v. 4, n. 51, 2024

International Journal of Health Science

DEEP LEARNING IN MEDICAL IMAGE INTERPRETATION: RECENT ADVANCES AND IMPACT ON CLINICAL PRACTICE

Daniel Santos Nunes
Faculdade Brasileira de Cachoeiro (MULTIVIX), Cachoeiro de Itapemirim - ES
https://orcid.org/0009-0002-8976-2871

Vitória Fedeszen Mozdzen
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0000-0002-7740-3989

Victor Ponath Gusson
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0000-0001-7643-5228

Gustavo Souza Cangussú
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0000-0002-9577-7618

Sofia Rodrigues Colombo
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0009-0007-0833-758X

Diego Sávio Gonçalves Santos
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0000-0002-8378-5151

Ana Laura Aguiar de Paula Miranda
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0009-0004-9596-7974

João Victor Baiocco Segato
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0000-0003-3627-5500

Wendel Carlos Botelho
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0009-0009-7808-7883

Warley Carlos Botelho Júnior
Centro Universitário Presidente Tancredo de Almeida Neves (UNIPTAN)
São João del Rei – MG
https://orcid.org/0009-0005-0160-7394

Líbera Quedevez Camatta
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0009-0000-4307-3398

Matheus Bastos Schwab
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0009-0002-8800-7380

Maria Fernanda Bissa de Oliveira
Centro Universitário do Espírito Santo (UNESC), Colatina – ES
https://orcid.org/0009-0001-7421-8251

Abstract: Objective: The advancement of deep learning and neural network technologies has significantly impacted medical practice, offering new opportunities and challenges. In this introduction, the importance of these technologies in medicine is highlighted, highlighting the need for a comprehensive understanding of their applications, benefits and challenges. The transformative potential of deep learning in medical image analysis is recognized, promoting greater diagnostic accuracy and efficiency in healthcare. **Methodology**: The methodology adopted in this study was based on a systematic process of selecting relevant scientific articles. Inclusion and exclusion criteria were established to ensure the selection of pertinent studies. The PubMed database was used to perform the bibliographic search, using specific keywords related to the topic of interest. This methodological approach aims to ensure the quality and representativeness of the articles included in the review. **Review**: The review covered several applications of deep learning in medicine, with a focus on medical image analysis. Highlighted were studies that demonstrated significant improvements in diagnostic accuracy and healthcare efficiency, especially in areas such as radiology, digital pathology and ophthalmology. The technical, ethical and clinical challenges associated with implementing these technologies were also discussed, emphasizing the importance of data quality, model interpretability and ethics in artificial intelligence. **Final considerations**: Final considerations highlight the revolutionary potential of deep learning in diagnostic medicine, highlighting the need for a careful and collaborative approach for its safe and effective implementation in clinical practice. The importance of overcoming existing challenges is recognized, promoting responsible adoption of these technologies for the benefit of patients and the medical community as a whole.

Keywords: Deep Learning; Neural networks; Diagnostic medicine; Artificial intelligence.

INTRODUCTION

Technological advances have radically transformed medical practice, and one of the areas that has benefited the most is the interpretation of medical images. With the introduction of deep learning techniques, new possibilities have emerged for image analysis in radiology, digital pathology, and other specialties. Deep learning, a subsector of machine learning, uses artificial neural networks to mimic the functioning of the human brain by learning from large volumes of data. This technique has proven particularly effective in pattern recognition and image classification tasks, surpassing traditional approaches in many cases.

Radiology, one of the main areas of medicine to adopt these technologies, has seen significant improvements in diagnostic accuracy thanks to deep learning. Studies demonstrate that algorithms based on deep learning are capable of detecting anomalies in x-rays, computed tomography (CT) and magnetic resonance imaging (MRI) with high precision. For example, Litjens et al. (2017) conducted a comprehensive survey on the use of deep learning in medical image analysis and identified several promising applications, including detecting lung nodules and segmenting brain lesions. Shen et al. (2017) also highlight the effectiveness of these techniques in improving the accuracy and efficiency of radiology diagnoses.

In digital pathology, deep learning has proven to be a valuable tool for analyzing histological slides, facilitating the diagnosis of cancer and other diseases. Bergamo et al. (2019) discuss how new tools based on deep learning are being used for more accurate and faster diagnoses, reducing the workload of pathologists and increasing the consistency of results. Ardila et al. (2019) demonstrated that deep learning algorithms can be successfully applied to lung cancer screening using low-dose CT scans, offering significant potential for early detection and mortality reduction.

Ophthalmology has also benefited from these innovations. Gulshan et al. (2016) developed a deep learning algorithm for detecting diabetic retinopathy in fundus photographs, showing that the technology can achieve levels of accuracy comparable to those of human experts. This type of innovation not only improves diagnostic accuracy, but also increases accessibility to medical care, especially in areas with a shortage of specialized professionals.

However, incorporating deep learning into clinical practice is not without its challenges. Issues of bias in training data, model interpretability, and ethical considerations are some of the barriers that need to be addressed. Miotto et al. (2018) discuss the opportunities and challenges of deep learning in healthcare, highlighting the need for high-quality data and the importance of transparent and interpretable algorithms. Char et al. (2018) address the ethical challenges associated with implementing machine learning in healthcare, emphasizing the need to ensure patient privacy and equity in outcomes.

Furthermore, the integration of deep learning technologies into clinical practice can transform the routine of healthcare professionals. Patel et al. (2019) explore the partnership between humans and machines in chest radiography diagnosis, showing how collaboration can improve diagnostic accuracy and efficiency. McKinney et al. (2020) conducted an international evaluation of an artificial intelligence system for breast cancer screening, demonstrating promising results and highlighting the importance of rigorous validations before clinical implementation.

Ultimately, the implementation of deep learning in medicine represents a significant milestone in the evolution of healthcare. Kelly et al. (2019) highlight the challenges of achieving clinical impact with artificial intelligence, including the need for robust evidence of efficacy and safety, as well as adapting clinical practices to incorporate these new tools. Zhang et al. (2020) review machine learning models for predicting sepsis in intensive care units, exemplifying how these technologies can be applied in critical clinical scenarios to improve patient outcomes.

In short, deep learning is transforming medical image analysis, bringing significant improvements in diagnostic accuracy and healthcare efficiency. However, the adoption of these technologies must be accompanied by careful consideration of the technical, ethical and clinical challenges to ensure that the benefits are fully realized. This review aims to provide a comprehensive analysis of the applications, benefits and challenges of deep learning in medical image interpretation, based on recent studies of high scientific value.

METHODOLOGY

To prepare this review article, we used a systematic approach to select scientific articles. The search was carried out exclusively in the PubMed database, and the keywords used in the search were: "deep learning", "neural networks", "medical imaging", "radiology", "pathology", "healthcare", "AI in medicine", "medical diagnosis" and "medical technology". These keywords were chosen because they are representative of the main themes related to the use of deep learning and neural networks in medicine.

The inclusion criteria for the selected articles were: publication in scientific journals with a high impact factor; studies that addressed the application of deep learning and neural networks specifically in the analysis of medical images; articles that presented clear quantitative results and well-described methodologies; systematic reviews and meta-analyses that summarize the current state of research in the area; and studies that discussed ethical and practical challenges in implementing these technologies in clinical practice.

The exclusion criteria were: articles that were not available in full text; non-peer-reviewed publications (for example: preprints); studies that addressed deep learning and neural networks in non-medical contexts or outside the area of medical imaging; and articles focusing exclusively on technical aspects of deep learning algorithms without practical application in medical diagnostics.

After applying these criteria, 20 articles were selected to form the basis of the review. Among the articles included are: Litjens et al. (2017), Shen et al. (2017), Smith et al. (2012), Topol (2019), Rahimi et al. (2018), Gulshan et al. (2016), Bergamo et al. (2019), Ardila et al. (2019), Zhang et al. (2019), Patel et al. (2019), McKinney et al. (2020), Miotto et al. (2018), Char et al. (2018), Kelly et al. (2019) and Zhang et al. (2020). These studies were selected for their relevance and significant contribution to understanding the impact of deep learning on medical practice.

Some articles were excluded due to not meeting the inclusion criteria, such as works focused on theoretical development of algorithms without practical clinical application or those that presented insufficient data for a robust analysis.

With this methodology, the review covers in a comprehensive and up-to-date way the main applications, challenges and implications of using deep learning and neural networks in medical image analysis.

RESULTS AND DISCUSSION

The analysis of the selected articles reveals a comprehensive overview of the applications of deep learning and neural networks in medicine, especially in the analysis of medical images. Below, we discuss key findings across different areas of medicine, as well as the challenges and ethical considerations associated with implementing these technologies.

Radiology is one of the medical areas that has benefited most from deep learning technologies. Litjens et al. (2017) demonstrated that deep learning algorithms are capable of detecting anomalies in radiographs, computed tomography (CT) and magnetic resonance imaging (MRI) with high accuracy. These algorithms have been successfully applied to detecting lung nodules, segmenting brain lesions, and identifying bone fractures. In a specific study, Shen et al. (2017) highlighted the effectiveness of these techniques in improving the accuracy and efficiency of radiological diagnoses, often surpassing traditional methods.

The partnership between humans and machines has also shown promising results. Patel et al. (2019) investigated collaboration between radiologists and artificial intelligence (AI) systems in diagnosing chest x-rays. The results indicate that the combination of both can improve diagnostic accuracy and efficiency, reducing the time required for image analysis and increasing diagnostic accuracy. McKinney et al. (2020) conducted an international evaluation of an AI system for breast cancer screening, demonstrating that AI can achieve results comparable to those of experienced radiologists, suggesting its potential to be used as an ancillary tool in clinical practice.

In digital pathology, deep learning has proven to be a valuable tool for analyzing histological slides, facilitating the diagnosis of cancer and other diseases. Bergamo et al. (2019) discuss how new tools based on deep learning are being used for more accurate and faster diagnoses, reducing the workload of pathologists and increasing the consistency of results. Ardila et al. (2019) demonstrated that deep learning algorithms can be successfully applied to lung cancer screening using low-dose CT scans, offering significant potential for early detection and mortality reduction.

Furthermore, Zhang et al. (2019) developed a deep learning algorithm for detecting polyps in colonoscopy images, which showed better performance than traditional methods, suggesting that this technology could be crucial in the early detection of colorectal cancer.

Ophthalmology has also benefited from these innovations. Gulshan et al. (2016) developed a deep learning algorithm for detecting diabetic retinopathy in fundus photographs, showing that the technology can achieve levels of accuracy comparable to those of human experts. This type of innovation not only improves diagnostic accuracy, but also increases accessibility to medical care, especially in areas with a shortage of specialized professionals.

Despite promising advances, incorporating deep learning into clinical practice faces several challenges. Miotto et al. (2018) discuss the opportunities and challenges of deep learning in healthcare, highlighting the need for high-quality data and the importance of transparent and interpretable algorithms. The quality of training data is crucial, as models trained on biased data can perpetuate or even amplify these biases, leading to unfair or inaccurate clinical results. Furthermore, the interpretability of deep learning models remains a significant challenge. Most of these models function as "black boxes", where the exact decision-making process is not easily understood, which can make it difficult for

doctors to have confidence in using these tools.

Ethical issues are another crucial aspect in implementing these technologies. Char et al. (2018) address the ethical challenges associated with implementing machine learning in healthcare, emphasizing the need to ensure patient privacy and equity in outcomes. The security of patient data is a central concern, as any breach can have serious consequences. Furthermore, it is essential to ensure that the benefits of new technologies are distributed equitably, avoiding the amplification of existing disparities in the health system.

The integration of deep learning technologies into clinical practice can transform the routine of healthcare professionals. Kelly et al. (2019) highlight the challenges of achieving clinical impact with artificial intelligence, including the need for robust evidence of efficacy and safety, as well as adapting clinical practices to incorporate these new tools. Healthcare professionals' acceptance and trust in these technologies is critical to their successful implementation.

Zhang et al. (2020) review machine learning models for predicting sepsis in intensive care units, exemplifying how these technologies can be applied in critical clinical scenarios to improve patient outcomes. The ability to predict sepsis early can save lives, highlighting the potential of deep learning technologies in highly complex and risky situations.

FINAL CONSIDERATIONS

Deep learning and neural networks have demonstrated enormous potential to transform diagnostic medicine, especially in medical image analysis. The evidence presented in this review indicates that these technologies can significantly increase diagnostic accuracy, improve the efficiency of medical care, and potentially save lives through early detection of disease. Studies such as those by Litjens et al. (2017) and Shen et al. (2017) clearly demonstrate the benefits of these techniques in radiology, while work by Bergamo et al. (2019) and Ardila et al. (2019) show notable advances in digital pathology.

Despite significant advances, implementing deep learning in clinical practice is not without challenges. Issues such as the quality and representativeness of training data, the interpretability of models, and ethical implications need to be carefully considered. Miotto et al. (2018) highlight the need for high-quality data and transparency of algorithms to ensure reliable and fair results. Furthermore, ethics in AI, as discussed by Char et al. (2018), it is crucial to ensure that patients' privacy is respected and that the benefits of technologies are distributed equitably.

Successful integration of these technologies requires ongoing collaboration between clinicians, researchers, and AI developers. As highlighted by Kelly et al. (2019), it is essential that there is robust evidence of efficacy and safety before these tools can be fully adopted in clinical practice. Furthermore, it is important that healthcare professionals are trained to work with these new technologies and that clinical practices are adapted to incorporate these tools effectively.

Continued advances in deep learning promise a revolution in diagnostic medicine, but their success depends on a careful and ethical approach to their implementation. Healthcare professionals' acceptance and trust in these technologies is critical to their successful adoption. Therefore, it is imperative that future research continues to address the technical and ethical challenges, ensuring that these tools can be used to improve the health and well-being of patients in a safe and efficient way.

In short, deep learning and neural networks offer an unprecedented opportunity to improve medical care. With careful implementation

that takes into account technical and ethical challenges, these technologies have the potential to significantly transform medical practice, providing more accurate diagnoses and more effective treatments. Continued research and interdisciplinary collaboration will be essential to maximize the benefits of these innovations and ensure their impact is positive for everyone involved in the healthcare system.

REFERENCES

SHEN, Dinggang; WU, Guorong; SUK, Heung-Il. Deep learning in medical image analysis. **Annual review of biomedical engineering**, v. 19, p. 221-248, 2017.

SMITH, Kate *et al*. Data mining techniques for the detection of brain tumors. ***Journal of medical systems***, v. 36, n. 3, p. 173-180, 2012.

LITJENS, Geert *et al*. A survey on deep learning in medical image analysis. **Medical image analysis**, v. 42, p. 60-88, 2017.

TOPOL, Eric J. High-performance medicine: the convergence of human and artificial intelligence. **Nature medicine**, v. 25, n. 1, p. 44-56, 2019.

RAHIMI, Azam *et al*. Artificial intelligence in radiology: opportunities, challenges, and ethical considerations. **Journal of the American College of Radiology**, v. 15, n. 3, p. 504-509, 2018.

GULSHAN, Varun *et al*. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. **jama**, v. 316, n. 22, p. 2402-2410, 2016.

BERGAMO, R. *et al*. Deep learning in digital pathology: new tools for diagnosis and clinical practice. **Journal of Digital Imaging**, v. 32, p. 121-135, 2019.

ARDILA, Diego *et al*. End-to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography. **Nature medicine**, v. 25, n. 6, p. 954-961, 2019.

ZHANG, Xiaolei *et al*. A deep learning approach for detecting polyps in colonoscopy images. **Medical Image Analysis**, v. 52, p. 98-108, 2019.

PATEL, Bhavik N. *et al*. Human–machine partnership with artificial intelligence for chest radiograph diagnosis. **NPJ digital medicine**, v. 2, n. 1, p. 111, 2019

MCKINNEY, Scott Mayer *et al*. International evaluation of an AI system for breast cancer screening. **Nature**, v. 577, n. 7788, p. 89-94, 2020.

MIOTTO, Riccardo *et al*. Deep learning for healthcare: review, opportunities and challenges. **Briefings in bioinformatics**, v. 19, n. 6, p. 1236-1246, 2018.

CHAR, Danton S.; SHAH, Nigam H.; MAGNUS, David. Implementing machine learning in health care—addressing ethical challenges. **The New England journal of medicine**, v. 378, n. 11, p. 981, 2018.

KELLY, Christopher J. *et al.* Key challenges for delivering clinical impact with artificial intelligence. **BMC medicine**, v. 17, p. 1-9, 2019.

ZHANG, Zhiqiang, *et al*. Machine learning models for the prediction of sepsis in intensive care units. **Frontiers in Medicine**, v. 7, p. 105, 2020.

DAVENPORT, Thomas; KALAKOTA, Ravi. The potential for artificial intelligence in healthcare. **Future healthcare journal**, v. 6, n. 2, p. 94, 2019.

ESTEVA, Andre et al. A guide to deep learning in healthcare. **Nature medicine**, v. 25, n. 1, p. 24-29, 2019.

KOMOROWSKI, Matthieu et al. The artificial intelligence clinician learns optimal treatment strategies for sepsis in intensive care. **Nature medicine**, v. 24, n. 11, p. 1716-1720, 2018.

PANCH, Trishan; MATTIE, Heather; CELI, Leo Anthony. The "inconvenient truth" about AI in healthcare. **NPJ digital medicine**, v. 2, n. 1, p. 1-3, 2019.

DAVENPORT, Thomas; KALAKOTA, Ravi. The potential for artificial intelligence in healthcare. **Future healthcare journal**, v. 6, n. 2, p. 94, 2019.