies like DNA profiling, digital autopsy, forensic imaging, artificial intelligence and high-resolution thermal and chemical analyses of post-mortem samples have made the medico-legal investigations leaner and more precise.

This specialty plays a vital role in criminal identification (such as forensic DNA), poisoning analysis, sexual assault examination, disaster victim identification and public health surveillance. This includes multidisciplinary forensic science, although modern forensic medicine practice has been good at breaking away from traditional autopsy only evidence analysis and medico-legal interpretation.

Although there has been much progress, forensic healthcare delivery in many developing nations continues to be hampered by issues such as poor infrastructure, insufficient trained professionals and late reporting systems, and limited access to technology.

Forensic services are highly dependent on timely justice delivery systems which can be improved in conjunction with forensic education, laboratory expansion number of cases tackled by them, advanced technology application and the overall medico-legal training.

In summary, forensic medicine is an indispensable aspect of modern health care and the justice system, continuing to evolve with the fast pace of scientific and technological advancements.

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