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REVIEW

# Application of artificial intelligence in the field of legal and forensic medicine: advances and future challenges

## Aplicación de la inteligencia artificial en el campo de la medicina legal y forense: avances y desafíos futuros

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## ABSTRACT

**Introduction:** artificial intelligence (AI) has emerged as a profoundly transformative tool in numerous fields of knowledge, and its application in legal and forensic medicine is opening a new chapter in forensic science. The development of the "JL-IDIF" system by the Forensic Research Institute (IDIF) has been recognized as an innovative step, setting precedents for the use of advanced technology for the recording and analysis of forensic data. AI represents an unprecedented opportunity to transform legal and forensic medicine, making these processes faster, more efficient, and more accurate.
**Method:** an information search was conducted from January to May 2025. Information was collected from scientific articles, books, technical reports, and publications in specialized media, using databases such as PubMed, Scopus, Google Scholar, and websites of forensic and government institutions. This approach allowed for a comprehensive and well-founded synthesis of the available information.
**Results:** the emergence of artificial intelligence (AI) has transformed multiple areas of medicine, and its incursion into forensic and legal medicine marks the beginning of a new era in forensic practice.
**Conclusions:** this review has shown that, while technological advances have demonstrated great potential, significant limitations remain related to data quality, the need for external validation, and the availability of adequate technological infrastructure. In Bolivia, initiatives such as the JL-IDIF project or the experimental implementation of generative AI models demonstrate the interest and initial capacity to explore these emerging technologies. AI should not be viewed as a substitute for human judgment, but rather as a powerful tool that enhances the work of experts, allowing them to focus on critical interpretation and decision-making.

**Keywords:** Artificial Intelligence; Forensic Medicine; Criminology; Forensic Reconstruction; Ethics.

## RESUMEN

**Introducción:** la inteligencia artificial (IA) ha emergido como una herramienta profundamente transformadora

en numerosos ámbitos del conocimiento, y su aplicación en la medicina legal y forense está abriendo un nuevo capítulo en la ciencia pericial. El desarrollo del sistema "JL-IDIF" por parte del Instituto de Investigaciones Forenses (IDIF) ha sido reconocido como un paso innovador, sentando precedentes sobre el uso de tecnología avanzada para el registro y análisis de datos forenses. la IA representa una oportunidad sin precedentes para transformar la medicina legal y forense, haciendo estos procesos más rápidos, eficientes y precisos.
**Método:** se realizó una búsqueda de información en el periodo enero-mayo de 2025. Se recopiló información de artículos científicos, libros, informes técnicos y publicaciones en medios especializados, utilizando bases de datos como PubMed, Scopus, Google Scholar y sitios web de instituciones forenses y gubernamentales. Este enfoque permitió una síntesis comprehensiva y fundamentada de la información disponible.
**Resultados:** la irrupción de la inteligencia artificial (IA) ha transformado múltiples áreas de la medicina y su incursión en la medicina legal y forense, marca el inicio de una nueva era en la práctica pericial.
**Conclusiones:** esta revisión ha evidenciado que, si bien los avances tecnológicos han demostrado un gran potencial, aún existen limitaciones significativas relacionadas con la calidad de los datos, la necesidad de validación externa y la disponibilidad de infraestructura tecnológica adecuada. En Bolivia hay iniciativas como el proyecto JL-IDIF o la implementación experimental de modelos de IA generativa, muestran que hay interés y capacidad inicial para explorar estas tecnologías emergentes. La IA no debe ser vista como un sustituto del juicio humano, sino como una herramienta poderosa que potencia la labor de los expertos, permitiéndoles enfocarse en la interpretación crítica y la toma de decisiones.

**Palabras Clave:** Inteligencia Artificial; Medicina Legal; Criminología; Reconstrucción Forense; Ética.

## INTRODUCTION

Artificial intelligence (AI) has emerged as a profoundly transformative tool in many fields of knowledge, and its application in forensic and legal medicine is opening a new chapter in forensic science. Traditionally, forensic medicine has required the combination of clinical and legal knowledge to clarify facts with criminal, civil, or administrative relevance. Today, with the incorporation of AI, this field is undergoing an unprecedented methodological revolution, where complex tasks can be complemented, accelerated, and, in some cases, partially automated.[1]

Among the most prominent applications are automated facial recognition, age estimation from skeletal or dental remains, forensic facial reconstruction, injury pattern detection, and interpretation of medical images in cases of violence, homicide, or suspicious deaths. These tasks, which used to rely solely on human expertise, are now enhanced by algorithms capable of processing large volumes of data with high speed and consistency. Technologies such as machine learning, deep learning, and convolutional neural networks (CNNs) allow complex patterns to be identified and assisted decisions to be made with increasing accuracy.[2,3]

Countries like China, Israel, Brazil, and Colombia have led successful international experiences. In China, for example, AI systems have been developed that automatically identify skull fractures in CT scans of victims; in Israel, predictive models help determine with high accuracy the probable cause of death from virtual autopsies. In Latin America, Brazil has implemented facial recognition in mass events, facilitating the identification of people wanted by the justice system, while in Colombia, AI has been key to identifying human remains in contexts of armed conflict through forensic reconstruction of faces.[4]

However, these advances come with technical, ethical, and legal challenges. One of the main problems is algorithmic bias: systems trained on unrepresentative data may generate erroneous or discriminatory results. In addition, there are serious concerns about privacy and personal data protection and the validity and legal acceptability of AI-assisted findings in legal proceedings. This requires clear regulatory frameworks, ongoing technology audits, and rigorous scientific validation protocols.[5]

In Bolivia's case, while AI's implementation in forensic medicine is still in its infancy, there are encouraging signs. The development of the 'JL-IDIF' system by the Institute of Forensic Investigations (IDIF) has been recognized as an innovative step, setting precedents for the use of advanced technology for the recording and analyzing of forensic data. Experimental tests with generative AI models have also been initiated. However, the country faces structural barriers such as poor technological infrastructure, limited training of forensic AI specialists, and the absence of specific regulations.

For Bolivia to fully reap the benefits of these tools, it will be crucial to invest in technical training, develop national standards adapted to local realities, and ensure the interoperability of technological systems with the needs of the judicial system. However, despite these shortcomings, the Free Justice System of the Public Prosecutor's Office and the JL-IDIF respond to the requirements of Law No. 1173 on Criminal Procedural Abbreviation and also has all the legal validity granted by Law No. 1080 on Digital Citizenship, giving users the advantages and benefits of modernization and technological advances, aimed at the development of artificial

intelligence tools.[6] AI represents an unprecedented opportunity to transform forensic and legal medicine, making these processes faster, more efficient, and more accurate. However, its implementation must be done cautiously, ethically, and responsibly, ensuring that these tools support forensic professionals and not as a substitute for their scientific and human judgment.

## METHOD

A search for information was carried out in the period January-May 2025. Information was collected from scientific articles, books, technical reports, and publications in specialized media, using databases such as PubMed, Scopus, Google Scholar, and websites of forensic and governmental institutions.

The inclusion criteria covered publications between 1997 and 2024 in English and Spanish that addressed AI applications in areas such as forensic image analysis, facial recognition, natural language processing, crime scene reconstruction, and criminal pattern analysis. Studies unrelated to forensics or lacking academic rigor were excluded.

The search was structured using keywords such as 'Artificial Intelligence,' 'Forensic Medicine,' 'Forensic Analysis,' 'Facial Recognition' and 'Machine Learning,' combined with specific terms such as 'Bolivia,' 'Brazil,' "Colombia" and 'AI ethics.' Thirty-five relevant sources were identified and analyzed, including references cited in the original paper.

The data were organized into thematic categories: AI applications, benefits, challenges, case studies, and emerging trends. In addition, practical examples from countries such as Brazil, Colombia, China, Israel, and the UK were examined to contextualize the use of AI in diverse forensic environments. The analysis was complemented by a critical assessment of ethical and technical aspects, considering Bolivia's technological limitations and regulatory needs. This approach allowed for a comprehensive and informed synthesis of the available information. In this review, we raise several points of view in the field of forensic medicine and forensic science, where the application of AI will greatly help experts in these areas.

## DEVELOPMENT

Artificial intelligence (AI) has transformed forensic medicine through applications that optimize evidence processing and improve case resolution accuracy. Forensic medicine is the application of medical knowledge to law enforcement, criminal investigation, and the legal system. Forensic toxicology applies this multidimensional knowledge of toxicology to law and the administration of justice. Forensic medicine and toxicology are the foundations of forensic science. They are used in various settings and are common in crime scene investigations and court cases.

Forensic experts employ a wide range of techniques to identify and determine whether someone was poisoned, infected, had a medical condition, or died from violence. These techniques include collecting and analyzing DNA and fingerprints, blood and other body fluids, and analyzing hair, fibers, weapons, bones, and soil samples at a crime scene.

In conducting a forensic medical-legal autopsy, a forensic expert must look for various points depending on the needs of the case to form a proper opinion on the cause of death and to answer the investigating agency's questions. These include verifying an individual's identity, externally examining various stains on clothing or the body, identifying and collecting samples of bodily fluids, examining wounds, etc.

In an internal examination of the body, the forensic expert must determine various pathological conditions of the organs to detect the cause of death; he must look for multiple fractures and minor injuries, which usually go unnoticed by the naked eye but may have contributed to the death of the person. You should also look for any affected or inflamed areas present on the body due to the effect of the poison. You should also examine trace evidence such as blood samples, seminal stains, and fingerprints.

In all these areas of forensics, AI can play a key role in helping forensic experts form more accurate, faster, and more consistent opinions on the analysis of forensic cases by comparing their findings data with available machine data. Similarly, weapons analysis and time-of-death calculations are also areas where AI can be helpful.[7,8,9]

Some aspects of forensics and AI need to be considered, such as:

*Image analysis and facial recognition.*

Analyzing forensic images using AI can improve the quality of pictures and detect specific patterns, such as fingerprints or ballistic marks, more accurately than traditional methods.[1,9] Deep learning algorithms, such as artificial neural networks, have proven effective in identifying unique features in forensic images.[10] In facial recognition, AI analyses facial features to verify identities and is used in criminal investigations to identify suspects in security footage.[11]

For example, in Brazil, since 2020, the Rio de Janeiro police have been using video surveillance cameras with machine vision algorithms to identify fugitives during mass events and detect irregular vehicle license

plates.[14] In Colombia, AI has been instrumental in reconstructing faces from skulls found in mass graves, facilitating the identification of victims in cases of enforced disappearances.[15]

*Natural Language Processing (NLP)*

Natural language processing (NLP) allows for analyzing legal and forensic texts and extracting relevant information from medical reports, testimonies, and court documents.[16] Based on advanced language models, NLP tools speed up the transcription and translation of documents, improving the accessibility of information in multilingual contexts.[17]

In Bolivia, systems such as ChatGPT and Gemini AI have been explored to analyze legal cases under Bolivian law, using structured prompts to generate accurate answers in the search for legal information.[18] These systems have shown potential to automate repetitive tasks, although their implementation requires clear and specific prompts to ensure reliable results.

*Crime scene reconstruction and pattern analysis*

AI facilitates the reconstruction of crime scenes through 3D modeling, integrating forensic data and testimonies to simulate events[19] accurately. These reconstructions help investigators visualize and analyze the dynamics of events, improving the interpretation of evidence.[20]

In addition, AI-based predictive analytics can identify criminal patterns from historical data, supporting crime prevention.[21] In Israel, following the Hamas bombing in October 2023, AI was used to identify dead bodies in poor condition by comparing CT scans with medical image databases, significantly reducing time.

**International experiences**

In China, AI has advanced in the courts with systems such as Xiao Zhi 3.0, which interprets testimony and issues judgments in simple cases, such as traffic accidents, reducing processing time by 80 %.[23,24] In the UK, AI is used to determine the age of people in images, supporting investigations into child pornography by analyzing body features.[25]


**Figure 1.** A timeline of the use of AI in Forensic Medicine in Europe, Asia and South America between 2020 - 2025

These cases illustrate how AI can be integrated into judicial systems to streamline processes, although they require strict regulations to avoid bias and ensure fairness. These developments are not isolated events but part of a global evolution that can be observed between 2020 and 2025. This historical process reveals a shared path of forensic innovation, where AI has evolved from a theoretical promise to an operational tool (figure 1).

**Future Perspectives and Challenges of AI in Forensic Medicine**

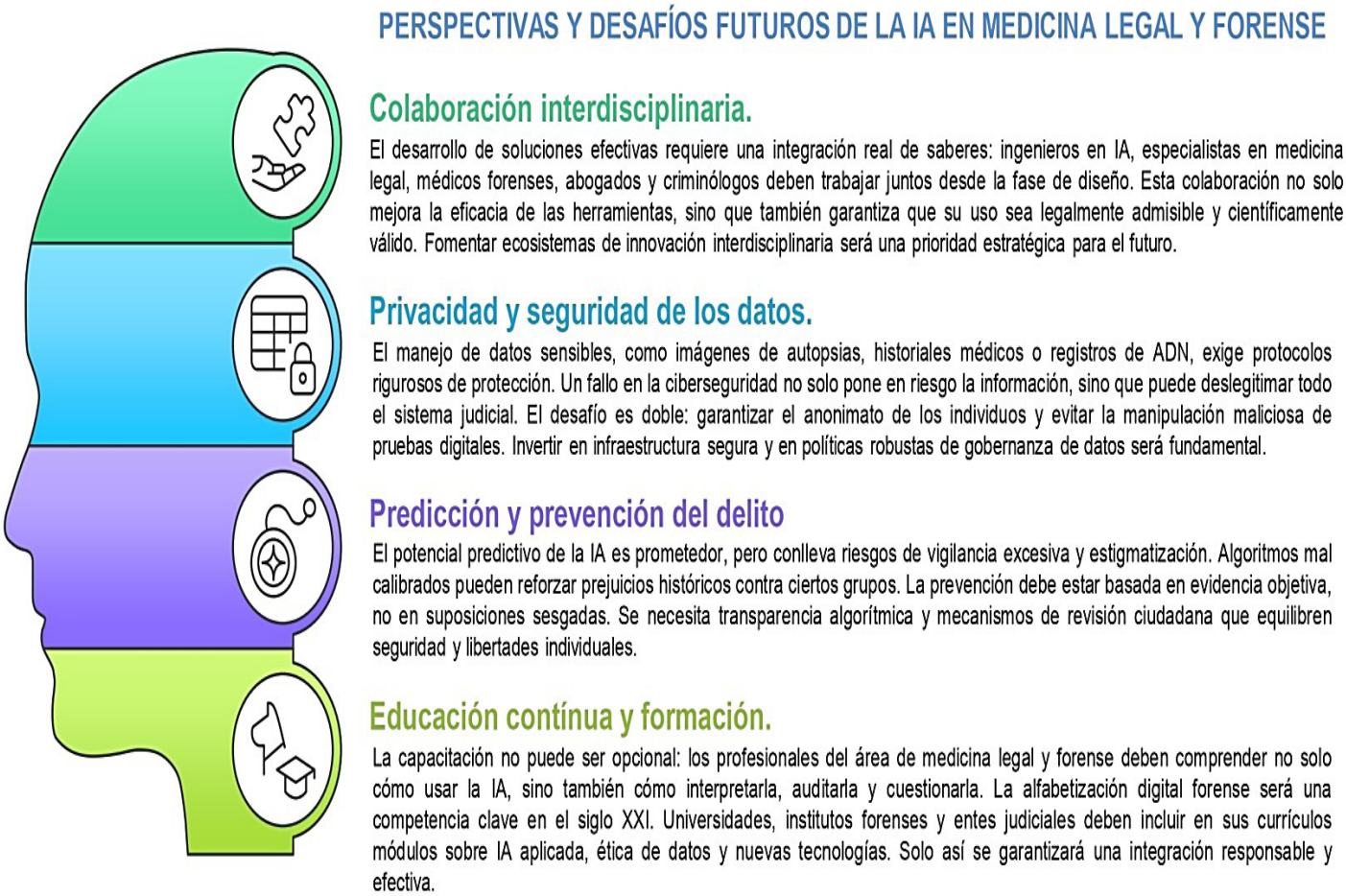
The increasing use of AI in forensic medicine raises profound dilemmas about fairness, transparency, and accountability. Who is responsible if an algorithm makes a mistake? Automation does not absolve human operators of responsibility.

Ethical frameworks must be built to regulate the design, implementation, and interpretation of AI results under principles of fairness, non-discrimination, and respect for human rights. Human oversight will continue to be indispensable (figure 2).

**Applications in Bolivia**

The use of AI in forensics and forensic medicine is in its infancy but shows promising advances. The JL-IDIF system, developed by the Institute of Forensic Investigations (IDIF), uses AI to standardize and make transparent procedures in evidence analysis and will be recognized with the National Award for Technological Innovation in 2023.[19]

However, lacking technological infrastructure and specialized training limits its large-scale adoption.




**Source:** Adapted from Singh et al.[35]

**Figure 2.** Future Perspectives and Challenges of AI in Forensic Medicine

**Tabla 1. Aplicación de la Inteligencia Artificial en Medicina Legal y Forense**

| Author(s) | Target | Modality | Algorithm Architecture | Results | Limitations |
|---|---|---|---|---|---|
| Atas I, Ozdemir C, Atas M, Dogan Y. [26] | | Experimental study | Modified artificial neural network (ANN) based on InceptionV3 (DXAGE) | MAE: 3,13 years; RMSE: 4,77 years; $R^2$: 87 %. | Limited sample size; need for external validation. |
| Fan *et al.*[27] | Develop an automated approach to forensic age estimation using dental panoramic radiograph images. | Experimental study | Personalised convolutional neural network (DENT-net) | High identification accuracy; improved process efficiency. | Requires high quality images; sensitivity to image variations. |
| Yu *et al.*[28] | Automate human identification using dental radiographs. | Experimental study | Convolutional neural network (CNN) based on RetinaNet with ResNet-101 | Significant improvement in speed and accuracy of diatom detection. | Need large datasets for training; possible over-fitting. |
| Wilder-Smith AJ *et al.*[29] | Automate the search for diatoms in electron microscopy images. | Experimental study | Hybrid CNN (HNNN) and U-Net | High segmentation accuracy; improved spill detection. | Requires high resolution images; sensitivity to image artefacts. |
| Kahaki *et al.* [30] | Locate and segment pericardial effusions in CT scans. | Experimental study | Deep CNN (DCNN) with convolution, normalisation and softmax layers | The results of the analysis suggest that the method can classify images with high performance, which enabled automated age estimation with high accuracy. | Need for diverse datasets; possible bias in classification. |
| Kim, Young Hyun *et al.*[31] | Assess age using global fuzzy segmentation and local feature extraction. | Experimental study | Fully automated CNN | High accuracy in identification; reduced analysis time. | Dependence on image quality and consistency; need for external validation. |
| Franco, Ademir *et al.* [32] | Automated human identification method based on dental panoramic radiographs. | Experimental study | Customised CNN | Significant accuracy in sex determination; improved objectivity of analysis. | Need for balanced datasets; sensitivity to anatomical variations. |
| Gómez, Ó., Mesejo, P., Ibáñez, Ó. *et al.*[33] | Evaluate the diagnostic performance of CNN for dental sexual dimorphism. | Experimental study | Personalised CNN | Improved accuracy of radiographic comparison; reduced analysis time. | Requires high quality images; need for validation in different forensic scenarios. |
| Kondou H *et al.*[34] | Evaluate AI for comparative radiography. | Experimental study | Deep neural network | Accuracy of age estimation; improved objectivity of analysis. | Dependence on image quality; need for external validation. |
| Apasrawirote *et al.*[36] | Age estimation of cadavers using CT images of vertebrae. | Experimental study | Convolutional neural networks (CNN): ResNet-101, DenseNet161, VGG19_bn and AlexNet. AlexNet was the most effective model for its balance between accuracy and speed. Integration with YOLO for automatic detection of the | High accuracy in identification with controlled data. A functional web application ('thefly.ai') was created for practical and mobile identification. | Only trained on 4 common species. Requires highly standardised images. Possible errors in morphologically similar species. |

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| | | | | | |
|---|---|---|---|---|---|
| Falissard L, *et al.*[37] | Automate identification of key fly larvae species for estimating post-mortem interval in forensic investigations. | Retrospective study | Deep neural network: structured text processing (ICD-10), socio-demographic variables and causal chain, entered as tensors and processed with convolutional and softmax networks. Implemented in TensorFlow. | Accuracy of 97,8 %, compared to 74,5 % for IRIS software. Demonstrated robustness for multiple pathologies and improved international harmonisation of data. | Less effective in rare causes. Difficulty of clinical interpretation. Requires large volumes of labelled data. Limited validation outside France. |

## CONCLUSIONS

The emergence of artificial intelligence (AI) has transformed multiple areas of medicine, and its incursion into forensic medicine marks the beginning of a new era in forensic practice. This review has shown that, although technological advances have demonstrated outstanding potential, there are still significant limitations related to data quality, the need for external validation, and the availability of adequate technological infrastructure. In Bolivia, initiatives such as the JL-IDIF project or the experimental implementation of generative AI models show initial interest and capacity to explore these emerging technologies. Despite these challenges, the future of AI in forensics and forensic medicine is hopeful. As more robust and ethically responsible algorithms are developed and clinical and forensic datasets expand, it will be possible to improve forensic analysis's accuracy, efficiency, and reproducibility. AI should not be seen as a substitute for human judgment but as a powerful tool that empowers experts, allowing them to focus on critical interpretation and decision-making. The synergy between AI and forensic science has the potential to redefine the standards of medico-legal practice, promoting more agile, objective, and evidence-based justice, particularly in contexts where resources are limited but commitment to progress is strong.

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