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Artificial intelligence and future perspectives in Forensic Medicine: a systematic review

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Abstract

Objective. Artificial intelligence (AI) is the ability of a computer machine to display human capabilities such as reasoning, learning, planning, and creativity. Such processing technology receives the data (already prepared or collected), processes them, using models and algorithms, and answers questions about forecasting and decision-making. AI systems are also able to adapt their behavior by analyzing the effects of previous actions and working then autonomously. Artificial intelligence is already present in our lives, even if it often goes unnoticed (shopping networked, home automation, vehicles). Even in the medical field, artificial intelligence can be used to analyze large amounts of medical data and discover matches and patterns to improve diagnosis and prevention. In forensic medicine, the applications of AI are numerous and are becoming more and more valuable.

Method. A systematic review was conducted, selecting the articles in one of the most widely used electronic databases (PubMed). The research was conducted using the keywords "AI forensic" and "machine learning forensic". The research process included about 2000 Articles published from 1990 to the present.

Results. We have focused on the most common fields of use and have been then 6 macro-topics were identified and analyzed. Specifically, articles were analyzed concerning the application of AI in forensic pathology (main area), toxicology, radiology, Personal identification, forensic anthropology, and forensic psychiatry.

Conclusion. The aim of the study is to evaluate the current applications of AI in forensic medicine for each field of use, trying to grasp future and more usable applications and underline their limitations.
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Keywords: *Artificial Intelligence, Forensic Medicine, Forensic Pathology*

Introduction

The term Artificial Intelligence (AI) was coined by John McCarthy in 1956 during a conference held on this topic. However, the possibility that machines are capable of simulating human thought was raised earlier by Alan Turing who in 1950 published in Mind magazine the article Computing machinery and intelligence developing the Turing test to differentiate humans from machines (1). Historically we began to talk about Artificial Intelligence (AI) at the beginning of the 20th century second half. The first to talk about it was John McCarthy, but also Alan Turing in the same years had also hypothesized that a thinking machine could be able to reproduce the reasoning of the "human-machine". Turing published the article Computer machines and intelligence in the magazine Mind and proposed the test that bears his name, useful in distinguishing between the two thoughts, the artificial one and the real one.

From that moment on, the AI calculation force has changed and increased, reaching the point of carrying out very difficult tasks even in negligible periods of time and reaching a computational finesse capable of immediately processing new information on the basis of data already evaluated in another moment. In recent years, AI has become the hottest technology of the moment, able to penetrate virtually every field, from internet applications to business applications, from perceptual AI to autonomous AI. In fact, today artificial intelligence is integrated into our daily life in many forms, such as personal assistants (Siri, Alexa, home automation etc..). Lately, artificial intelligence has also begun to be used as an aid in the most diverse areas of medicine(2). Furthermore, artificial intelligence is increasingly present also in every field of medicine. There are two fields of artificial intelligence in medicine. The first field is the most useful for managing health programs. The second one is represented by machines, sometimes even anthropomorphic, which serve both for patient assistance and also for surgical aid (Da Vinci Robot) (3).

Also, in the field of forensic medicine this skill has been applied in various sectors. Artificial intelligence is the ability of a computing machine to display human capabilities such as reasoning, learning, planning and creativity. This information processing technology receives the data (already prepared or collected), processes them, using models and algorithms, and answers the questions posed to it on forecasting and decision-making processes (4). AI systems are also capable of adapting their behavior by analyzing the effects of previous actions and then working autonomously.

In recent years, numerous studies have also been conducted in the forensic field based on artificial intelligence

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and on the possibility that the latter can solve and overcome the limits of human subjective prejudice of the traditional approach of forensic science. Artificial intelligence could therefore help improve the performance of human experts in various fields of investigation, such as, for example, sex estimation, age assessment, characterization of bite marks, post-mortem interval estimation, measures for comparative analyzes of living organisms, the study of the growth of dental elements in forensic dentistry and much more (5).

The aim of this study is to evaluate the actual methods of use in forensic medicine for each field of use, to investigate potential benefits, trying to grasp the future and more usable applications, and underlining their limits.

Despite the numerous and useful applications of AI in medicine and forensic medicine, we recall also that the ethical problem of the indiscriminate and uncontrolled use of artificial intelligence remains. In fact, scientific personalities among the most qualified have also expressed themselves negatively on the use of AI; This technology has also been described negatively by Stephen Hawking who in 2015 expressed some reservations about the influence that AI could have on the world economy. The physicist has even expressed his fear of a replacement of the humans by this technology.

Materials and Methods

For the study presented in this document we used the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. All studies published between 1990 and 2023 on artificial intelligence applied to forensic medicine were included. The following search terms were used: («AI forensic») AND («machine learning forensic»), in a single scientific database (PubMed).

PRISMA chart

This study did not include documents that analyzed the possible medicolegal uses of artificial intelligence on animals and did not include variables not compared to human skills, data not arising from AI technique and not following guidelines or regulations. At last, 100 studies were included in this review (refer to Fig.1).

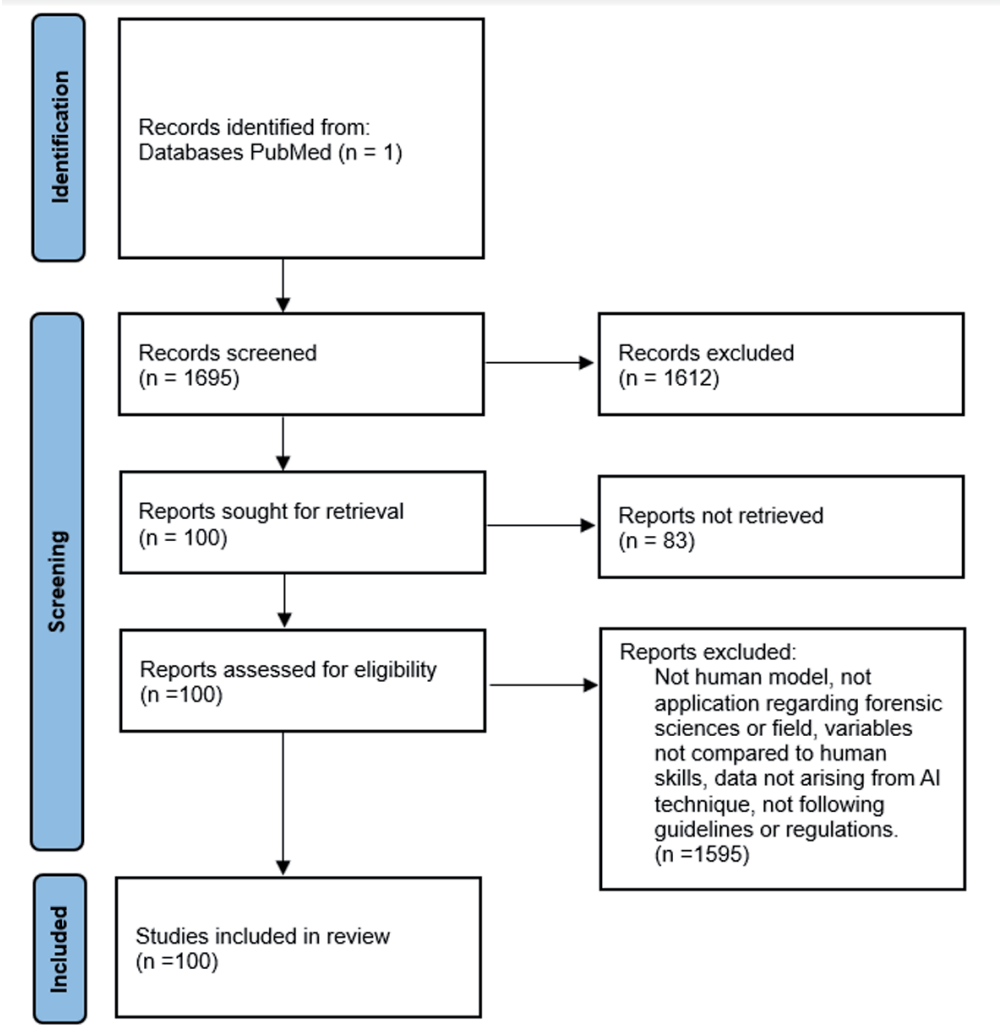

Fig. 1. Prisma Chart

7 fields of interest were identified and analyzed: forensic pathology, forensic radiology, personal identification, forensic psychiatry, anthropology, forensic toxicology and ethics.

Results

The search yielded 100 full text articles which were screened for inclusion in this review. The following discussions provide a more complete description of the top 7 fields of application of artificial intelligence in forensic science. In order of percentage of cases we find forensic pathology, forensic radiology, personal identification, forensic psychiatry, anthropology, forensic toxicology and ethics. 30 articles on forensic pathology, 20 on forensic radiology, 12 on personal identification, 10 on ethics, 8 on anthropology, 7 on forensic psychiatry and 5 on forensic toxicology were identified (refer to Fig.2).

Forensic Pathology

Artificial intelligence techniques have shown potential in several areas of forensic pathology, especially in: forensic microbiology; drowning cases and autopsy investigations in general. In particular, *He et al.* summarized the actual knowledge of microbial metagenomics and the different ways of using artificial intelligence in forensic microbiology, whose use is currently included in post-mortem interval (PMI) estimation, personal identification, geolocation and tissue/fluid identification (6). In detail, next-generation sequencing (NGS) is able to rapidly and accurately analyze the entire microbial community and to generate a huge amount of data on the microbiome. Recently, artificial intelligence technologies have opened new perspectives in the field of forensics through the possibility of analyzing big data and the creation of new prediction models that have facilitated specialists to improve their knowledge of microbial communities through the analysis of post-mortem changes of microorganisms in different organs/tissues at various taxonomic levels (7). Sharma et al. then focused on the use of Machine Learning in this area of forensic pathology. Various types of machine learning have proven to be thorough and reliable and can outperform researcher misjudgments. Anyway, this research is restricted and conducted primarily on targeted human groups. Further research would be useful to better understand the real impact of Machine Learning. (8). As for the application of artificial intelligence to microbial metagenomics in personal identification, numerous studies have been published in this regard and analyzed by He and co-workers, who went on to explain how everyone carries a characteristic set of micro-organisms and could therefore be identified through microbiome analysis. The study of environmental metagenomics also introduces a potential for new applications in forensics, namely geographical identification. The use of artificial intelligence algorithms and machine learning techniques has made it possible to identify the geographical origin of microbiome samples. In the field of drowning, on the other hand, artificial intelligence techniques have mainly been used for the analysis of diatoms. Automatic diatom testing with artificial intelligence is a technological innovation in drowning diagnosis that is based on the morphological characteristics of diatoms

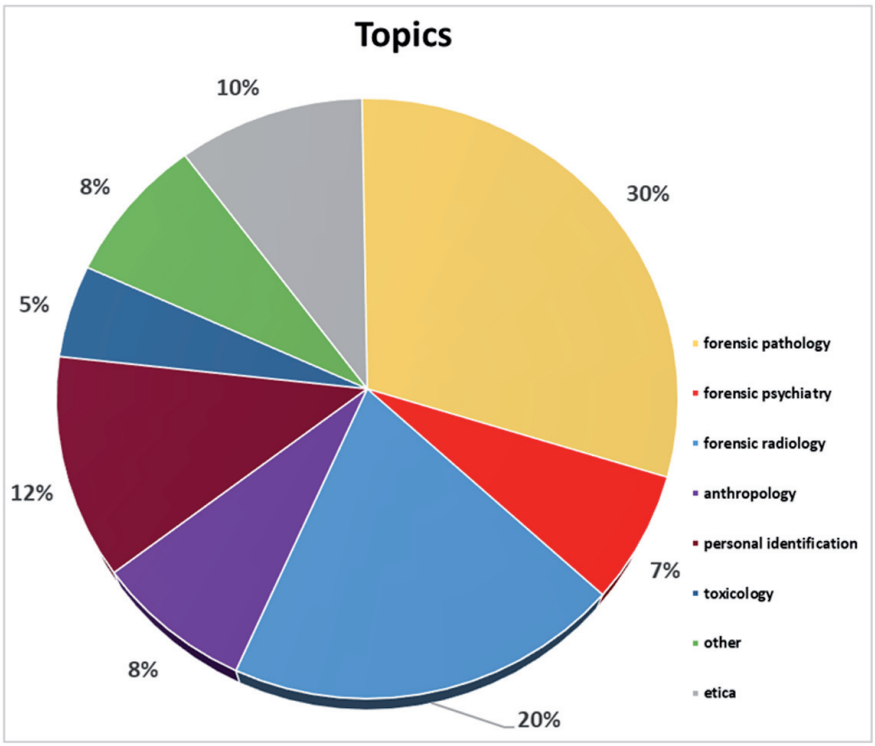

Fig. 2. Topics

and the application of the AI algorithm for the automatic identification and classification of diatoms in tissues and organs (9). Yu and co-workers in their study paid particular attention to a long-standing problem with performing such an examination that involves a large number of laborious and repetitive observations which must be physically performed by forensic pathologists. It is therefore of particular interest for academic research to explore the ability to automatically detect diatoms and/or recognize diatom genera. To this end, a solution based on the application of artificial intelligence is proposed in the aforementioned study, based on deep learning mechanisms (10). Zhou et al also carried out a study in which convolutional neural network (CNN) models were trained on thousands of tiles from full-sheet digital images of diatom smears. The CNN model showed superior performance to human experts (11). Furthermore, there are databases of diatoms that resume their seasonal cycle in waterways; these are very useful for confirming the origin of a drowning body, especially when the actual site where the drowning occurred is unknown. A simple, fast, and economical system was proposed by *Zhang et al*. and is based on a deep learning algorithm that manages to analyze diatom populations in a quantitative and qualitative way. This technology has given more reliable results than traditional methods and can therefore help the police in confirming the identity of bodies found in the water. (12-13). Lastly, artificial intelligence has shown considerable potential in the field of autopsy, by using robotic-assisted technology that could improve the quality of autopsy surgery itself, while also reducing the risks of exposure injuries for healthcare workers. Cutting the skull using an oscillating saw always generates noise, fine dust with infectious capabilities, and the possibility of traumatic injury, all of which can pose occupational risks for healthcare workers. Jumlongkul and co-workers carried out a comparative study between the use of a common oscillating saw and a new robotic-assisted surgery system that showed a reduction in noise levels and a limited release of aerosol particles through the use of robotic-assisted technology. Further research could attempt to consider other health problems occurring during autopsy and apply robot-assisted technology to autopsy surgery (14). Furthermore, a forensic medical expert could take advantage of deep learning technologies in the interpretation of gunshot wounds. A study conducted by Oura and co-workers analyzed the ability of AI to correctly estimate the firing distance based on photographs of gunshot wounds. Deep learning showed the ability to calculate shooting distance with an overall accuracy of 98%. Furthermore, some algorithms could also be useful to provide relevant indications on the type of weapon, type of projectile and trajectory of the shot or, in a broader context, for other types of injuries such as blunt weapon injuries or any other injury relevant from the forensic point of view (15).

Forensic Radiology

Artificial intelligence methods can be applied also in forensic radiology (16,17). AI methods are applied to achieve efficient forensic dental identification in large-scale disasters, where the bodies of many victims are severely damaged; in these cases, the dental characteristics generally remain unchanged even after death. Compared to the comparison method based on traditional ante- and post-mortem radiographic data, this process, using specific neural networks (CNN, R-CNN) identifies the subjects in a much shorter time, qualities of fundamental importance in the present cases (18,19,20). Fields of use of AI in forensic dentistry are numerous; These possible applications include skeletal recognition, age estimation, as well as gender determination. Deep CNN was used for age estimation through staging of third molar development corresponding to the Demirjian classification in panoramic radiographs (21-23). Patil et al. (2020) The study by Patil et al. (2020) showed the applicability of ANN for sex determination through the analysis of anthropometric values obtained from mandible and maxilla x-ray. (24). Matsuda et al. (2020) also evaluated the use of CNN for the purposes of personal recognition, comparing approximately sixty x-ray exams (25).

Machine learning methods can also be useful for recognizing specific body components, including blood vessels of different sizes and parenchymatous and hollow organs(26); they can be useful for having 3D images of organs (27) and for digital post-mortem examinations; for identification of bone and joint disorders or pathology(28); for fluids quantification and recognition in body cavities (29); estimation of the size of an organ compared to the size of the body (30).

Therefore, the application of ML also in the forensic field has positive implications, firstly for temporal efficiency, using transfer learning; secondly, by combining multiple MLs with multi-stage computational systems that increase accuracy; and finally, the use of an active learning precedence, through which the human workload can be alleviated.

Personal Identification

Artificial Intelligence finds a wide field of use in image processing and recognition in sex determination, age, cephalometric landmarks, orthopantomography (OPG) (31), gut microbiome (32), and DNA. AI easily manages to automate processes, overcomes human limitations and is able to use facial recognition as a new fingerprint (33). CNNs (Convolutional Neural Networks) are an optimized deep learning architecture designed specifically for computer vision, which is that branch of AI that focuses on teaching computers to see and then recognize what is subjected to its observation. Numerous studies in this area have set out to bridge the interdisciplinary gap between forensic specialists and deep learning computer engineers, enabling the activation of clinical forensic experts with a basic knowledge of advanced AI techniques and interest in its implementation to further advance research in that field of interest (34). CNN models can make use of data obtained through computed tomography (CT) scans, through specific searches for specific landmarks, through which information about sex and age estimation can be obtained to determine the identity of human remains or recognition through imaging, growth vector prediction or facial soft tissue estimation for 3D reconstruction (35). Some studies have focused on biometrics. Biometrics is the field of study that uses a person's physical characteristics to verify his or her identity. Recent advances in deep learning have enabled the field of biometrics to make major leaps, allowing AI to verify, through it, the identity of any human being

with better performance than humans. In situations where many features can be collected and combined, accuracy will be virtually perfect. In fact, it can be predicted that in the coming years the use of Smart biometrics for investigation and forensics will enable a great many cases to be solved and reduce the crime rate. In addition, another area of growing interest of AI related to human identification concerns forensic genetics, as it is estimated that such support will be able to assist, thanks to standardized multiracial databases, in the recognition of unknown samples following disasters and mass accidents through even genetic sequences such as mitochondrial DNA (36).

On the other hand, the need was noted for further review of automated processes, more quality control to standardize results, and more attention to risks of manipulation, such as the generation of Deepfakes (37): digitally altered or synthetically created facial media content via deep learning neural networks such as the Generative Adversarial Network (Gan, consisting of a pair of "adversarial" deep learning neural networks, forger vs. investigator), which can lead to identity swapping with all that it entails. Such risks should by no means be underestimated and should be countered by information and training of personnel assigned to use such technologies.

Forensic Psychiatry

Artificial intelligence technologies were used to estimate the capacity to 'predict' self-harm behavior in cases of psychiatric pathologies. a specific database based on a methodology called Leave-One-Subject-Out was used. The outcomes revealed high accuracy, sensitivity and specificity. Different artificial intelligence techniques were mixed, and the union of the results showed a great potential to enhance the quality of assistance and care of people with this kind of behavior. The techniques used until now were based on the analysis of the facts once they had already manifested themselves. This new technique, however, seems to make it possible to analyze and monitor subjects suffering from psychiatric pathologies with self-harming acts and therefore be able to act preventively. (38). This technique could be called "AI neuroprediction" and involves the identification of potential neurocognitive markers for the prediction of recidivism in the event of violence, in order to prevent crime and to allow for the activation of early intervention (39).

People with disabilities compose a sizable population according to WHO estimates (40) and AI has also been used to improve and speed up accessibility to the assessment and certification of disability for psychiatric patients, reducing the management difficulties for assessment visits, by-passing the unavailability of experts in the area.

Another use of AI is in the study of child sexual abuse (CSA). Considering the damage that child sexual abuse creates on mental and physical health of individuals (41), it is crucial not only avoid these types of crimes but also effectively examine alleged cases. Nevertheless, the victim's testimony is frequently the sole proof available making investigative interviews central (42). That's why Powell's team proposed a device based on digital avatars with the aim of training interviewers to conduct such interrogations in the best possible way (43).

Recently has been studied the efficacy of complete training programs involving virtual interviews based on the use of avatars, and lately, were assessed even the impact of extended training. This strand of studies has also been further explored by Baugerud and his group (44-47). Finally, there are facial emotion recognition systems (FERD screener) capable of discriminating the apparently apathetic expression of schizophrenic patients from that of subjects erroneously believed to be such (48).

Forensic Anthropology

The aim of forensic anthropology is to reconstruct the biological profile of an individual, starting from the analysis of bone remains of unclear origin. Artificial intelligence has therefore been applied to anthropology for the estimation of ancestry, for the recognition of sex, the estimation of the age of living subjects or human remains (49). AI has also been used in forensic odontology to identify bite marks, and sex and age assessment, specifically through the use of convolutional neural networks and artificial neural networks. (50). Some authors used CNNs to determine the gender characteristics of craniums and tested more than 100 skulls; only 5 skulls were misclassified for sex (51).

Pelvic X-rays have been used to create an AI-based model capable of estimating bone age for forensic purposes (52). Compared to another pre-existing model, the authors noted that their model, based on convolutional neural networks, performed better but was also less precise. The studies have reported that their models show results comparable in accuracy and precision to those achieved by well-trained human examiners. These models seem to hold promise for the identification of fatalities in large-scale catastrophes and for further support in forensic settings (53).

Furthermore, ancestor profiling has proven to be of considerable importance for criminal investigations and thus in forensic medicine. Identifying offenders or victims of unsolved crimes through genetic testing may be hindered by the scarcity of investigative clues, the consequent lack of reference profiles of the perpetrator. In this situation, is required additional genetic information, like biogeographic ancestry (BGA), which provided the evidence samples at the crime scene (54). AI models that could both foresee and deduce the biogeographic ancestry of unknown subjects have been developed and evaluated.

However, while Alladio et al.'s analysis allows an individual to be assigned to his or her source population through an easily understandable method, it doesn't produce meaningful divergences among populations and clearly cannot be utilized on its own in a medical legal setting. Many study results showed accurate, standardized, and fast readings. On the other hand, the AI was unable to identify anomalies or previous traumas, which are instead identified with precision by the human operator.

Forensic Toxicology

The aim of toxicology is to investigate the consequences of exogenous chemical compounds on humans and animals. It is therefore clear that toxicological studies applied to fo-

rensic medicine are very important for the purposes of civil and criminal proceedings (55).

Several methods are available for the chemical analysis of various biological samples for forensic toxicology analysis. These techniques also include spectrometry and chromatography, etc. (56). Even considering that the technologies are very accurate, simple human mistake can lead to incorrect analysis of the sample; these methods need expert personnel for a correct analysis. Artificial intelligence therefore comes to our aid. Intelligent technology must be equipped with algorithms that can study the sample using less analysis time and giving us more accurate results (57-59).

AI in toxicology improves the reliability and speed of testing. It is also useful for identifying new psychoactive substances and understanding the functioning of molecules that can also be used as new treatments. The limits are represented by the costs and the paucity of data currently available. A further limit is the legal value of the data analyzed and reported by the AI. Precisely in this context, the review of a human expert is necessary, who can define and more appropriately attribute the data analyzed to the specific case.

Ethics

Artificial intelligence seems ideally suited to certain applications where it could overcome the limits based on human judgment precisely because it is not hindered by them. Indeed, AI has been used to mitigate human biases by replacing them with unadulterated predictions based only on data. Caution is needed, however: Can an algorithm-driven technology behave ethically? Can it consider external implications such as social, economic, and political systems? The results of the studies are still unclear, and the scientific debate is heated, also full of more or less realistic fears for the human society of the future.

Other

On the other hand, this macro-area includes those fields of application of AI to forensic medicine that present a smaller number of scientific publications in the sector. For example, entomology and assessment of biological damage are included in this area, topics certainly of proven interest but still in a nutshell with respect to the application of AI.

We wanted to summarize in a table (Table 1) the general characteristics of some of the studies included in our research, in different numbers for each branch of application of AI to forensic medicine and in proportion to the percentage of application. The data extracted from the articles refers to the area of application, year of publication, authors, type of study and highlights.

Discussion

In this review it was possible to underline how artificial intelligence is currently an effective and applicable strategy also in the field of forensic sciences, with obvious future advantages. AI is used above all to improve and simplify technical aspects that until now have been exclusively of human relevance, with the limits and the possibility of error that this naturally entails.

In particular, the overall data collected on the subjects investigated (forensic pathology, forensic radiology, personal identification, forensic psychiatry, anthropology, toxicology, and ethics) represent the fields in which artificial intelligence techniques are most used in the medico-legal field. Despite the undoubted increase in data evaluation speed, many doubts remain regarding the future applications of AI in forensic science: indeed it is not possible to fully explain the real procedures that are involved in that process and convert initial data into results you can rely on. In addition, these models must be programmed using a huge amount of previously collected data for effective performance. Many studies on the utility of AI, including those analyzed within this review, have shown promising and encouraging results for multiple and disparate new developments; however, it's clear that AI, despite being a useful aid tool for researchers, cannot yet be fully integrated or replaceable with conventional methods of clinical and forensic practice, both due to the physiological limits of a branch still at the dawn of its possibilities, and due to the social and ethical evaluations that this technology inevitably brings with it. In addition, other limits are represented by the high costs and the social non-acceptance of non-human evaluation.

Lastly, AI was also described negatively by Stephen Hawking who in 2015 expressed some reservations about the influence that AI could have on the world economy. The physicist has even expressed his fear of a replacement of the human race by this technology. (58,59). Therefore, along with multiple and undisputed advantages, there are still many aspects to be clarified about AI applied to forensic medicine.

Limitations

Our initial research was conducted solely based on the title and abstract of the analyzed documents. It is, therefore, necessary to consider the hypothesis that articles analyzing AI methodologies applied to forensic sciences may have been unintentionally omitted, as they were present only in the body of the text and not in the title and abstract. Another limitation of the study is the actual applicability of AI in forensic sciences, especially in Italy, where it is still underutilized. When used, there is often a lack of ability to explain the underlying processes of the computational analyses performed by AI. Lastly, it is worth noting that the sample size in our study is not extensive, possibly due to the limited practical applicability of this technology in the forensic field. In conclusion, the primary limitation of our study appears to be the inability to guarantee the desired completeness of the research, partly due to the reliance on a single search engine. Furthermore, it should be noted that the research was conducted solely on articles published in the English language.

Author Contributions: LD and GV contributed to study design and search strategy development, ran the searches, managed the screening and inclusion process; FS screened articles for inclusion, extracted data, analysed and interpre-

Table 1. Characteristics of the included studies

Topics	Year	Title	Authors	Study design	Highlights
Forensic pathology	2022	Application of artificial intelligence and machine learning technology for the prediction of postmortem interval: A systematic review of preclinical and clinical studies	Sharma R, Diksha, Bhute AR, Bastia BK	systematic review	Application of AI for prediction of post-portem interval
	2019	Digital whole-slide image analysis for automated diatom test in forensic cases of drowning using a convolutional neural network algorithm	Zhou Y, Zhang J, Huang J, Deng K, Zhang J, Qin Z, Wang Z, Zhang X, Tuo Y, Chen L, Chen Y, Huang P	pilot study	Use of CNN and machine learning to study diatoms, reducing long human times
	2022	An improved automated diatom detection method based on YOLOv5 framework and its preliminary study for taxonomy recognition in the forensic diatom test	Yu W, Xiang Q, Hu Y, Du Y, Kang X, Zheng D, Shi H, Xu Q, Li Z, Niu Y, Liu C, Zhao J	preliminary study	AI based on the YOLOv5 framework for the automatic detection and recognition of the diatom genera
	2021	Robotic-Assisted Surgery for Cadaveric Skull Opening: A New Method of Autopsy Procedure	Jumlongkul A, Chutivongse P	experimental study	Use of robotic-assisted technology that could improve the quality of autopsy surgery
	2021	Deep learning in forensic gunshot wound interpretation-a proof-of-concept study	Oura P, Junno A, Junno JA	proof-of-concept study	Deep learning to calculate type of weapon, projectile, trajectory, shooting distance in firearm injury
Forensic radiology	2020	Optimization technique combined with deep learning method for teeth recognition in dental panoramic radiographs	Mahdi FP, Motoki K, Kobashi S	Research articles	Machine learning to compare ante and post-mortem radiographic data for dental identification in large-scale disasters
	2016	Machine learning based analytics of micro-MRI trabecular bone microarchitecture and texture in Type 1 Gaucher disease	Sharma G.B., Robertson D.D., Laney D.A., Gambello M.J., Terk M.	control study	Digital post-mortem examination to identify patologies
Personal identification	2022	Machine Learning Techniques for Human Age and Gender Identification Based on Teeth X-Ray Images	Santosh KC, Pradeep N, Goel V, Ranjan R, Pandey E, Shukla PK, Nuagah SJ	experimental study	Artificial Intelligence to determinate human age and gender identification and other human characteristics
	2022	Use of deep learning in forensic sex estimation of virtual pelvic models from the Han population.	Cao Y, Ma Y, Yang X, Xiong J, Wang Y, Zhang J, Qin Z, Chen Y, Vieira DN, Chen F, Zhang J, Huang P	retrospective study	Use of deep learning to trace human sex from pelvic bones.
	2022	The application of machine learning to predict genetic relatedness using human mtDNA hypervariable region I sequences	Govender P, Fashoto SG, Maharaj L, Adeleke MA, Mbunge E, Olamijuwon J, Akinnuwesi B, Okpeku M	Research, supported study	Interest of AI related to human identification in mass disaster
Forensic Psychiatry	2022	A Machine Learning Approach for Predicting Non-Suicidal Self-Injury in Young Adults. Sensors (Basel)	Marti-Puig P, Capra C, Vega D, Llunas L, Solé-Casals J	experimental study	"AI neuroprediction" to predict self-harm behavior in cases of psychiatric pathologies
	2019	Long-term outcomes of childhood sexual abuse: an umbrella review	Hailes H. P., Yu R., Danese A., Fazel S.	ambrella review	Use of AI is in the study of child sexual abuse, using digital avatars

(table follows)

	2020	Sensitivity and specificity of a facial emotion recognition test in classifying patients with schizophrenia.	Lee SC, Liu CC, Kuo CJ, Hsueh IP, Hsieh CL	research supported study	Use of facial recognition systems (FERD screener) for schizophrenic patient identity
Forensic Anthropology	2019	Forensic age estimation for pelvic X-ray images using deep learning	Li Y, Huang Z, Dong X, Liang W, Xue H, Zhang L, Zhang Y, Deng Z	retrospective study	AI-based model capable of estimating bone age for forensic purposes
	2022	Multivariate statistical approach and machine learning for the evaluation of biogeographical ancestry inference in the forensic field	Alladio E, Poggiali B, Cosenza G, Pilli E	proof-of-concept study	AI models that could both foresee and deduce the biogeographic ancestry of unknown subjects have been developed and evaluated.
Forensic Toxicology	2000	Knowledge discovery and data mining in toxicology	Helma C, Gottmann E, Kramer S	survey	use of AI for the chemical analysis of biological samples in less time and more accurately
	2022	Artificial Intelligence in Forensic Medicine and Toxicology: The Future of Forensic Medicine	Wankhade TD, Ingale SW, Mohite PM, Bankar NJ	review	

ted data and co-led manuscript drafting; MO ran updated searches, screened articles for inclusion and extracted data; MZ contributed to study design and search strategy development, for inclusion and contributed to manuscript drafts; RLR provided technical guidance and supervised work; MA screened articles for inclusion, extracted data, assisted with analysis and contributed to manuscript drafts; FS,and LD and MO screened articles for inclusion and contributed to manuscript drafts; GV and RLR screened articles for inclusion, supervised work and contributed to manuscript drafts. All authors read and approved the final manuscript.

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