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Wavelet Coherence as a Tool for Markers Selection in the Diagnosis of Kidney Disease

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ABSTRACT

A study was conducted on the relationship between different markers in the diagnosis of kidney disease. As such markers were considered: glomerular filtration rate, renal arterial blood flow velocity, resistive renal artery index. The relationship between the markers was investigated taking into account the return and body mass index of patients. This allows you to identify various risk groups. We used wavelet coherence to explain the results of the relationship between markers and visualize the research process. The expediency of using the wavelet methodology for conducting intellectual diagnostics for the detection of kidney diseases is shown. As a prevailing preference in the study of markers for the diagnosis of kidney disease, a body mass index was determined. The results of various experiments are presented.

Key words: Diagnostic, Glomerular Filtration Rate, Renal Arterial Blood Flow Velocity, Resistive Renal Artery Index, Wavelet Analysis, Wavelet Coherence, Kidney.

1. INTRODUCTION

Data analysis is one of the tools that help to research and understand various processes, phenomena, events [1]-[5]. Such an analysis can be qualitative and quantitative. To do this, use various methods and approaches. As a result of such an analysis, additional information can be obtained. Additional information is also a source of data for analysis.

As data for their analysis, you can use various sets of indicators, parameters. The scope of such an application can be varied. One of the key areas for data analysis is medical research [6], [7]. This is due to the fact that in this case, a diagnosis of human health is carried out, possible diseases are identified.

Among various medical studies, it is necessary to highlight the study of the internal organs of a person. The peculiarity of such a study is determined by the fact that we can study the internal organs for a number of indicators – markers. A set of markers is special for each study. There can be several such markers. In this case, it is important to know which group of markers needs to be investigated. These questions are the subject of this article.

We will consider the analysis of various markers in the diagnosis of kidney disease. Such a choice is based on the importance of the functioning of the kidneys for the human body, the difficulty of conducting such studies, the difficulty of choosing markers prevailing in the study. It should also be noted about the increase in the number of diseases that are determined by the functioning of the kidneys.

It should also be noted that consideration of various methods and approaches for the analysis of primary data helps to better understand the processes that are being investigated. It also allows you to define new procedures in the diagnosis of kidney disease, taking into account various markers. The answers to such questions are the goal of this study.

2. MATERIALS AND METHODS

2.1. Markers for the diagnosis of kidney disease

Diagnosis of kidney disease is one of the areas of medical research. To do this, you can use various markers that allow for high-quality and reliable diagnosis of various kidney diseases.

In [8], various markers for the diagnosis of kidneys are considered. Particular attention is paid to markers that help determine chronic kidney disease. The authors also note that the plasma placental growth factor is the most effective marker. But this marker can only be used for women.

M. Ostermann and M. Joannidis use markers such as serum creatinine; anti-diuretic hormone; glomerular filtration rate; the level of protein that binds fatty acids to the liver; neurophilic gelatinase-associated lipocalin [9]. At the same time, the authors share such markers for different types of kidney diseases.

A. S. Levey, C. Becker and L. A. Inker examine the relationship between glomerular filtration rate and albuminuria for the diagnosis of kidney disease [10]. This approach allows you to take into account various factors that indicate kidney disease.

The work [11] also analyzes various markers for the diagnosis of kidney disease. Such an analysis is based on pairwise correlation analysis for various markers.

The authors of the study [12] compare the glomerular filtration rate and the blood flow velocity in the renal artery for the diagnosis of kidney diseases. Such a comparison is also paired, where only the indicated markers are considered.

Thus, it should be noted that various markers are used to diagnose kidney diseases. This allows analysis and diagnosis for various kidney diseases. However, it should also be noted that other markers are not considered in this aspect. For example, it is important to consider such simple markers as the patient’s age (or duration of illness), body mass index. This is due to the fact that simple markers can be indicators of a quick diagnosis of a possible disease. It is also important to know the mutual influence of different markers for different indices of body weight or age of patients. This allows you to choose the most optimal treatment method, taking into account possible complications and other types of diseases.

At the same time, various tools for analyzing primary data can be used to diagnose kidney diseases.

2.2. Primary data analysis tools for diagnosing kidney disease

Markers for the diagnosis and analysis of kidney disease can be represented in different data sets. These sets are the primary data to be processed.

For the analysis of these markers, as a rule, various statistical methods are used. Among these methods, it is worth highlighting: correlation analysis [13], data classification methods [14], analysis of variance [15]. The classical methods of descriptive statistics [16] are also used.

For the diagnosis of kidney disease, the theory of fuzzy sets and the theory of neural networks are also used [17], [18]. This approach allows you to classify various kidney diseases in the early stages of diagnosis. It also allows predictive analysis for various types of kidney disease.

However, a comparative analysis is also necessary for various markers, taking into account some factor. This can be done using the ideology of wavelets [19], [20]. For this analysis, the wavelet coherence method is used [21], [22].

Wavelet coherence makes it possible to cross-analyze between markers that are compared. At the same time, we can rank the markers by some factor. Then we can make a comparison between the markers with this factor in mind. This approach is promising in the study of markers for the diagnosis of kidneys. At the same time, wavelet analysis can be used as a tool to consider prevailing preferences in the study of markers in the diagnosis of kidney disease.

2.3. Data for analysis

For our study, we use data from a group of 210 patients who have different kidney diseases. These data were considered in [23], [24]. As individual markers we consider: glomerular filtration rate, renal arterial blood flow velocity, and renal artery resistance index.

Glomerular filtration rate (PSV) allows you to quantify the degree of stenosis.

Blood flow in the renal artery (GFR) determines the functionality of the kidneys.

The resistive renal artery index (RI) characterizes the vascular hemodynamics of the renal arteries.

We also review the age and body mass index of patients.

Classical studies examine the relationship between PSV, GFR, and RI. This relationship is considered in pairs. But we noted above that it is important to know this relationship regarding the age and body mass index of patients. At the same time, we are reviewing PSV, GFR, and RI for each kidney (right – Rt and left – Lt).

Table 1 shows the main statistical characteristics for the markers that we are considering [23], [24].

Table 1: The statistical characteristics of the markers, which are investigated

Markers	Statistical characteristics*			
	minimum	maximum	mean	Standard Deviation
GFR Rt	37.70	80.70	60.44	10.61
GFR Lt	23.9	75.55	48.82	12.47
PSV Rt	25.1	42.9	34.64	5.19
PSV Lt	19.1	39.9	29.40	5.98
RI Rt	0.45	0.87	0.69	0.10
RI Lt	0.44	0.81	0.62	0.08

significance level 0.95

From table 1 it is seen that all the data differ from each other and are statistically significant.

The age of patients is from 9 to 76 years. Body mass index is the 61-86 kg [23], [24].

3. RESULTS AND DISCUSSION

Consider the relationship between different markers (PSV, GFR, and RI) taking into account the age and body mass index of patients. For this, we use the ideology of wavelet coherence and the method described in [19].

Below are the values of wavelet coherence. Each figure shows:

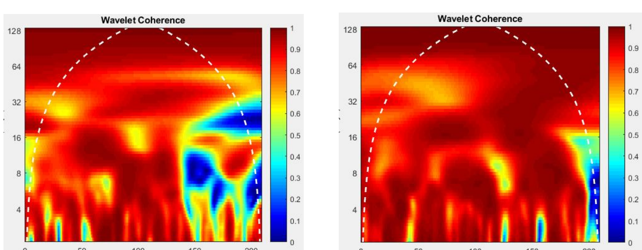
– along the axis x of the patient age value. These values are represented by serial numbers in accordance with the number of patients in the sample;

– along the axis y – the depth of the relationship between the studied data values, for which we determine the values of wavelet coherence;

the dashed white line limits the region of reliable values of wavelet coherence (with a confidence level of at least 0.95). These values are inside the dashed line;

the figure also shows a scale for analyzing the significance of wavelet coherence data. Such data for clarity also have color values.

Figure 1 shows the wavelet coherence between the PSV and GFR for the right kidney, taking into account the age of the patients (Figure 1a), taking into account the patient's body mass index (Figure 1b).

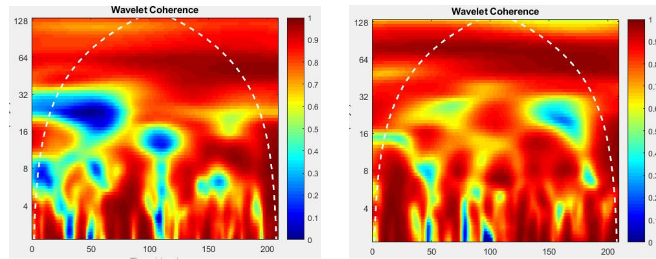


a) b)

Figure 1: Wavelet coherence between PSV and GFR for the right kidney, taking into account the age of the patients (a), taking into account the patient's body mass index (b)

The data in figure 1 show that the relationship between PSV and GFR for the right kidney, taking into account the patient's body mass index is more significant and representative. It should also be noted that the relationship between PSV and GFR for the right kidney, taking into account the age of patients, is more significant and representative for a less age group of patients.

Figure 2 shows the wavelet coherence between the PSV and GFR for the left kidney, taking into account the age of the patients (Figure 2a), taking into account the patient's body mass index (Figure 2b).



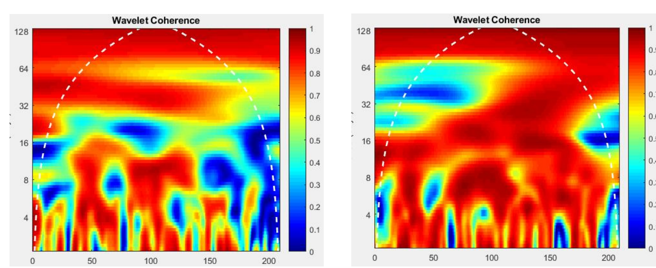
a) b)

Figure 2: Wavelet coherence between PSV and GFR for the left kidney, taking into account the age of the patients (a), taking into account the patient's body mass index (b)

We can also see that the relationship between PSV and GFR for the left kidney, taking into account the patient's body mass index, is more significant and representative. The relationship between PSV and GFR for the left kidney, taking into account the age of the patients, is more significant and representative for the older age group of patients.

Thus, the prevailing preference for analyzing the relationship between PSV and GFR in the diagnosis of kidney disease is the patient's body mass index.

Figure 3 shows the wavelet coherence between the PSV and RI for the right kidney, taking into account the age of the patients (Figure 3a), taking into account the patient's body mass index (Figure 3b).

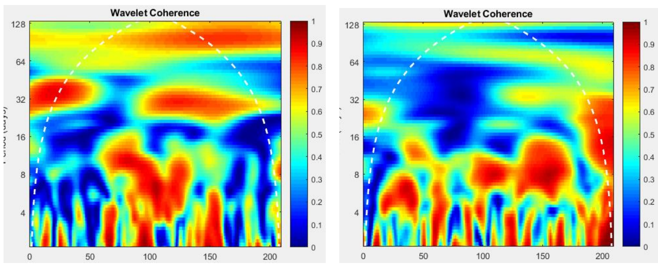


a) b)

Figure 3: Wavelet coherence between PSV and RI for the right kidney, taking into account the age of the patients (a), taking into account the patient's body mass index (b)

The relationship between the PSV and RI for the right kidney (see Figure 3) is not as stable as between the PSV and GFR for the right kidney (see Figure 1). However, the relationship between PSV and RI for the right kidney, taking into account the patient's body mass index, is more significant and representative. The relationship between PSV and RI for the right kidney, taking into account the age of patients, is more significant and representative for the average age of patients.

Figure 4 shows the wavelet coherence between the PSV and RI for the left kidney, taking into account the age of the patients (Figure 4a), taking into account the patient's body mass index (Figure 4b).



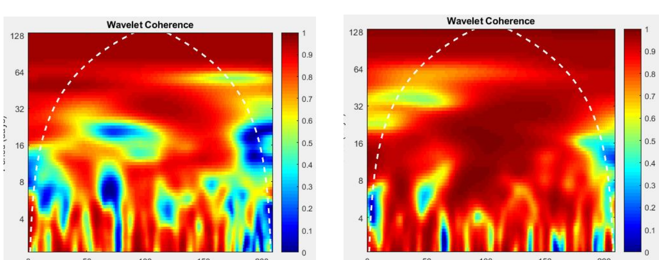
a) b)

Figure 4: Wavelet coherence between PSV and RI for the left kidney, taking into account the age of the patients (a), taking into account the patient's body mass index (b)

The coherence wavelet values between PSV and RI for the left kidney are less significant than for the data in Figure 1 – Figure 3. The relationship between PSV and RI for the left kidney, taking into account the body mass index for different groups of patients, is evenly distributed. The relationship between PSV and RI for the left kidney, taking into account the age of patients, is more significant for the middle age group. At the same time, the relationship between PSV and RI for the left kidney, taking into account the body mass index, is more representative and significant.

Thus, the prevailing preference for the analysis of the relationship between PSV and RI in the diagnosis of kidney disease is the patient's body mass index.

Figure 5 shows the wavelet coherence between the GFR and RI for the right kidney, taking into account the age of the patients (Figure 5a), taking into account the patient's body mass index (Figure 5b).



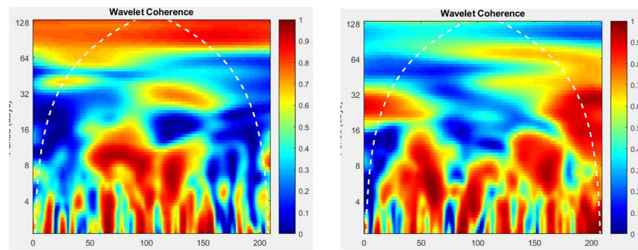
a) b)

Figure 5: Wavelet coherence between GFR and RI for the right kidney, taking into account the age of the patients (a), taking into account the patient's body mass index (b)

The relationship between the GFR and RI for the right kidney, taking into account the body mass index, is more significant and representative. The relationship between the GFR and RI for the right kidney, taking into account the age of the patients, is less significant and representative.

The relationship between the GFR and RI for the right kidney is evenly distributed among all patient groups.

Figure 6 shows the wavelet coherence between the GFR and RI for the left kidney, taking into account the age of the patients (Figure 6a), taking into account the patient's body mass index (Figure 6b).



a) b)

Figure 6: Wavelet coherence between GFR and RI for the left kidney, taking into account the age of the patients (a), taking into account the patient's body mass index (b)

The data in Figure 6 inherits the data in Figure 4. We see that the wavelet coherence between the GFR and RI for the left kidney values are evenly distributed, taking into account the body mass index. These values are more significant and representative. The wavelet coherence between the GFR and RI for the left kidney values, taking into account the age of the patients is most significant for middle-aged patients.

However, the prevailing preference for analyzing the relationship between GFR and RI in the diagnosis of kidney disease is the patient's body mass index.

It should also be noted that the results correlate with classical approaches that are used in the diagnosis of kidney disease. At the same time, wavelet analysis allows us to expand the boundaries of research and diagnosis of kidney diseases. In particular, wavelet analysis allows you to identify risk groups based on the age and body mass index of patients.

Thus, wavelet coherence can be used as a tool for analyzing prevailing preferences in the study of markers for the diagnosis of kidney disease.

4. CONCLUSION

Diagnosis of kidney disease is one of the tools for timely assistance in the treatment of related diseases. In this case, it is important to have a high-quality diagnosis, which allows you to make timely conclusions.

Wavelet coherence is a tool that helps explain and understand the relationships between the markers studied in kidney diagnosis. This fact distinguishes this work from classical studies, expands the possibilities of diagnosis. In particular, the work shows the relationship of various markers in the diagnosis of kidneys taking into account the age and body mass index of patients. This allows a qualitative diagnosis of kidney disease, taking into account possible risk groups.

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