The use of artificial intelligence in nephrology

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ABSTRACT

Introduction and methods

Artificial Intelligence(AI) is a relatively new branch of science that studies the display of intelligent behavior by machines and its use in advanced analysis and computation. Due to the potential use of AI, it has also been introduced into medicine and nephrology.

The following article is an analysis of the current knowledge on the potential of AI in nephrology and its relevance to clinicians based on the latest publications contained in the PubMed and Google Scholar databases.

Stage of knowledge

AI found its application in the prognosis of the development of IgA nephropathy thanks to the use of a neural network, which by analyzing the results of research and the drugs used in a large group of patients has learned to detect patients at high risk of developing severe complications at the beginning of the disease. What is more, AI makes it possible to detect DKD earlier and delay renal replacement therapy. In patients undergoing hemodialysis, artificial intelligence developed a model that calculated the appropriate duration of the procedure and adjusted drugs to control blood pressure. Another example of the use of AI is its use in relation to patients undergoing kidney transplantation. The AI calculates the beneficial concentration of an immunosuppressive drug specifically for a given patient, which allows clinicians to limit adverse effects.

Summary

AI is a breakthrough technology that is constantly being developed. Despite the high cost of implementing this technology, it is believed that it could represent the future of medicine and be a new way in treatment techniques and in the early detection of diseases in nephrology.

INTRODUCTION

The term "Artificial Intelligence" (AI) was first introduced in 1956 by John McCarthy, although its topic had been discussed somewhat earlier. This field has found wide application in everyday life, and over time has become one of the most promising tools of today. The possibilities of artificial intelligence are used in transport, aviation, agriculture, information technology and in many other disciplines, including, of course, medicine.

Kidney disease is one of the most common problems facing our society. This is due to the presence of many etiological factors such as diabetes, hypertension, obesity, which are more and more common today. Both acute and chronic kidney disease are a serious problem that more and more people around the world have to contend with. That is why it is so important to search for new aids and methods that could improve the recognition process and enable predicting the progress of various pathological processes.

One of the newest ideas is the use of artificial intelligence in nephrology. Research has commenced on the possibilities of using AI techniques in the diagnosis, treatment and assessment of the advancement of kidney diseases. Due to the large number of nephrological patients, this is one of the most promising aid ideas on a global scale. Given that many kidney diseases are painless, more and more warning technologies are needed to prevent kidney failure [1,2].

Due to the growing interest in AI, we looked at the potential of AI in nephrology and its relevance to clinicians. For this purpose, we used the latest publications contained in the PubMed and Google Scholar databases using the following keywords: artificial intelligence; nephrology; AI; dialysis.

WHAT IS ARTIFICIAL INTELLIGENCE?

The concept of artificial intelligence is characterized by a huge variety of definitions. One of the most common describes it as the field of science and engineering related to the computation and understanding of what is called intelligent behavior, and the field concerned with the creation of artifacts that display this behavior. For a better understanding of the issue, it can also be defined as the intelligence displayed by artificial devices. In recent times, a significant increase in interest in this field of science has been observed, which is primarily related to the development of new technologies and the world's demand for newer and newer solutions to facilitate the functioning in the 21st century. The techniques used by artificial intelligence can have an impact on many areas of science, especially medical sciences. Thanks to the ability to analyze complex medical data, it has become a potential device for, among others to make accurate diagnoses and search for the most appropriate methods of treatment, and thus ultimately to solve various problems and clinical dilemmas [3].

The constant evolution of artificial intelligence, research and continuous improvement have made it a great opportunity to improve healthcare, especially in terms of its digitization. The use of artificial intelligence brings great prospects not only for the medical arts, but also for every field of medical science. Despite the high costs associated with the introduction of new technologies to medicine, it may turn out to be a breakthrough in the effectiveness of the diagnostic and therapeutic process and in increasing the safety and efficiency of healthcare around the world [4].

THE USE OF AI IN NEPHROLOGY

THE USE OF AI IN THE DIAGNOSIS OF PROGRESSIVE IGA NEPHROPATHY

IgA nephropathy, formerly known as Berger's disease, is a chronic autoimmune kidney disease first discovered in France 50 years ago. It is the most common primary nephritis globally. The pathogenesis of this disease is based on the deposition of IgA in the glomerular mesangium, resulting in the development of chronic kidney disease, which in 10%-60% after 10 years, and in 20% of patients within 40 years, leads to end-stage renal failure [5,6]. Epidemiologically, nephropathy develops most frequently in the Asian population, and the majority of the disease is sporadic, although some families with a familial occurrence have been registered. It should be remembered that the course of IgA nephropathy is highly variable, both in terms of clinical symptoms and disease progression. There are patients who will develop a mild course of the disease, while others will experience deterioration of renal function requiring renal replacement therapy. In many cases, nephropathy is subclinical, and patients are diagnosed only after long-term effects of the disease such as hematuria, proteinuria, or even kidney failure [7].

It is the unpredictability of IgA nephropathy that makes it difficult for physicians to predict the course of individual patients. It is difficult to judge whether a patient will develop disease progression and how quickly, or whether the course will be mild and not lead to kidney failure. This created an opportunity to search for modern methods of predicting and assessing the progress of this disease. Artificial intelligence has just found application here [8].

An artificial neural network has been developed that can predict the progression of IgA nephropathy using specific patient data. A specific group of patients was tested, in which the input data of the network were: age, sex, systolic and diastolic blood pressure, the amount of

prescribed antihypertensive drugs, proteinuria and serum creatinine concentration. Then, the network was trained using the "pocket knife" method, which resulted in the identification of patients at high risk of progressing IgA nephropathy. Until now, the physician has not been able to determine at the beginning of the diagnosis which patient will develop progressive IgA nephropathy and which will not. Thanks to the creation of this neural network, it became possible. To prove the plausibility of the new invention, these results were then compared to the predictions of several experienced nephrologists. It has been proven that artificial intelligence is able to predict disease progression in more patients than specialists [9].

AI AND DIABETIC KIDNEY DISEASE

Diabetic Kidney Disease (DKD) is a complication of diabetes mellitus leading to kidney damage as a result of chronic hyperglycemia. The prevalence of DKD increases with the prevalence of diabetes in society [10,11]. Unfortunately, this ailment has become a disease of civilization, and the obesity epidemic, which is one of the most serious problems of the 21st century, also played its part in it. [10]. DKD develops in 30% of people with type 1 diabetes and in 40% of people with type 2 diabetes [12,13]. What is more, It is the most common cause of hemodialysis [14].

To date, the most important prognostic factor for the progression of DKD is microalbuminuria. However, efforts are being made to develop a method that would allow faster and more accurate detection of disease progression. It was for this purpose that the possibilities of artificial intelligence and machine learning Big Data were used. Based on electronic medical records, a study was conducted on patients with diabetes, in which, using various clinical features, data from documentation and the possibilities of Big Data, AI determined which patients are stable and who will deteriorate. The more parameters were introduced, the more precise the predictive model turned out to be. This discovery made it possible to intervene earlier in the disease progression and it gave a chance to postpone renal replacement therapy in patients with DKD [15].

THE IMPACT OF AI ON DIALYSIS:

a) HEMODIALYSIS

Hemodialysis is a procedure whose main goal is to "purify the blood". It consists in removing unnecessary substances from the blood, i.e. metabolic products and excess water. All this is possible thanks to hemodialysis machines, commonly referred to as "artificial kidneys". They have become the point of many studies and improvements because they are devices that save human life [16,17]. The hemodialysis process is quite complicated and has many consequences, therefore artificial intelligence has proved to be useful here in many ways.

Blood pressure and fluid volume monitoring are the primary tools for a physician to assess the effectiveness of dialysis. However, this is not the simplest of tasks, and even a challenge for nephrologists. Hypertension is common in dialysis patients and is more often seen when starting dialysis treatment [18]. Unfortunately, high blood pressure and fluid overload significantly increase cardiovascular risk and mortality in these patients [19]. The control of these parameters is possible in many ways, such as an appropriately selected dialysis prescription, dietary recommendations or the inclusion of appropriate medications. However, when used alone, neither of these methods gives the expected results. It is still very difficult for a nephrologist to adjust all these elements so that the dialysis efficiency parameters are correct. Therefore, hope for the precise refinement of all elements is brought by the possibilities of artificial intelligence. For this purpose, an artificial neural network was developed, which with the participation of 60 variables can predict the SBP patient's heart rate and weight after dialysis for each dialysis session. With this invention, it is possible to reduce the risk of cardiovascular events and mortality in hemodialysis patients [20].

One of the most serious problems that hemodialysis patients with end-stage renal disease have to deal with is anemia. Treatment of anemia in these patients remains a major challenge for the nephrologist. Therefore, the possibilities of artificial intelligence were used here and the Anemia Control Model (ACM) was developed using an artificial neural network with clinical data of patients. In this way, hemoglobin values   in patients were predicted with greater accuracy, which allowed for a more precise determination of the doses of erythropoiesis-stimulating agents (ESAs). This is a significant discovery due to the significant side effects of these drugs. Thanks to AI, it is possible to reduce the doses of

ESA in order to reduce their adverse effects, but also to reduce the cost of purchasing these drugs [21].

b) PERITONEAL DIALYSIS

Peritoneal dialysis is one of the methods of renal replacement therapy in which dialysis fluid is introduced into the peritoneum, thanks to which, by diffusion, substances are exchanged between the blood and the dialysate [22]. After all, the fluid is expelled. Peritoneal dialysis affects approximately 11% of dialysis patients [23]. This method is unfortunately burdened with complications. One of them is peritonitis, which often causes dialysis discontinuation and is also characterized by high mortality [24,25].This condition can be caused by a wide range of both gram-positive and gram-negative bacteria. Unfortunately, the waiting time for the results of microbiological tests is often long and it is necessary to initiate empiric antibiotic therapy in these patients [24,25].

That is why we are looking for better and better methods to improve the diagnosis of peritonitis, which would enable precise and specific selection of the appropriate treatment. Artificial intelligence methods have been applied here, which, using the potential of the immune system, allowed to create an immune fingerprint. A study was carried out which found that individual groups of microorganisms induce specific and specific immune responses in humans, which can be described as a type of biomarker. Using artificial intelligence tools we are able to find biomarkers specific to a specific inflammatory reaction and estimate which specific pathogens are involved in peritonitis, and thus select the appropriate antibiotic therapy much faster [26]. Artificial intelligence has an advantage over traditional diagnostic methods because they take more time and additionally carry the risk of errors[27].

AI AND KIDNEY TRANSPLANTATION

Artificial intelligence has also found application in kidney transplantation. Tacrolimus is a known and common drug used in the immunosuppressive treatment of patients after kidney and other organ transplants [28]. Unfortunately, it is a drug with a very narrow dosage range. Too low doses may cause transplant rejection, while too high doses are toxic to the organism [29,30]. Caution should be exercised and patients should be monitored regularly for tacrolimus levels as there is a large variability in the tolerance of each individual.That is why an artificial neural network has been developed to predict the appropriate dose of

tacrolimus individually for a patient. A study was conducted in which the network inputs were age, gender, BMI, creatinine, CYP3A5 * 3 and others, while the starting data was the bioavailability of tacrolimus. It has been proven that women have greater bioavailability than men, and it tends to increase with age [31]. Literature reports that the use of artificial intelligence in transplantation will bring many benefits. This will certainly allow for more efficient and accurate monitoring of patients after kidney transplantation, especially those at a higher risk of incorrect dosing of tacrolimus. In this way, it will also have a positive effect on reducing the incidence of acute transplant rejection. In addition, it is a relatively cheap method compared to the AUC calculations used so far [32].

SUMMARY

Artificial intelligence has found many applications in the modern world. It has become a breakthrough tool for medicine. AI techniques offer great opportunities in nephrology. It was used in the diagnosis and treatment of, inter alia, IgA nephropathy, diabetic kidney disease, and in dialysis and kidney transplantation. Thanks to AI, it is possible to more accurately predict the progression of certain diseases or to implement antibiotic therapy faster and more precisely in order to prevent complications caused by dialysis. It is also of utmost importance to be able to closely monitor kidney transplant patients and prevent transplant rejection. The literature on which we were based in our work proved that artificial intelligence is only just developing in nephrology. The potential of this invention has so far been known only to a small extent. This field still hides many secrets that will undeniably still surprise us.

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