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CONTRIBUTION OF ARTIFICIAL INTELLIGENCE IN THE EARLY DETECTION OF PATIENTS AT RISK OF CARDIAC ARREST IN A HOSPITAL CONTEXT

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Abstract: Background: Artificial Intelligence (AI) tools have been analyzed and tested in hospital healthcare to early detect the risk of the patient going into Cardio-Respiratory Arrest (CPA). Goals: To describe the scientific evidence on the contribution of AI in the early detection of patients at risk of CRA in a hospital context and to reflect on the importance of using AI tools in hospital practice. Methodology: An integrative literature review was carried out. Data collection was performed from June to July 2021, in PubMed, ScienceDirect, BMC and Medline databases, with the equation "Artificial Intelligence AND Heart Arrest AND Early Diagnosis". Results: Of the 162 articles obtained by the search, 6 articles were selected after applying the inclusion criteria: Of these, 5 quantitative, retrospective cohort studies and 1 case study, which involved a total of 88592 patients. Conclusion: The AI algorithms identified are more sensitive for the early detection of patients at risk of CRA compared to conventional methods already existing in hospital settings. AI tools have the potential to assist and assist healthcare professionals during clinical practice in decision making.
Keywords: Artificial intelligence, cardiac arrest and early diagnosis.

INTRODUCTION

Cardiorespiratory arrest (CRA) is defined as the absence or abrupt reduction of cardiac output, resulting in inadequate perfusion of vital organs (Baid et al., 2016). Organs and tissues do not receive enough blood and cells are not supplied with enough oxygen and nutrients, resulting in organ failure and, consequently, death (Kim et al., 2019).

CPA in a hospital setting is not usually a sudden event, but the result of slow and progressive physiological deterioration (INEM, 2020). When cardiac arrest takes place in a hospital setting, it is expected that the start of cardiopulmonary resuscitation (CPR) will be as soon as possible (Silva et al., 2016). According to a study carried out in the United States, the prevention of CPA in this environment is potentially possible with the early recognition and detection of the deterioration of the person's general condition, leading to a post-discharge survival rate of 25% of patients (Andersen et al., 2019). Comparatively, in Portugal, according to INEM (2020), survival at the time of hospital discharge is low, being less than 20%.

Early detection of CRP is considered the first link in the chain of survival in cases of in-hospital CRA (Souza et al., 2019). The identification of the patient's clinical deterioration is accompanied by neurological hemodynamic changes. This way, its early identification and intervention can prevent CA, increasing patient survival and safety (Taguti et al., 2013).

Artificial intelligence (AI) has been widely used in the healthcare field (Kim et al., 2019), as it detects and diagnoses faster, resulting in better patient care (Mintz & Brodie, 2019). According to the same authors, in medicine, AI improves the workflow of health professionals, thus reducing clinical error. As a consequence, there is a decrease in patient mortality and morbidity. The authors reinforce that AI has not come to replace human care, but to assist and increase this care. Lobo (2017, p.188) defines AI as "a branch of computer science that proposes to develop systems that simulate the human ability to perceive a problem, identifying its components to solve problems and propose/make decisions."

Efficiency and effectiveness in decision making are usually associated with greater knowledge and experience acquired by health professionals. However, its evolution is conditioned by the time factor that makes it impossible for human beings to acquire all existing knowledge and experience all experiences (Mintz & Brodie, 2019). In this sense, AI is important as it can acquire and process a large volume of information in a short time and, consequently, help professionals make better decisions in critical situations (Cho et al., 2020).

With the present work, we therefore propose to reflect on the importance of using AI tools in hospital practice in order to describe the scientific evidence on the contribution of AI in the early detection of patients at risk of CRA in a hospital context. Thus, we ask: "What is the contribution of AI in the early detection of patients at risk of CRA in a hospital context?".

METHODOLOGY

An integrative literature review study was carried out. For the elaboration of the review, we validated, through the Descriptors in Health Sciences – DeCS (compatible with Medical Subject Headings - MeSH), the descriptors: artificial intelligence (artificial intelligence), cardiac arrest (heart arrest) and early diagnosis (early diagnosis). Databases were used: PubMed, ScienceDirect, BMC and Medline. We used the English language and temporally defined publications between 2016 and 2021. Data collection was carried out from January to February 2022.

Using the advanced search form with the equation "Artificial Intelligence AND Heart Arrest AND Early Diagnosis" we obtained 162 articles. Of the total, 69 were excluded by reading the abstract and title, 5 by eligibility criteria, 79 by being literature reviews and 3 were repeated (Figure 1). After applying all criteria (Table 1), 6 articles were included.

Selection criteria	Inclusion criteria
Participants	Studies conducted with adults and the elderly, excluding the pediatric population.
Place	Study carried out in a hospital environment, excluding studies carried out in the laboratory and in an extra-hospital environment.
Study design	Studies with a qualitative or quantitative approach.
Context	Studies that address patients evaluated in an in-hospital context

Table 1 - Inclusion criteria.

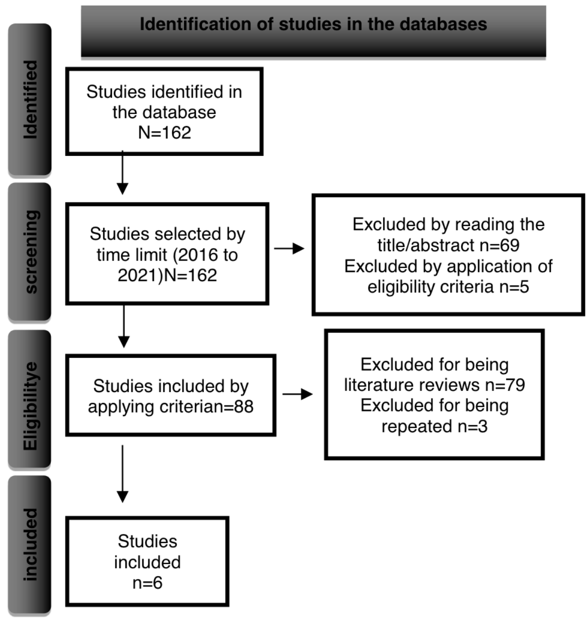

Figure 1 - Screening of scientific evidence.

RESULTS

The most relevant information was organized in table 2 in order to facilitate the reading and understanding of the results.

<table>
<tr><th>Author, Year, Title, Publication, Country</th><th>Study Type Data Collection Instrument</th><th>Participants Sample</th><th>General goal</th></tr>
<tr><td>1. Layeghian Javan, S., & Sepehri, M. M. (2021). A predictive framework in healthcare: Case study on cardiac arrest prediction. Artificial Intelligence in Medicine, 117, 102099. Irão.</td><td>Quantitative/Case Study. They used the MIMIC III (Medical Information Mart for Intensive Care) database, which contains patient information regarding vital signs, laboratory tests, state of consciousness, information on admission to intensive care units, demographic information, and personal history.</td><td>N=7769
n=2760 (79 with PCR and 2681 without PCR)</td><td>Develop a model for early detection of CRP in patients with sepsis.</td></tr>
<tr><td colspan="4">Main Conclusions: The model was developed based on the ISAF method in order to detect PCR 1h before it occurs. The authors tested the model between 1 and 25h before the occurrence of PCR and concluded that the closer to the PCR event, the better the sensitivity and precision of the algorithm. Between 1h and 5h before the occurrence of PCR, the model has a sensitivity above 73%, an accuracy above 18% and an f1-score above 29%. Between 6 and 25h before the PCR event, the performance of the algorithm did not vary considerably. As a probable cause, the authors justify that the most significant physiological changes appear closer to the event. In order to demonstrate the effectiveness of the model, the authors compared it with other existing warning systems such as
APACHE II (Acute Physiology and Chronic Health Evaluation) and the MEWS (Modified Early Warning Score). 1h before the occurrence of PCR, the proposed model has a sensitivity of 85%, an accuracy of 29% and an f1-score of 43%, while the APACHE II scale has a sensitivity of 67%, an accuracy of 18% and an f1-score of 28 % and the MEWS scale has a sensitivity of 62%, an accuracy of 20% and an f1-score of 30%, thus concluding that the proposed model presents the best performance. The model that the authors propose was designed to detect CRP in patients who had sepsis, however they state that it can be developed for other groups of patients.</td></tr>
<tr><td>2. Layeghian Javan, S., Sepehri, M. M., Layeghian Javan, M., & Khatibi, T. (2019) An intelligent warning model for early prediction of cardiac arrest in sepsis patients. Computer Methods and Programs in Biomedicine, 178, 47-58.</td><td>Retrospective cohort study. Clinical data for each patient with sepsis were extracted from the MIMIC III database.</td><td>N=7769
n=2760 (79 with PCR and 2681 without PCR)</td><td>Use AI to propose a model (Stacking) for predicting CRP in adults with septicemia.
To investigate the effect of vital signs assessment in the early detection of CRP.</td></tr>
<tr><td colspan="4">Main conclusions: The model predicts the incidence of PCR up to 6 hours before the event, and with a sensitivity and accuracy greater than 70%. The assessment of vital signs over a given period of time is
of great importance in predicting the incidence of CRP in patients with sepsis. They concluded that the assessment of vital signs plays an important role in predicting the occurrence of CPA with results of accuracy of 17%, sensitivity of 70% and f1-score of 27%. To measure the performance of this model, they tested it between 1 to 6 hours before the occurrence of PCR. They inferred that the effectiveness of the model decreases as we move away from the time period of the CRP occurrence. However, and compared to other existing methods (APACHE II and MEWS), the proposed model (Stacking) has a higher sensitivity and f1-score with results of accuracy of 19%, sensitivity of 77% and f1-score of 31 %.</td></tr>
<tr><td>3. Cho, K.-J., Kwon, O., Kwon, J., Lee, Y., Park, H., Jeon, K.-H., Kim, K.-H., Park, J., & Oh, B.-H. (2020). Detecting Patient Deterioration Using Artificial Intelligence in a Rapid Response System: Critical Care Medicine, 48(4), e285–e289. Coreia do Sul.</td><td>Retrospective cohort study. They associated conventional rapid response systems (MEWS and SPTTS) as well as the AI system developed by the authors (DEWS).</td><td>N = 8039 adults
n = 83 adults with clinical deterioration</td><td>To compare the performance of an AI system based on early detection of CRP with conventional methods in a hospital.</td></tr>
</table>

Main conclusions: The DEWS algorithm detected 122% and 68.7% more clinical deterioration events than the MEWS algorithm and all other conventional methods, 15h before the event. DEWS sensitivity is acceptable at 43.5% and showed a 257% higher sensitivity than conventional methods. The study demonstrated that vital signs can be analyzed by AI and prevent in-hospital cardiac arrest with greater accuracy than conventional methods. In addition, AI can be included in a system of rapid response associated with a set of electronic health devices that is useful to identify patients with clinical deterioration and help in decision making. In the study, they also identified the vital signs that contribute most significantly to the early detection of CRP, namely blood pressure (38.1%), heart rate (26.7%), respiratory rate (13.4%) and body temperature (20.8%).			
4. Kwon, J., Lee, Y., Lee, Y., Lee, S., & Park, J. (2018). An Algorithm Based on Deep Learning for Predicting In-Hospital Cardiac Arrest. Journal of the American Heart Association, 7(13).	Retrospective cohort study. Patients from two hospitals, hospital A (cardiovascular university hospital) and hospital B (general hospital) were included. Hospital A data were used to develop and determine DEWS parameters. Hospital B data were used to verify the applicability of the DEWS system.	N = 56076 – all patients admitted to two hospitals in 91 months n = 52121	Develop an AI-based early detection algorithm to predict CRP.
Main conclusions: The algorithm used has high sensitivity and low false alarm rate to detect patients with CRP. The algorithm (DEWS) detected in more than 50% the risk of patients developing CPA in the hospital context 14h before the event occurred and was able to detect 78% of CRP 30 minutes before it happened. Compared with the MEWS system, it has 24.3% higher sensitivity and has a 41.6% reduction in false alarms. With this system, the hospital emergency team is able to detect more quickly and more accurately patients at risk of CRA. It is also an easy-to-apply system in various in-hospital contexts and uses only 4 patient vital signs (systolic blood pressure, heart rate, respiratory rate and temperature). The present study showed that the DEWS algorithm can be applied in rapid response systems, and its interpretation can help hospital staff to reduce clinical decision time.			
5. Kwon, J., Kim, K.-H., Jeon, K.-H., Lee, S. Y., Park, J., & Oh, B.-H. (2020). Artificial intelligence algorithm for predicting cardiac arrest using electrocardiography. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 28(1), 98.	Retrospective study. Patients from two hospitals were included in the study for the development, internal and external validation of the algorithm.	n=47,505 ECG (electrocardiogram) of 25,672 patients from two hospitals	Develop an AI algorithm (DLA) to predict CRP using electrocardiogram (ECG).
Main Conclusions: The aim of the algorithm is to predict the occurrence of CRP up to 24 hours after the ECG. The authors hypothesized classifying ECGs from patients with signs of clinical deterioration as "CRP ECGs" although, in reality, they may not have progressed to CRP within 24 hours after the ECG. When carrying out the external validation, they concluded that patients with ECGs classified with this hypothesis had CRP and hospitalizations in intensive care units in the two weeks following the ECG. The algorithm has a sensitivity of 90% and in the cases identified as no occurrence of PCR, they are correct with 99.8% of accuracy.			
6. Jang, D.-H., Kim, J., Jo, Y. H., Lee, J. H., Hwang, J. E., Park, S. M., Lee, D. K., Park, I., Kim, D., & Chang, H. (2020).; Developing neural network models for early detection of cardiac arrest in emergency department; Republic of Korea.	Retrospective study. Documentary analysis of the electronic health record in the emergency department.	n = 2,910,321 changes in the patient's condition	Identify and test artificial neural networks (ANN) for the early detection of patients at risk of cardiac arrest in the emergency department.
Main conclusions: The ANN compared to the MEWS scale presents a better performance for the prediction of CRP in emergency services. Of the three models used, the hybrid ANN obtained the best performance according to the AUROC (predictive performance) scale that was used, obtaining values above 90%. They concluded that by including the patient's chief complaint and vital signs at the entrance to the emergency department, the model has greater accuracy. The study only examined the performance of the model to identify patients most likely to have a CRA, and it was not yet clear how many CRAs were avoided. However, the authors say that in an overcrowded emergency, the model can help alert the physician to identify patients at risk of CRA. They claim that it can be used in a triage system as well as during the patient's stay in the emergency department.			

DISCUSSION

In order to reflect on the subject under study, 6 international articles were selected. They refer to quantitative studies, 5 cohort retrospectives and 1 case study. Among the studies, the main goals were to develop and test an AI algorithm for the early detection of patients at risk of CRA and to compare it with existing detection methods.

CPA is an in-hospital reality with high associated mortality rates. Early detection of the patient's risk of developing CPA can provide the time needed to intervene and prevent its onset, consequently reducing mortality rates (Layeghian Javan et al., 2019). According to the same authors, AI, when compared to conventional methods, provides the best performance for the early detection of CRP. In studies by Layeghian Javan & Sepehri (2021) and Layeghian Javan et al. (2019) concluded that the most significant physiological changes in patients appear closer to the CRP event and, consequently, the AI model is also more effective in detecting CRP. These results corroborate the study by Kim et al. (2019). According to Layeghian Javan & Sepehri (2021), 1h before the occurrence of PCR, the proposed AI model has a sensitivity of 85% and a precision of 29%, inferring a high performance. In the same vein, the authors Layeghian Javan et al. (2019) obtained similar results with a sensitivity and accuracy of 70%. These results are in agreement with the study by Kim et al. (2019) who used AI to predict CRP between 1 and 6 h before it occurs and obtained results with a sensitivity of 85.7% and an accuracy that exceeds 70%.

From the evidence produced, it was possible to highlight through the contribution of the study by Kwon et al. (2018) that the algorithm developed and applied by the authors predicted CRP in more than 50% of the sample 14 hours before the event occurred and 78%, 30 minutes before.

Kwon et al. (2020) used the ECG to develop the AI algorithm to detect CRP early. They identified that patients with ECG who showed clinical deterioration ended up having CPA or admission to intensive care units (ICU) two weeks after performing the complementary diagnostic method presented. The algorithm has 90% sensitivity. However, according to Kim et al. (2019) must not be expected to use the ECG alone as a decision support using it in the AI model. The same authors refer that models must be developed that can be used in an emergency context that analyze the patient's physiological data in real time.

In addition to the algorithms developed by the authors, it was possible to highlight the importance of evaluating and interpreting vital signs (VS) in predicting the occurrence of CPA. Layeghian Javan et al. (2019) when investigating the effect of VS on the early detection of CRP, obtained results of precision of 17% and sensitivity of 70%. In the same sense of results Cho et al. (2020) concluded that the VS associated with the developed model can be analyzed by AI and prevent hospital CPA with greater precision than conventional methods, and the VS that contributed most significantly to this early detection were blood pressure (TA) (38.1%) and heart rate (HR) (26.7%). A study by Souza et al. (2019), which aimed to identify changes in VS in patients with CPA and correlate them with this event, concluded that most had abnormal BP and HR. 45.5% of the patients had abnormal BP and 56.5% had abnormal HR, which can be said to correlate with this physiological change and CRP. As the authors of Silva Portela et al. (2018), AI started to support the clinical decision-making process, as the models under study allow the analysis of the various physiological parameters of the patient, such as VS, in real time, allowing for the prediction of possible complications such as multiorgan failure.

Cho et al. (2020) also mention that AI can be included in a rapid response system associated with electronic health devices, being useful to identify the clinical deterioration of patients by health professionals. Two years before these results, Kwon et al. (2018) reported that the algorithm they developed allows in-hospital emergency teams to detect CRP faster and more accurately, reducing the time for clinical decision-making. In an overcrowded emergency room, the AI model can help healthcare professionals identify patients at risk for cardiac arrest (Jang et al., 2020). Mintz & Brodie (2019) state that AI is a technology that is being adopted to improve performance, accuracy, efficiency, as well as to reduce costs inherent to healthcare. They refer that AI in medicine translates into better patient care through early detection and diagnosis, better workflow and reduction of medical errors, morbidity and mortality. In a study carried out by Raita et al. (2019), it is concluded that with the use of AI models it is possible to predict patient hospitalizations and thus reduce the excess of resources used in triage.

CONCLUSION

The AI algorithms developed have been shown to be effective in the rapid detection of patients at risk of CRA, thus allowing health professionals to make timely decision and action. In addition, the evident importance of the assessment and interpretation of VS by AI tools in predicting the occurrence of CPA, namely AT and HR, was demonstrated. It is a tool under development with the potential to assist health professionals in clinical practice, however, it is a topic that has not yet been explored, which limited the present literature review. On the other hand, the choice of databases and languages for carrying out the research may have conditioned the results obtained. The language and technicality of the articles made their interpretation complex. In Portugal, AI tools are already being developed and tested in critically ill patients in the hospital context, however, it is a topic little recognized by health professionals. We suggest further studies to prove the benefit and effectiveness of using AI as an auxiliary tool used in health care.

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