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A review of the artificial intelligence application as a guideline tool for the wound management

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Abstract. *The global interest and substantial challenges on this subject contribute to its relevance. This analysis centers on the implementation of artificial intelligence within the medical field, with a specific focus on its application in managing wounds. Through an examination of numerous online studies and publications, we can gain insight into how artificial intelligence is being employed to enhance the diagnosis, treatment, and monitoring of wound healing. The integration of artificial intelligence in this sector has the capacity to transform medical practice by improving precision, effectiveness, and individualized patient care. As a result, it is a leading area of research and advancement on a global scale. We used the PubMed and Google Scholar electronic databases of medical publications, searching for abstracts using the following key phrases: artificial intelligence and wound management, artificial intelligence and gunshot wounds, artificial intelligence and war medicine, artificial intelligence and surgery. Based on search results, a literature analysis was performed.* ***Conclusions.*** *It is necessary to create numerous working groups of highly qualified specialists from each discipline and direction of medical activity, where the specific weight of each symptom, laboratory indicator, each radiological and ultrasound examination result is determined based on the data of real cases. And such work should have no less discipline and structure than medical research, it is optimal to get a universal software tool for this stage of work, which can be used with certain variations for the whole variety of pathological conditions and processes.*
Keywords: *artificial intelligence; wound care; machine learning; neural network; personalized diagnosis; FAIT*

Introduction

The purpose of this study is to review publications on the use of artificial intelligence (AI) in medical practice. As an example, publications were selected that considered the use of AI in the diagnosis, prevention, and treatment of wound processes of various etiologies [1].

AI is considered as an effective and promising tool in various fields of medicine, including high medical education and routine clinical setting to help students and then medical doctors in data analysis and support decision for management of the patients [2, 3]. Other possible applications for AI might be considered in various fields of biomedicine as well

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as for the management of severe trauma, including injuries by high-energy weapon and wound treatment after such an injury and in conditions of limited medical resources [2, 4–6]. The ongoing war in Ukraine showed various aspects of severe gunshot injuries because of previously unknown course of wounds due to ballistic missiles, drones, etc., which is frequently used by russians [7–17]. In such conditions, decision-making process by military medical doctors must be quick and rational; however, in case of massive casualties, combined trauma (e.g., thoracoabdominal gunshot injury), medical doctors might have permanent challenges to apply appropriate care and individualized approach. Another issue to be considered is pathologic changes in the human tissues within the area of gunshot wound and its canal as well as patient outcomes.

Materials and methods

Our focus will be on examining the current techniques and instruments utilized in the field of artificial intelligence, providing a quick explanation and an overview of each. There are two approaches to automatic data sorting: AI and machine learning. Both methods can be very effective in identifying relationships between available information for data classification. Although artificial intelligence and machine learning are often used interchangeably, machine learning is actually a subset of the broader category of artificial intelligence. We used the PubMed and Google Scholar electronic databases of medical publications, searching for abstracts by the following key phrases: artificial intelligence and wound management, artificial intelligence and gunshot wounds, artificial intelligence and war medicine, artificial intelligence and surgery. Based on search results, a literature analysis was performed.

Random forest, a technique for ensemble learning, builds numerous decision trees during the training phase and provides the mode of the classes (for classification) or the mean prediction (for regression) from the individual trees [18]. The random forest algorithm proves to be effective in analyzing intricate datasets for predicting wound healing results. It can be utilized to evaluate various factors, such as patient demographics, wound characteristics, and treatment methods, in order to predict the duration of healing or identify wounds at high risk. For example, a research study could employ random forest to anticipate the probability of wounds getting infected by utilizing historical patient data and wound attributes [18].

Support vector machine, known as SVMs, are models used in supervised learning for both classification and regression tasks. The primary function of SVMs is to locate the optimal hyperplane that effectively distinguishes between classes within the feature space [19]. By utilizing SVMs, it becomes possible to classify wound images and accurately assess the type and severity of the wound. Additionally, SVMs can be employed to identify edges and contours within these images, which is essential for precise measurement and ongoing monitoring. For instance, SVM could be trained on a dataset consisting of labeled wound images representing various stages of healing. Consequently, this trained SVM would then be able to classify new images into their respective healing stages [19].

The statistical model known as **logistic regression** employs a logistic function to create a model for a binary dependent variable [20]. Its purpose is to determine the likelihood that a specific input point belongs to a particular class. By utilizing logistic regression, it becomes possible to estimate the probability of wound healing or infection by considering various predictors, including patient age, wound size, and comorbid conditions. For instance, a logistic regression model could be utilized to forecast the probability of wound healing within a specific timeframe using initial wound assessment data [20].

The **K-nearest neighbors** (KNN) algorithm is a method of learning that operates on instances, with the output being determined by the majority vote of the k nearest training examples in the feature space [21]. This algorithm can be employed to classify wound images by comparing them to a collection of labeled images. Additionally, it has the capability to predict patient outcomes by examining the current patient's data in relation to similar cases stored in the database. For instance, a KNN model may classify a wound by identifying the most comparable cases within a designated training set [21].

FAIT, or information aware deep neural network, is a unique variant of deep learning that prioritizes awareness of the informational content within the data. This emphasis on information awareness enhances both the efficiency and precision of the model [22]. FAIT models excel in processing extensive collections of wound images, extracting significant features, and generating forecasts regarding wound healing stages and treatment outcomes. For instance, by training a FAIT model on a vast dataset of wound images and patient records, it allows for analysis and treatment recommendations, enhancing the accuracy of diagnoses and treatment strategies [22].

Deep neural networks known as **convolutional neural networks (CNNs)** have proven to be incredibly powerful when it comes to analyzing visual imagery [23]. Their effectiveness in tasks, such as image recognition and classification, is unparalleled. In the specific context of wound images, CNNs play a crucial role in their classification and segmentation. By automatically extracting important features like wound size, depth, and color, CNNs enable accurate monitoring of the healing process. For instance, a CNN can categorize wound images into different types (e.g., acute, chronic) or stages of healing, while also providing precise measurements through wound area segmentation [23].

The role of AI in enhancing wound care management

The integration of AI technologies, particularly CNN, is revolutionizing the field of wound care by enhancing the diagnosis of wound types and severities [23]. CNNs, a class of deep learning algorithms, are adept at processing images, making them particularly useful for analyzing wound photographs [24]. By training these models on vast datasets of wound images, AI can learn to recognize patterns and features indicative of different wound types, such as ulcers, surgical wounds, or burns, as well as assess their severity [25]. This capability is crucial for healthcare workers, as accurate diagnosis is the first step towards effective treatment [26].

Moreover, the use of CNNs in wound care represents a significant advancement over traditional methods, which rely heavily on visual inspection and subjective assessment by medical professionals. For example, evaluation of autofluorescence and use of ICG in the near-infrared spectrum are promising tools for visually verifying microcirculation that could potentially be integrated in CNN, leading to better patient outcomes [27–29].

AI models, including the information aware deep neural network (FAIT), are playing a pivotal role in creating personalized wound care plans, marking a significant leap forward in tailored healthcare solutions [24]. FAIT, by leveraging deep learning and information theory, can process a multitude of patient data points, from wound images to historical health records, to generate customized treatment strategies [30]. This approach not only considers the wound's current state but also incorporates patient-specific factors, such as underlying health conditions, previous wound history, and potential for healing, ensuring a holistic approach to wound management [31]. The personalized plans derived from AI models like FAIT can drastically improve patient outcomes by addressing the unique needs of each individual, a significant improvement over the one-size-fits-all approach traditionally used in wound care [25]. This advancement underscores the transformative potential of AI in healthcare, offering more effective, efficient, and patient-centered treatment options [24].

The use of AI technologies, especially forest algorithms and SVM, has proven to be remarkably effective in monitoring wound healing progress and predicting outcomes. These models can analyze time-series data from wound images, patient vitals, and treatment responses to assess healing progress and anticipate potential complications [23]. Forest algorithms, known for their ability to handle complex, nonlinear data, can identify subtle changes in the wound's condition that might indicate improvement or deterioration [32]. Similarly, SVM, with its classification and regression capabilities, can predict the future trajectory of wound healing, enabling healthcare workers to make informed decisions about treatment adjustments [12, 33]. This predictive capacity is invaluable, as it allows for early intervention in cases where the wound is not healing as expected, potentially preventing complications and ensuring timely recovery [34]. The application of forest and SVM in wound management exemplifies the broader trend of AI's transformative impact on medical practice, offering tools for more proactive and precise care [23, 24].

Comparative analysis of the algorithms

Utilizing logic regression in predicting wound infection risks and complications involves harnessing AI to analyze various factors that could influence the healing process. Logic regression, a form of machine learning, excels at identifying relationships between different variables and outcomes, making it an ideal tool in the medical field for predictive analysis. This methodology relies on the creation of logical combinations of binary predictors to model complex interactions that can predict the likelihood of wound infections and complications. By feeding the model with historical patient data, including wound characteristics, patient demographics, and treatment outcomes, healthcare workers can gain insights into the risk factors associated with wound healing. This predictive capability enables a more personalized approach to patient care, allowing for the implementation of preventative measures and tailored treatment plans that can significantly improve patient outcomes [35].

The application of KNN in identifying effective treatment methodologies based on historical data demonstrates the power of AI in leveraging past patient outcomes to inform current treatment strategies. KNN works by identifying the "nearest" data points in a dataset based on similarity measures, which in the context of wound care could include variables, such as wound type, size, location, and patient health status. The model then analyzes the treatment outcomes of these similar historical cases to predict the most effective treatment for a new patient with comparable characteristics. This approach not only streamlines the decision-making process for healthcare professionals but also enhances the accuracy of treatment predictions, ultimately leading to better patient care and recovery rates. The simplicity and flexibility of KNN make it particularly appealing for use in medical applications where treatment decisions need to be made quickly and efficiently based on a wide range of factors [33].

Deep learning models like CNN are increasingly being trained on vast datasets to refine treatment strategies over time, demonstrating the advancements in AI's role in medical treatment optimization. CNNs, a class of deep neural networks, are especially adept at processing and analyzing visual data, such as medical images of wounds. By training these models on extensive collections of wound images, annotated with information regarding wound type, treatment applied, and healing outcomes, CNNs can learn to identify subtle patterns and indicators that may not be apparent to human observers. This capability allows for the enhanced assessment of wound states and the prediction of the most effective treatment methods, taking into account the complexities and nuances of each individual case. Furthermore, as more data is collected and fed into these models, their accuracy and predictive power continue to improve, offering the potential for even more personalized and effective treatment strategies over time [2].

Challenges and future directions in AI-driven wound care

The integration of AI into medical practice, particularly in wound care, necessitates a shift towards more transparent AI models. Transparency in AI models is crucial, as it not only builds trust among healthcare professionals but also provides a deeper understanding of how AI decisions are made, which is essential for clinical acceptance and application [23]. Traditional machine learning models, such as SVM and KNN, are appreciated for their simplicity and interpretability [36]. However, as the complexity of models increases with advancements like convolutional neural networks and information aware deep neural networks (FAIT), the need for transparency becomes more pronounced. Ensuring that these advanced models can be scrutinized and validated by practitioners is vital for their responsible deployment in medical settings.

Transparent AI models would allow healthcare professionals:

— to understand the rationale behind AI-driven recommendations;

— assess the reliability of AI-generated diagnoses;

— enhance patient care by integrating AI insights with clinical expertise.

The development of sophisticated AI models, such as the FAIT for wound care, underscores the importance of interdisciplinary collaboration. Integrating clinical expertise into the development process of AI models is paramount to ensure their effectiveness and applicability in real-world medical settings [24]. The invaluable insights and practical knowledge held by clinical professionals can play a crucial role in refining AI algorithms, ensuring they are better equipped to understand the intricacies of medical diagnosis and treatment. For instance, by working closely with clinicians, AI developers can incorporate feedback on the FAIT model's performance in identifying and assessing wound characteristics, leading to enhanced predictive accuracy and treatment personalization.

Such collaboration facilitates:

— the alignment of AI model objectives with clinical realities;

— the fine-tuning of AI algorithms based on direct clinical feedback;

— the bridging of the gap between technological innovation and practical medical application.

AI's role in predictive analytics and personalized treatment for wound care presents a promising avenue for future research and development [25]. The potential of AI to analyze vast datasets and identify patterns undetectable by human analysis could revolutionize the approach to wound management. Predictive analytics powered by AI can lead to more accurate forecasts of wound healing trajectories, enabling personalized treatment plans that consider the unique characteristics of each patient's wound. Additionally, the continuous evolution of AI models, through the incorporation of more complex algorithms and diverse datasets, holds the promise of further enhancing the precision of treatment recommendations [1].

It is necessary to develop software and hardware complexes for automatic determination of the wound area, using the principles of old developments and the achievements of modern technologies. This will allow to objectify the wound healing follow-up process and assess the influence of various factors on it. Further algorithmization of ballistic experiment results is very promising but requires digitization using bullet wound examples, and in the future, the study of fragment-induced damage [13, 37].

Key areas for future exploration in AI-driven wound care include:

— developing AI models that can predict wound infection risk and healing time with high accuracy;

— utilizing AI for tailor wound care treatments to the individual's specific physiological and environmental factors;

— improving the interoperability of AI systems for seamless integration with current healthcare IT infrastructure ensuring data analysis in real-time and decision support.

Discussion

As a result of possibly incomplete but representative review, we can say that the given methods are used not to full extent and barely differ from standard methods that are used without artificial intelligence. There are practically no recommendations regarding artificial intelligence training tools in one way or another, how to train artificial intelligence, first of all, to determine the specific weight of each fact. That is, on the one hand, there are no thorough trainings of AI by doctors, and, on the other hand, control of the obtained results and correction as asking questions and submitting material. Secondly, a mechanism for asking questions on behalf of artificial intelligence to researchers or to doctors for clarifying certain nuances of the processes being observed has not been developed, that is, there is no direct dialogue between AI and medical workers to improve accuracy and adequacy of the answer depending on the situation. Intelligence should "doubt", demand clarifications and move away from banal linear logic to ensure that even most difficult cases like fragment injuries from high-energy weapons can be processed by AI [10].

Usually, lack of adequate response can be explained by the fact that medical and technical tasks are created by doctors or people who have a medical education but have zero or insufficient skills in both conventional programming and software architecture, as well as in the concept of artificial intelligence in general, they do not understand all its possibilities — benefits and limitations. They do not have this completeness of data. Developers, having received already formulated medical and technical task, carry it out purely from a formal point of view. Information about the possibilities and features of artificial intelligence, unlike the usual coding, which they possess, they do not convey to doctors and medical workers, moreover, developers, more often than not, act not as co-authors of the creative process, but as ordinary performers.

Conclusions

It is necessary to create numerous working groups of highly qualified specialists from each discipline and direction of medical activity, where the specific weight of each symptom, laboratory indicator, each radiological and ultrasound examination data is determined based on the results of real cases. And such work should have no less discipline and structure than medical research, it is optimal to get a universal software tool for this stage, which can be used with certain variations for the whole variety of pathological conditions and processes.

It is necessary to create a two-stage system of setting tasks. The first stage of setting a medical task is created by medical workers in cooperation with digital specialists for the initial formalization of the request.

At the second stage, a broad working group is established under the leadership of a certified AI specialist. In the process of dialogue, communication with medical workers takes place, the goals and objectives are clarified, and based on the proposed AI tools and methods, correction is made with the possible expansion or detailing of certain data. Only then the work begins with the involvement of the results of the established specific weight of factors and the developed architec-

ture of the methodology for the construction of these or other systems. Once again, it is worth emphasizing that AI systems should not be one-sided but rather have the nature of a dialogue with both medical workers and patients, and should not have the character of linear logic, but use indirect and non-obvious connections in the process of program work.

This is only a superficial, perhaps not the most perfect scheme of work, but the involvement of AI must be systematic in order to obtain truly important and reliable data, and the result must not be at the level of a generative pretrained transformer.

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Огляд застосування штучного інтелекту як протокольного інструменту лікування ран

Резюме. Глобальний інтерес та суттєві проблеми в цій галузі сприяють її актуальності. Цей аналіз зосереджується на впровадженні штучного інтелекту в сфері медицини з особливим акцентом на його застосуванні для лікування ран. Завдяки численним онлайн-дослідженням і публікаціям ми можемо отримати уявлення про те, як штучний інтелект використовується для покращення діагностики, лікування й моніторингу загоєння ран. Інтеграція штучного інтелекту в цей сектор здатна змінити медичну практику шляхом підвищення точності, ефективності та індивідуального догляду за пацієнтами. Як наслідок, ця сфера досліджень і прогресу стала провідною в глобальному масштабі. Ми використовували електронні бази даних медичних публікацій PubMed і Google Scholar, шукаючи анотації за такими ключовими фразами: штучний інтелект і лікування ран, штучний інтелект та вогнепальні поранення, штучний інтелект і військова медицина, штучний інтелект та хірургія. На основі результатів пошуку було проведено аналіз літератури. ***Висновки.*** Необхідно створити численні робочі групи висококваліфікованих спеціалістів з кожної дисципліни та напрямку медичної діяльності, щоб за результатами реальних випадків визначати питому вагу конкретного симптому, лабораторного показника, кожного результату рентгенологічного й ультразвукового дослідження. Така робота повинна мати не менші порядок і структурованість, ніж медичні дослідження. Для цього етапу оптимально отримати універсальний програмний засіб, який можна використовувати з певними варіаціями для всієї різноманітності патологічних станів і процесів.

Ключові слова: штучний інтелект; лікування ран; машинне навчання; нейромережа; персоніфікований діагноз; FAIT