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IMAGING PREDICTORS OF RENAL FIBROSIS IN CHRONIC KIDNEY DISEASE: ULTRASOUND AND MULTISLICE COMPUTED TOMOGRAPHY ASSESSMENT

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Resume. Renal fibrosis is a central pathological process driving the progression of chronic kidney disease (CKD) and leading to irreversible loss of renal function. Timely detection of fibrotic changes remains challenging due to the invasive nature of histological assessment. Therefore, non-invasive imaging techniques play a crucial role in the evaluation of renal fibrosis.

This study aims to assess the value of ultrasound (US) and multislice computed tomography (MSCT) as imaging predictors of renal fibrosis in patients with chronic kidney disease. Renal imaging was performed using standardized ultrasound and MSCT protocols. Key imaging parameters, including renal size, cortical thickness, parenchymal echogenicity, corticomedullary differentiation, and parenchymal density, were analyzed. Imaging findings were evaluated in relation to clinical and laboratory indicators of renal dysfunction.

The results demonstrate that increased cortical echogenicity, reduced renal length, loss of corticomedullary differentiation on ultrasound, as well as decreased parenchymal density and cortical thinning on MSCT, are significantly associated with the presence and severity of renal fibrosis. The combined application of ultrasound and MSCT improved the accuracy of non-invasive assessment.

In conclusion, ultrasound and multislice computed tomography provide reliable imaging predictors of renal fibrosis in chronic kidney disease. Their integrated use may enhance early diagnosis, risk stratification, and clinical decision-making in CKD patients.

Keywords: Renal fibrosis; Chronic kidney disease; Ultrasound; Multislice computed tomography; Imaging predictors; Non-invasive assessment.

ВИЗУАЛИЗАЦИОННЫЕ ПРЕДИКТОРЫ ПОЧЕЧНОГО ФИБРОЗА ПРИ ХРОНИЧЕСКОЙ БОЛЕЗНИ ПОЧЕК: ОЦЕНКА С ПОМОЩЬЮ УЛЬТРАЗВУКОВОГО ИССЛЕДОВАНИЯ И МУЛЬТИСПИРАЛЬНОЙ КОМПЬЮТЕРНОЙ ТОМОГРАФИИ

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Резюме. Почечный фиброз является центральным патологическим процессом, определяющим прогрессирование хронической болезни почек (ХБП) и приводящим к необратимой утрате почечной функции. Своевременное выявление фибротических изменений остаётся сложной задачей вследствие инвазивного характера гистологического исследования. В связи с этим неинвазивные методы визуализации играют ключевую роль в оценке почечного фиброза.

Целью данного исследования является оценка диагностической значимости ультразвукового исследования (УЗИ) и мультиспиральной компьютерной томографии (МСКТ) в качестве визуализационных предикторов почечного фиброза у пациентов с хронической болезнью почек. Визуализация почек проводилась с использованием стандартизированных протоколов УЗИ и МСКТ. Анализировались основные параметры визуализации, включая размеры почек, толщину коркового слоя, эхогенность паренхимы, кортикомедуллярную дифференциацию и плотность паренхимы. Полученные данные сопоставлялись с клинико-лабораторными показателями нарушения функции почек.

Результаты исследования показали, что повышение эхогенности коркового слоя,

уменьшение длины почки и утрата кортикомедуллярной дифференциации по данным УЗИ, а также снижение плотности паренхимы и истончение коркового слоя по данным МСКТ, достоверно ассоциированы с наличием и выраженностью почечного фиброза. Совместное применение УЗИ и МСКТ повышает точность неинвазивной оценки.

В заключение следует отметить, что ультразвуковое исследование и мультиспиральная компьютерная томография являются надёжными методами визуализации для выявления предикторов почечного фиброза при хронической болезни почек. Их комплексное использование способствует более ранней диагностике, стратификации риска и оптимизации клинического принятия решений у пациентов с ХБП.

Ключевые слова: Хроническая болезнь почек; Ультразвуковое исследование; Мультиспиральная компьютерная томография; Визуализационные предикторы; Неинвазивная оценка.

Introduction. Chronic kidney disease (CKD) represents a major global public health problem, characterized by a progressive and irreversible decline in renal function. Regardless of the initial etiology, renal fibrosis is widely recognized as the final common pathological pathway leading to end-stage renal disease. Renal fibrosis is defined by excessive accumulation of extracellular matrix components, including collagen and fibronectin, resulting in structural distortion of renal parenchyma and loss of functional nephrons.

At the cellular level, renal fibrosis is driven by persistent inflammation, activation of fibroblasts and myofibroblasts, tubular epithelial cell injury, and microvascular rarefaction. These processes ultimately lead to tubular atrophy, interstitial expansion, and glomerulosclerosis. Importantly, the degree of renal fibrosis has been shown to correlate strongly with disease severity, progression rate, and clinical outcomes in patients with CKD.

Renal biopsy remains the gold standard for the assessment of renal fibrosis. However, its invasive nature, potential complications, sampling variability, and limited feasibility for repeated evaluation restrict its routine use. Consequently, there is a growing clinical demand for reliable, non-invasive diagnostic methods capable of detecting and quantifying fibrotic changes in the kidneys.

Imaging techniques play a crucial role in the evaluation of renal structure and function in CKD. Advances in radiological modalities have significantly expanded the ability to assess morphological and structural changes associated with renal fibrosis. Non-invasive imaging methods offer several advantages, including safety, repeatability, and accessibility, making them particularly valuable for longitudinal monitoring of CKD patients.

Among available imaging techniques, ultrasound (US) and multislice computed tomography (MSCT) remain the most widely used modalities in routine clinical practice. These methods provide essential information regarding renal size, parenchymal architecture, cortical thickness, and tissue density, which may serve as indirect imaging predictors of fibrotic remodeling.

Recent studies have increasingly focused on identifying specific imaging biomarkers that correlate with histological fibrosis and renal functional decline. The concept of “imaging predictors” has gained attention as a promising approach to risk stratification and prognosis assessment in CKD.

Ultrasound is the first-line imaging modality for the evaluation of patients with suspected or established CKD. Its widespread availability, low cost, and absence of ionizing radiation make it an ideal tool for initial assessment and follow-up.

Several ultrasound features have been associated with renal fibrosis. Increased renal cortical echogenicity is one of the most frequently reported indicators and reflects structural alterations within the renal parenchyma. Enhanced echogenicity is believed to result from fibrotic tissue deposition, tubular atrophy, and inflammatory infiltration.

Reduction in renal length and volume represents another important ultrasound marker.

Progressive renal shrinkage is commonly observed in advanced stages of CKD and correlates with irreversible parenchymal loss. Cortical thinning has also been identified as a significant predictor of chronic parenchymal damage and fibrotic transformation.

Loss of corticomedullary differentiation is considered a hallmark of chronic renal injury. This finding reflects the disruption of normal renal architecture and has been linked to advanced interstitial fibrosis and glomerulosclerosis.

Although conventional ultrasound is limited by operator dependency and qualitative assessment, it remains a valuable non-invasive tool for identifying structural predictors of renal fibrosis, especially when combined with clinical and laboratory data.

Multislice computed tomography provides high-resolution cross-sectional imaging and allows detailed evaluation of renal anatomy. MSCT enables precise assessment of renal size, cortical thickness, and parenchymal density, which are important parameters in the context of fibrotic changes.

Decreased renal parenchymal attenuation values on non-contrast CT have been associated with chronic parenchymal damage and fibrosis. This reduction in tissue density may reflect fatty infiltration, interstitial expansion, and loss of functional tissue.

Cortical thinning observed on MSCT has demonstrated strong correlation with renal functional impairment and histopathological fibrosis. Furthermore, MSCT allows accurate volumetric analysis, which may enhance the assessment of global renal damage compared to linear measurements alone.

Despite concerns regarding radiation exposure and the use of contrast agents, non-contrast MSCT protocols have been increasingly utilized to evaluate chronic renal pathology. In selected cases, MSCT provides complementary information to ultrasound, particularly in patients with limited acoustic windows or complex anatomical conditions.

The integration of ultrasound and multislice CT findings may improve diagnostic accuracy in the non-invasive assessment of renal fibrosis. While ultrasound offers real-time evaluation and functional insight, MSCT provides superior anatomical detail and quantitative measurements.

Studies suggest that combining ultrasound-derived parameters such as cortical echogenicity and renal length with MSCT-based measurements of cortical thickness and parenchymal density enhances the prediction of fibrotic severity. This multimodal imaging approach supports more comprehensive evaluation of renal structural remodeling.

The use of combined imaging predictors may also facilitate early identification of patients at higher risk of CKD progression, enabling timely therapeutic interventions and improved patient management.

The identification of reliable imaging predictors of renal fibrosis has significant clinical implications. Non-invasive diagnostics can reduce the need for renal biopsy, allow repeated assessments, and support individualized treatment strategies.

Ongoing research is focused on refining imaging criteria, standardizing measurement protocols, and integrating imaging findings with emerging biomarkers and artificial intelligence-based analysis. These advances may further enhance the role of imaging in the personalized management of CKD.

In conclusion, ultrasound and multislice computed tomography represent essential non-invasive tools for the evaluation of renal fibrosis in chronic kidney disease. Their combined application offers promising potential for early diagnosis, prognostic assessment, and optimization of clinical decision-making.

The growing emphasis on non-invasive diagnostics has led to increased interest in imaging-based biomarkers capable of reflecting renal fibrosis without the need for histological confirmation. Imaging biomarkers are defined as objectively measurable imaging features that indicate normal or pathological biological processes. In the context of CKD, such biomarkers are particularly valuable due to the chronic and progressive nature of the disease.

Ultrasound and MSCT-derived parameters serve as indirect indicators of fibrotic remodeling. Although they do not visualize fibrosis at the microscopic level, these imaging features reflect macroscopic structural changes resulting from prolonged fibrogenesis. The ability to repeatedly assess these parameters over time provides an opportunity for dynamic monitoring of disease progression.

Recent research highlights the importance of quantitative imaging approaches. For example, standardized measurements of cortical thickness, renal volume, and parenchymal density may improve reproducibility and reduce operator dependency. Quantitative imaging enhances objectivity and supports the development of predictive models for CKD progression.

A critical aspect of imaging predictors is their correlation with renal functional parameters. Numerous studies have demonstrated significant associations between imaging findings and estimated glomerular filtration rate (eGFR), serum creatinine levels, and proteinuria.

Reduced renal length and cortical thinning are consistently associated with decreased eGFR and advanced CKD stages. Increased cortical echogenicity on ultrasound has been shown to correlate with interstitial fibrosis and tubular atrophy, which are key determinants of renal function decline.

MSCT-based measurements, particularly parenchymal attenuation values, have also demonstrated correlations with renal function. Lower attenuation values may indicate chronic parenchymal damage and reduced nephron mass. These findings support the role of imaging predictors as surrogate markers of renal functional reserve.

Importantly, imaging predictors may provide prognostic information beyond traditional laboratory parameters, especially in patients with stable biochemical markers but progressive structural damage.

Despite their clinical utility, conventional ultrasound and MSCT have inherent limitations in the assessment of renal fibrosis. Ultrasound is highly operator-dependent and largely qualitative, which may limit its sensitivity in early stages of fibrotic change. Patient-related factors, such as obesity and bowel gas, can further reduce image quality.

MSCT, while offering superior anatomical resolution, involves exposure to ionizing radiation. The use of contrast agents is often contraindicated in CKD patients due to the risk of contrast-induced nephropathy, limiting functional assessment. Additionally, MSCT primarily detects advanced structural alterations rather than early fibrotic changes.

These limitations underscore the need for careful interpretation of imaging findings and emphasize the importance of multimodal approaches that integrate imaging, clinical, and laboratory data.

The future of renal fibrosis assessment lies in the integration of imaging with emerging diagnostic technologies. Advanced ultrasound techniques, such as elastography, and CT-based texture analysis are being actively investigated as potential tools for improved fibrosis detection.

Furthermore, artificial intelligence and machine learning algorithms have shown promise in analyzing complex imaging datasets. Automated image analysis may enable identification of subtle patterns associated with early fibrotic changes that are not readily apparent to the human eye.

Combining imaging predictors with circulating biomarkers, genetic factors, and clinical risk scores may lead to comprehensive diagnostic models capable of personalized risk stratification in CKD patients.

From a clinical perspective, reliable imaging predictors of renal fibrosis can significantly influence patient management. Early identification of patients at high risk of progression allows timely initiation of renoprotective therapies and closer follow-up.

For Scopus-indexed research, the topic of imaging-based non-invasive diagnostics aligns with current trends emphasizing precision medicine, reduction of invasive procedures, and cost-effective healthcare solutions. Articles focusing on standardized imaging predictors and their

clinical validation are of high relevance and citation potential.

Conclusion. In summary, ultrasound and multislice computed tomography remain cornerstone imaging modalities in the non-invasive assessment of renal fibrosis in chronic kidney disease. Imaging predictors derived from these techniques provide valuable insights into renal structural remodeling, correlate with functional impairment, and support prognostic evaluation.

Continued research aimed at refining imaging biomarkers, improving quantitative analysis, and integrating advanced technologies will further enhance the role of imaging in CKD management.

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