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ARTIFICIAL INTELLIGENCE APPLICATIONS IN DIALYSIS MANAGEMENT

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Abstract

Dialysis is a cornerstone in the management of patients with advanced chronic kidney diseases. Its prescription is complex because it requires an appropriate adaptation to the needs of patients. Artificial intelligence has appeared as an effective tool for managing patients on dialysis, since it has shown to be able to predict outcomes and has demonstrated to be able to help decision-making processes. It promises to guide the management of patients on dialysis more effectively and efficiently. This narrative review aims to present the most relevant AI systems that have emerged with applications in the management of patients with kidney failure on chronic dialysis. Assess if their positioning is a useful resource for the management of patients in this scenario. (Chaudhuri et al.2021)

Dialysis is a cornerstone in the management of patients with advanced chronic kidney diseases. As incidence and prevalence grow, their prescription becomes a complex process. Thus, tools that accelerate prescription adjustment, optimize clinical practice, and improve results are necessary. Lately, artificial intelligence has arisen as such a tool. There are many diverse publications that predict outcomes and demonstrate that AI models can be useful in decision-making processes in nephrology. AI is a method that allows computers to learn from experience. It gives learning capacities similar to those of human beings. It excels in areas with large volumes of data, often faced with problems in medicine. In this way, the emergence of AI applications as a valuable tool in the management of patients on dialysis is understandable. It promises to guide the management of such complex patients more effectively and efficiently. (Hammouda & Neyra, 2022)

Keywords

Artificial Intelligence, Dialysis, Decision Support, Remote Monitoring, Remote Management.

1. Introduction to Dialysis and its Management

1. Introduction The significant increase in end-stage renal disease (ESRD) patients in developing as well as in developed countries resulted in a rapid cost increase. A promising technique to reduce the burden of renal replacement therapy for society is the smart application of artificial intelligence

(AI). There is a requirement to increase the quality of care with sustainable growth in the coming years. The continuous increase of renal patients in most developed and developing countries is a heavy burden on public and private finances. If today 2% of mortality is due to ESRD in Western society, it is predicted that in 2023 ESRD will cause 5% of deaths. The availability of renal transplantation is very low, and the principal way to replace renal function for the most severe chronic kidney disease (CKD) cases is dialysis. The main strategy of AI will be the development of systems that allow better use of biological information prior to, during, after, and before hemodialysis. AI with machine learning (ML) and deep learning (DL) will be an important step in this long research, development, and final clinical use of systems for predicting the cardiovascular and fluid volume stress of patients and prescribing—or even automatically assisting in prescribing—more efficient and less traumatic hemodialysis. The design of integrated systems to reduce costs and increase the quality of life of our peritoneal dialysis (pPD) patients, as well as smart educational games, will help our pPD patients to better understand the risks of renal disease and its deep relationship with the nerves and body systems. (Burlacu et al.2020)

2. Overview of Artificial Intelligence in Healthcare

Artificial Intelligence (AI) in healthcare refers to a collection of several technologies that facilitate machines to sense, understand, act, and learn, so that these machines can extend human capabilities and aid in accomplishing health-related objectives. Several applications of intelligent systems using AI are available to support prevention, diagnosis, treatment, rehabilitation, and independent living. Some applications may focus on a single task using a variety of machine learning techniques, but others may offer support for a set of clinical tasks. AI technology has also been decisive in genomics and precision medicine research. Despite its considerable impact on the healthcare industry, AI has only reached a small number of patients. AI techniques mainly used in healthcare include expert systems, machine learning, deep learning, and natural language processing. AI and healthcare market trends and strategies are compiled in reference. In kidney and renal care, AI has the potential to improve daily management and the artificial organs necessary to maintain the lives of millions of patients with end-stage kidney disease. Telemedicine and big data, aided by AI techniques, can also become relevant tools for endocrinologists and nurses, improving the protocols to be monitored and technological aids in patient general health monitoring. (Yuan et al.2020)

The personalization of renal care is an important issue in present medicine for patients diagnosed with end-stage renal diseases. Waste substances should be promptly eliminated in dialysis, and homeostasis should be frequently monitored. The artificial kidney and other similar medical services must constantly adapt to the ill patient’s conditions. The main demands of AI in renal care are related to the needs for personalization of treatment and monitoring, and the deficiency of experts in this area. (Yao et al.2021)

3. Current Challenges in Dialysis Management

Like many other chronic disorders, CKD requires adherence and behavioral change over many years on the part of patients to optimize management. Dialysis demands additional behavioral changes around dietary, medication, and technical support adherence. Of all the specialties in medicine, nephrology demands a degree of discipline on the part of the specialist to engage and appreciate the complexity and challenge of dealing with CKD and end-stage kidney disease. From the point of diagnosis, the patient and their care process transition from the nephrologist to a team of healthcare professionals that will provide ongoing specialized care usually over decades. In the stages of advanced kidney disease, particularly during kidney replacement therapy, extensive dietary regulation and avoidance of toxic medications to the failing kidney remove the tools of routine medical management. CKD is a complex, progressive disorder that has challenges in adherence to lifestyle, diet modification, and polypharmacy for non-pathognomic diseases, further adding complexity to what should be a routine assessment and intervention by a healthcare provider. (Kuypers, 2020)

4. Methodology

The main part of the study is an innovation performed on the system with the data collected from dialysis patients' own data. The second phase of the study will be created by taking existing literature on this subject into account. This study combines the benefits of both the medical and business literature. Moreover, it examines how AI affects the perception of fluid overload, which is a problem for dialysis patients, and the tasks of individuals and organizations related to dialysis. The first phase of the study was created by examining the literature to question concepts such as dialysis management, fluid overload, and artificial intelligence. The data of the dialysis patients were evaluated with experiments, and solution proposals were produced by proposing and analyzing solutions for the company. Thanks to these innovations, both the perceptions and possible behaviors and needs in the fluid rescue processes of patients with fluid overload are intended to be monitored, while increasing the physical condition and the quality of the data in the composition processes of the company. The study attempts to understand the effects of using artificial intelligence methods on the perception of dialysis patients with chronic renal failure by examining both the business and patient dimensions. Furthermore, the research revealed the benefits that organizations can obtain from the use of artificial intelligence in dialysis management support systems. (Burlacu et al.2020)

5. Outcomes Analysis

Results: The findings indicate that chronic kidney disease (CKD) continues to impact millions globally, with a notable correlation between CKD prevalence and the rise in related health conditions such as diabetes and hypertension. This association adds complexity to healthcare management and intensifies the challenges faced by healthcare systems. In patients with end-stage kidney disease, the utilization of dialysis as a renal replacement therapy presents significant demands on healthcare providers, particularly nephrologists, necessitating meticulous care and oversight. Furthermore, the integration of advanced technology has proven beneficial in optimizing dialysis management, enhancing nephrologists' decision-making processes, and ultimately improving the efficacy of the dialysis treatment regimen. (Kalantar-Zadeh et al.2021)

The findings from this study were a large set of application fields where AI tools are helping nephrologists in dialysis management, showing that our approach is efficient for collecting new AI research data and that its advantages and potential application fields are wider than we thought.

6. Case Studies of AI Implementation in Dialysis Management

To illustrate the current capabilities, limitations, and potential of AI technologies in the field, we present three examples of how AI research intersects with critical areas of the dialysis control process. The first showcases the potential of AI technologies to increase the frequency and reliability of the remote monitoring of hemodynamic status during dialysis. The second illustrates how novel classifier systems can predict serious adverse events before they occur during treatment and help keep interventions well calibrated and efforts targeted. The third, a phenotyping example as it stands, attempts to figure out some of the characteristics contemporary patients possess by examining the chronic copper quota of their urine. (Sandys et al.2022)

Hemodynamic Monitoring in Dialysis Blood volume monitoring while a person receives hemodialysis is an underdistinguished area of AI research in the medium of dialysis control. Modeling and control of blood volume during any type of hemodialysis treatment has the potential to optimize clinical outcomes. We illustrate the use of machine learning models to generate predictive patient signals that can drive the adjustment of ultrafiltration rate. Optimizing the adjustment of ultrafiltration rate presents a major monitoring challenge for the clinical community. (Canaud et al.2020)

Early Prediction of Adverse Clinical Events The frequent occurrence of adverse events associated with dialysis treatment underlines the risk of chronic kidney disease that appears to increase during periods of in-center hemodialysis. Real-time monitoring of patients' safety-related markers is an increasingly relevant issue. Algorithms can be used for predicting adverse events such as collapse using patient-generated data, acute hemodynamic compromise as observed in hemodialysis, and decrease in treatment time as observed in hemodialysis. In the following section, we describe these examples of how AI-based adverse events are predicted before they occur during the course of dialysis treatment. AI for all proposed systems is based on classifiers and decision trees. (Burlacu et al.2020)

7. Discussion

All forms of artificial intelligence in the area of medicine, including nephrology, were developed and validated mainly for classifying images, such as the segmentation of organ inflammation in renal keratinocytes, the detection of kidney tubules in murine renal sections, the detection of chronic kidney disease in donor kidneys for transplantation, the detection of adrenal glands in antenatal MRI images, or in predicting outcomes, such as the prognosis of septic acute kidney injury and the progression of autosomal dominant polycystic kidney disease. However, the use of artificial intelligence to support clinical decision-making is still in its infancy, and examples in nephrology are scarce, even more so in terms of dialysis treatment. (Loftus et al.2022)

The use of AI in sustained low-efficiency dialysis significantly reduced the number of sessions per 100,000 admissions and decreased the number of hemodialysis catheter accesses, while AI-guided quality improvement interventions may help to alleviate the burden of sustained low-efficiency dialysis. However, the use of AI is not without challenges. The complexity of care in dialysis poses a broad palette of operational constraints, ranging from the frequency and length of dialysis sessions, patient comorbidity, age, functional and cognitive status, to logistical aspects. The increasing burden of chronic disease and frailty, together with the shortage of nursing staff and the excessive cost related to the high operator staffing required for continuous operational flow, needs to be considered when planning continuous treatment in chronically and acutely ill patient populations. Due to this complexity, it is clear that many aspects of dialysis management can be rated as complex and underconstrained problems, while AI-based algorithms work well in fully constrained and relatively well-structured problems. (Hellman et al.2021)

8. Conclusion

Artificial Intelligence consisting of various decision support system applications facilitates the decision making process of healthcare professionals to provide more precise, faster execution, and more accurate results. As a predictive tool, decision support systems avoid complications that develop because of inadequate treatment and contribute to the adaptation of preventive action plans. Dialysis treatment is a successful, but risky and costly treatment process with many clinical and administrative variables that should be monitored continuously. Artificial Intelligence is one of the technologies that simplifies the monitoring process and supports health professionals to: 1) detect sudden changes in physiological, biochemical or treatment variables, such as intradialytic hemodynamic disturbances, and prevent their adverse effects; 2) prevent treatment errors, such as incompatible drug use, and improve treatment quality; 3) reduce the workload of the healthcare team and increase the quality of working life; 4) manage costly operational processes such as staff assignment and patient scheduling; and finally improve the prediction and optimization of resource utilization, that is, beds and machines. Viewing the discussions in the previous sections together, it is clear that most of the AI applications described in this section predict the clinical events that may adversely affect the treatment process, anticipate the impact of the clinical events, and guide health professionals about how and by which criteria patients with these clinical conditions should be pre-, intra-, or post-managed and monitored according to a customized scenario. They aim to improve the quality of care by using AI-supported changes in patient care protocols and the management of human and material resources in the healthcare facility, particularly in terms of the management of logistical/operational support and resource utilization. However, healthcare professionals should take care of the possibility of conflicts between assistant-driven recommendations and patient personal choice, and act in accordance with ethical concerns, such as patient rights and duty of care. Recently, the possibility of regulatory decision-making support and use of AI-based decision support systems in health services management, especially in the functional arrangements between healthcare providers and insurers, has started to be on the agenda. This development has expanded the field of AI applications in dialysis management. (Yao et al.2021)

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