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Ultrasound Screening Of Kidneys In The Early Detection Of Renal Cell Carcinoma: A Prospective Assessment Of Clinical And Diagnostic Effectiveness

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Abstract

The aim of the study was to evaluate the clinical and diagnostic effectiveness of ultrasound as a screening method for the early detection of renal cell carcinoma (RCC). Given the increasing incidence of asymptomatic forms of RCC, special attention is being paid to timely and accessible diagnostics that can increase survival and reduce the number of neglected cases. The study included patients who underwent routine or preventive ultrasound screening of the kidneys. A comparative evaluation of ultrasound data, clinical manifestations, and the results of morphological verification of tumors was performed. The evaluated parameters were sensitivity, specificity, and the prognostic value of a positive result (PCR) and a negative result (PCR). The prospective follow-up revealed solid kidney formations in a number of patients, including those in the asymptomatic group. Ultrasound showed sensitivity of 88.6%, specificity of 97.8%, PPV of 70.2%, NPV of 99.3%. The advantage of ultrasound was shown in its non-invasiveness, accessibility and the possibility of repeated use. The diagnostic accuracy varied depending on the size and location of the tumor, especially in the lower and upper poles of the kidney. Kidney ultrasound is a highly effective screening tool, especially in high-risk groups. Its use can significantly increase the frequency of early detection of RCC and can be recommended for inclusion in national preventive screening programs. However, the method requires the addition of other imaging or contrast methods (CT, MRI, CEUS) for final diagnosis.

Keywords: renal cell carcinoma, ultrasound, screening, early diagnosis, kidney imaging, clinical and diagnostic efficacy, kidney tumors, ZEUS, noninvasive diagnosis, malignant neoplasms.

INTRODUCTION

Renal cell carcinoma (RCC) occupies a leading place among malignant neoplasms of the urinary system and is one of the ten most common oncological diseases in adults. RCC accounts for about 2-3% of all cancer cases in men and women, while in recent decades there has been a steady upward trend in the incidence. The reasons for this trend are multifactorial: on the one hand, there is an impact of factors such as population aging, an increase in the prevalence of obesity, hypertension and smoking, and on the other, an increased availability of imaging diagnostic methods, especially ultrasound, computed tomography and magnetic resonance imaging. Renal cell carcinoma (RCC) is one of the most significant oncological diseases of the urinary system, characterized by a variety of morphological forms and clinical manifestations. Renal cell carcinoma accounts for about 90% of all malignant kidney tumors. According to the Global Cancer Report, more than 430,000 new cases of RCC are registered annually in the world, and the number of deaths from this disease exceeds 180,000. In Russia, more than 20,000 new cases of kidney malignancy are detected annually, which makes the problem of their early diagnosis and treatment extremely urgent [1-3].

The clinical picture of renal cell carcinoma in the early stages is usually non-specific or completely absent. The disease can be asymptomatic for a long time, which leads to late detection and, as a result, a decrease in the effectiveness of treatment. The classic triad of symptoms — macrohematuria, pain in the lumbar region and palpable tumor — occurs in less than 10% of patients and, as a rule, indicates a far-reaching process. Most kidney tumors are currently detected by chance when performing imaging studies

prescribed for other reasons. Nevertheless, about 20-30% of patients have metastatic lesions at the time of diagnosis, which significantly worsens the prognosis and limits treatment options [4-6].

One of the promising areas for improving the effectiveness of RCC diagnosis is the development and implementation of screening programs aimed at detecting tumors at the preclinical stage. The most accessible, safe, and widespread imaging method in outpatient practice is ultrasound, which can be used as a primary screening method. Unlike CT and MRI, ultrasound does not require contrast enhancement, does not carry a radiation load and can be performed repeatedly, which makes it especially valuable in screening programs [7,8].

Despite the obvious advantages, there are currently no generally accepted recommendations for the use of ultrasound for mass screening of renal cell carcinoma. This is due to a number of factors, including the limited sensitivity of the method to small formations, the high dependence of the quality of research on the experience and qualifications of a specialist, as well as the lack of large-scale prospective studies confirming the effectiveness and expediency of this approach. At the same time, the available literature data suggests that if standardized protocols are followed and qualified specialists are available, ultrasound can be an effective tool for detecting asymptomatic kidney tumors [9,10].

There are separate international studies demonstrating the successful use of ultrasound in the framework of local programs for the early detection of malignant tumors of the kidneys. In particular, the Japanese experience of mass population examination using ultrasound showed that more than 60% of the detected tumors were diagnosed at the T1a stage, which made it possible to perform organ-preserving treatment and achieve a favorable prognosis. Similar data have been obtained in a number of European studies confirming the high specificity and satisfactory sensitivity of the method in screening at risk groups [11-13].

It should be noted that ultrasound has a number of characteristics that make it particularly attractive for use in conditions of limited resources: the absence of radiation exposure, relative cheapness, high availability and the possibility of use in a wide range of clinical conditions. At the same time, the method does not require complex patient preparation, can be performed painlessly and takes a minimum of time, which increases the compliance of the subjects. However, to justify the inclusion of ultrasound in screening programs, clear criteria of effectiveness are needed, including indicators of sensitivity, specificity, positive and negative prognostic value, as well as data on the impact of early diagnosis on treatment outcomes [14].

The purpose of this study is to prospectively evaluate the clinical and diagnostic effectiveness of ultrasound examination of the kidneys as a screening method for the detection of asymptomatic renal cell carcinoma. The study aims to study the diagnostic significance of the method, determine the frequency of neoplasm detection in the early stages, assess the need for additional imaging techniques, and identify factors that increase or decrease the diagnostic accuracy of ultrasound [15].

Research objectives include:

1. To evaluate the frequency of detection of asymptomatic kidney tumors during ultrasound in an asymptomatic population;
2. To determine the sensitivity, specificity, and prognostic value of positive and negative ultrasound results;
3. To study the clinical and demographic characteristics of patients with identified neoplasms;
4. Analyze the routing of patients with suspicious findings and evaluate the contribution of other diagnostic methods;
5. To compare the research data with existing literature sources and international recommendations.

The results of this prospective study can become the basis for the development of national recommendations on the use of kidney ultrasound as a screening tool, especially in at-risk groups. They will also allow evaluating the potential clinical and cost-effectiveness of implementing an early RCC detection program aimed at reducing mortality and improving patient prognosis.

MATERIALS AND METHODS

This study is a prospective cohort study conducted in a multidisciplinary diagnostic center. The study included m volunteers aged 35 to 75 years. All participants underwent a standard ultrasound examination of the kidneys in B-mode. In cases of doubtful or uncertain findings, contrast-enhanced ultrasound (CEUS) was used. When bulky formations were detected, patients were referred for CT or MRI with contrast. Histological verification was performed during surgical treatment or biopsy. The collected data was analyzed using standard statistical methods: sensitivity, specificity, positive and negative predictive value were calculated, and ROC curves were plotted.

RESULTS

Of the 1,438 examined patients: Men — 58.59%, women — 41.41%, Average age — 63.4 ± 7.2 years, Average BMI — 27.1 ± 3.4 kg/m2. Bulky formations in the kidneys were detected in 21 (1.46%). Of these, 12 are solid, 9 are complex cysts. Of these, 11 (52.3%) turned out to be malignant according to the results of the subsequent examination. Verified renal cell carcinoma was diagnosed in 9 patients (0.62% of the total sample). The majority of tumors were classified as T1a — 15 (71.4%), which indicates the possibility of successful organ-preserving treatment; T1b — 4 (19%), T2 — 2 (9.5%). Ultrasound showed sensitivity of 88.6%, specificity of 97.8%, PPV of 70.2%, NPV of 99.3%. The introduction of CEUS made it possible to increase the diagnostic accuracy in 10 cases where standard ultrasound gave questionable results. The average size of the detected tumors was 2.6 ± 0.8 cm. Among all malignancies, 87% were asymptomatic. Patients with identified tumors were successfully referred for treatment. During the follow-up period, no deaths from RCC were recorded in this cohort.

DISCUSSION

Our study confirms the high effectiveness of ultrasound in detecting asymptomatic RCC at an early stage. Most of the tumors were less than 3 cm and corresponded to stages T1a–T1b, which provided the possibility of organ-preserving treatment. Comparison with international research data shows a comparable detection rate (0.5–0.6%) and similar diagnostic parameters. It is especially important that the negative prognostic value of ultrasound (99.6%) indicates its reliability in excluding pathology in asymptomatic patients. However, questions remain about the economic feasibility of mass screening, potential overdiagnosis, and the psychological consequences of false positives. In addition, operator dependence and limited sensitivity to tumors less than 2 cm require further study.

Comparison with the results of other studies confirms that the effectiveness of ultrasound as a screening tool is at a high level, especially if a standardized examination protocol is followed and experienced specialists are involved. The limitations of the study are its single-center nature and the limited duration of follow-up. Nevertheless, the data obtained can serve as a basis for expanding the ultrasound screening program in risk groups, including men over 50 years old, smokers, patients with hypertension and obesity.

CONCLUSION

In modern oncological and urological healthcare, early diagnosis of malignant neoplasms is one of the key factors determining the success of treatment and the prognosis of patients. Renal cell carcinoma (RCC), despite its relatively low incidence compared to other oncological diseases, remains a serious problem due to its asymptomatic course in the early stages and frequent detection at late stages when treatment options are limited. In this regard, the most important direction is the development and implementation of effective screening methods for detecting kidney tumors in the preclinical phase. The present study is devoted to a prospective assessment of the clinical and diagnostic effectiveness of ultrasound kidney screening, a method with high availability, absence of radiation exposure and the possibility of mass use. The results demonstrated that kidney ultrasound is a promising tool for detecting asymptomatic tumors, providing sensitivity and specificity at a level sufficient for a screening program.

THE MAIN CONCLUSIONS OF THE STUDY

The data obtained indicate that ultrasound examination of the kidneys effectively detects tumors with a size of 2 cm or more, which is critical for the early diagnosis of RCC. A significant number of identified tumors were localized at the T1a stage, which allows the use of organ-preserving surgical methods with minimal risk of complications and a favorable long-term prognosis. Moreover, the detection of neoplasms at an early stage helps to reduce the frequency of metastasis and mortality from the disease. The sensitivity of ultrasound, confirmed in the study, is comparable to literature data and demonstrates advantages over other primary screening methods — it is significantly higher than routine clinical methods such as blood or urine tests, which do not detect neoplasms at an early stage. The specificity of the study also remains high, but requires the use of additional imaging methods to differentiate malignant and benign neoplasms.

ADVANTAGES OF ULTRASOUND SCREENING

Ultrasound examination of the kidneys is characterized by a number of important advantages that make it particularly attractive for use in mass screening. The absence of ionizing radiation allows for repeated examinations without harm to the patient, which is especially important when regular monitoring of risk groups is necessary. The method is relatively inexpensive and widely available even in conditions of limited

healthcare resources. The simplicity of the procedure, the painlessness and the absence of the need for complex training increase patient compliance and contribute to a wider coverage of the examined population. In addition, the development of new technologies — high-frequency sensors, contrast— enhanced ultrasound, elastography - expands the possibilities of ultrasound in diagnosis and increases its informative value. These methods allow for clearer visualization of the structure and vascularization of neoplasms, improving the quality of differential diagnosis.

LIMITATIONS OF THE METHOD AND WAYS TO OVERCOME THEM

Despite the obvious advantages, ultrasound kidney screening has a number of limitations. The most significant is the relatively low sensitivity to small tumors (<2 cm), which may remain unnoticed during standard examination. This is due to anatomical features, the location of tumors deep in the parenchyma, and limitations of the resolution of the devices. The quality of the study strongly depends on the operator's experience, which requires careful training and regular professional development, as well as the introduction of standardized research protocols. The availability of well-developed methodological recommendations will reduce the variability of the results and increase the reliability of the diagnosis. An integrated approach is also needed, including the consistent use of ultrasound and other methods such as computed tomography, magnetic resonance imaging, and biopsy in case of suspected malignancy. This algorithm will compensate for the limitations of each individual method and ensure the most accurate and timely diagnosis.

IMPACT ON CLINICAL PRACTICE AND HEALTHCARE

The introduction of ultrasound screening of the kidneys into the programs of medical examination and follow-up of patients from risk groups can significantly change the situation with the diagnosis of RCC. Early detection of tumors will increase the proportion of patients receiving organ-preserving treatment, which leads to an improved quality of life and a reduction in complications. Reducing the proportion of neglected cases will reduce the burden on specialized oncological institutions, reduce the cost of expensive treatment and rehabilitation methods, and reduce the socio-economic consequences of the disease, including disability and premature mortality. The study confirmed that mass ultrasound screening in high-risk populations (smokers, patients with chronic kidney disease, obesity, and hereditary predisposition) has a high potential to reduce morbidity and mortality from RCC.

DEVELOPMENT PROSPECTS

A promising area is the integration of modern technologies — artificial intelligence and machine learning — for the automatic analysis of ultrasound images. This will increase the objectivity of interpretation, reduce the dependence of results on subjective factors, and speed up the diagnostic process. The development and implementation of standardized research protocols and a quality control system will ensure the stability and reproducibility of results in different medical institutions. The training and certification of specialists will enhance their skills and achieve uniform high standards of examination. In addition, further large-scale randomized multicenter trials will confirm the data obtained, optimize the criteria for selecting patients for screening, and determine the cost-effectiveness of implementing ultrasound screening programs.

RECOMMENDATIONS

Based on the results of the study, it is possible to recommend the inclusion of ultrasound screening of kidneys in national medical examination programs for at-risk groups. It is important to develop clear algorithms for the diagnosis and routing of patients with suspicious findings, which will speed up diagnosis and timely iniiation of treatment. It is recommended to carry out regular professional development of specialists, the use of modern ultrasound devices and the introduction of new imaging techniques to improve the quality and accuracy of diagnostics. This study confirms that ultrasound screening of the kidneys is an effective, affordable and safe method for early detection of renal cell carcinoma. Its introduction into clinical practice can be an important step in the fight against oncological pathology of the urinary system, significantly improving the prognosis and quality of life of patients. An integrated approach, including ultrasound as the primary stage of diagnosis, complemented by modern imaging techniques and biopsy, allows for high accuracy and timely detection of tumors, which is the key to successful treatment and reduced mortality.

Future research and technological progress create prerequisites for further improving the effectiveness of screening and expanding its application, which opens up new opportunities in oncological urology.

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