Research Progress of Ultrasonography in Diagnosis of Diabetic Nephropathy

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Abstract: Diabetic nephropathy is a common disease in clinical practice, and its incidence increases with age. Early diagnosis and discovery of diabetic nephropathy are important prerequisites for the treatment and delay of diabetic nephropathy. Ultrasonography plays an important role in early evaluation and diagnosis of diabetic nephropathy. With the development of ultrasound technology, the evaluation of diabetic nephropathy by ultrasound is generally divided into several categories, including two-dimensional grey-scale ultrasound, three-dimensional ultrasound, ultrasonic backscattering integral, color Doppler flow imaging, color Doppler energy imaging, contrast enhanced ultrasound, ultrasound elastography, etc., each of which is endowed with its own advantages and disadvantages. This article reviews the research progress of ultrasound in the diagnosis of diabetic nephropathy.

1 Preface

With the growing aging population, the incidence of diabetes increased year by year, diabetes is a common metabolic disease, which causes high blood sugar by inhibiting the production of human insulin. Long-term high blood sugar can lead to vascular lesions, and multiple target organs, such as the eyes, kidneys and nervous system, etc. will be damaged[1].Consequently, many malignant symptoms will occur. Diabetic nephropathy is one of the most common complications in diabetic patients. Due to the influence of hyperglycemia on renal metabolic function, abnormal renal arterial blood flow dynamics at all levels leads to impaired renal function in patients. 40% of diabetic patients will develop chronic renal disease. Early diagnosis and discovery of diabetic nephropathy are important prerequisites for the treatment and delay of diabetic nephropathy. Assessment of ultrasound in the early diagnosis of diabetic nephropathy development played an important role [2] .In this paper, two dimensional gray scale ultrasound, three dimensional ultrasound, ultrasound backscattering integral, color Doppler flow imaging, color Doppler energy imaging, contrast-enhanced ultrasound, ultrasound elastography and other techniques to evaluate the progress of diabetic nephropathy were reviewed.

2 Ultrasonic Technology

2.1 Evaluation of Diabetic Kidney by Two-Dimensional Gray Scale Ultrasound

Schujeger J et al. [3] found that, before the occurrence of renal dysfunction, patients with diabetic nephropathy had developed pathophysiological abnormalities, such as increased glomerular intracapsular pressure glomerular filtration rate (GFR), and increased renal volume under the stimulation of hyperglycemia, hyperinsulinemia and a variety of cytokines. Early diabetic nephropathy can be considered when the renal volume exceeds 170 cm 3 in diabetic patients [4].The renal volume of diabetic nephropathy patients in clinical stage still increased, while the renal volume of end-stage diabetic nephropathy patients decreased significantly. Therefore, renal volume can be taken as the key point of early evaluation when ultrasound is used in the diagnosis of diabetic nephropathy. Two-dimensional ultrasound measures the renal length diameter, anteroposterional diameter and left-right diameter through the renal hilum, and then the formula π/6

× length diameter × anteroposterional diameter × left-right diameter (cm) is used to calculate renal volume. This formula is simple and practical, and is still used today [5].

2.2 Evaluation of Diabetic Kidney by Three-Dimensional Ultrasound

Since diabetic nephropathy can lead to increase of renal volume in the early stage, it is of certain significance to include morphological indexes reflecting renal volume changes in the prediction model, and three-dimensional ultrasound can accurately reflect renal volume [6].In the study by Li Nan et al., three-dimensional ultrasound was used to obtain renal volume. Combined with the clinical data of patients, logistic regression was used to construct the differential diagnosis prediction model equation. It was found that the right kidney volume index in the DN group was higher than that in the NDRD group, and the difference was statistically significant [7].Three-dimensional ultrasound can, by the accurate measurement of renal parenchyma volume, reflect the size of the kidney, which can provide information on illness development of diabetic nephropathy patients with the volume of a more accurate quantitative indicators. Quantitative measurement for the volume of kidney enjoys a good accuracy, repeatability through the full and accurate imaging to obtain accurate volume parameter.It provides a more accurate volume quantitative index for the development of nephropathy. At the same time, 3D ultrasound can be used to clearly display the surface characteristics, three-dimensional shape and the spatial structure relationship between the lesion and adjacent organs and tissues. It has made rapid progress in clinical application.

2.3 Evaluation of Diabetic Kidney by Color Doppler Flow Imaging

In the early stage of diabetic nephropathy, there is no significant change in the urine trace protein, urine protein excretion and excretion rate, but at this time, the kidney will be enlarged and the blood flow resistance of all renal arteries will change, so that the hemodynamics of the kidney blood vessels will be changed, and ultrasound can be used to diagnose the disease [8, 9].Color doppler ultrasound images for normal healthy people show renal artery blood flow spectrum at all levels for high-speed low-resistance type velocity curve. Diabetic nephropathy patients with renal pathological changes, glomerular capillary basement membrane thickening, developed into a state of high filtration. The permeability was changed as the glomerular capillaries continue to dilate. Consequently, luminal stenosis, glomerular and capillary was blocked, vascular resistance increases, the diastolic blood flow at a slower pace, glomerular sclerosis of these pathological changes results in lower diastolic blood flow velocity and low perfusion imaging characteristics, high resistance. When the disease deteriorates, blood flow in the kidney can be reduced, and blood flow signals in the arcuate arteries and interlobar arteries can disappear. Blood flow signals change more and more obviously with the aggravation of the disease, which is of great significance for the early diagnosis, serious analysis and intervention treatment of the disease.

2.4 Evaluation of Diabetic Kidney by Elastography

All biological tissues have the basic property of hardness or elasticity. The same biological tissues or different biological tissues have obvious differences in the characteristics of elasticity under different physiological and pathological states. Elastography is to stimulate the tissue, and the distribution of strain, shift and velocity of the tissue will change in accordance with specific physical laws. By applying this concept to ultrasonic imaging and combining with digital signal processing technology, accurate changes in the internal tissues can be obtained to reflect the elastic characteristics of the tissue. Application of ultrasound elastography technology include qualitative and/or half quantitative ultrasound elasticity imaging and quantitative ultrasound elasticity imaging techniques, the former is also called static and (or) of quasi static ultrasound elasticity imaging technology, mainly through the contrast group in the pressure before and after the pressure of the ultrasonic signal, and the organization of strain, and its implementation of colour coding imaging is analyzed. Red indicates that the hardness of the tissue to be tested is lower than that of the control tissue, green indicates that the hardness of the tissue to be tested is equal to that of the control tissue, and blue indicates that the hardness of the tissue to be tested is harder than that of the control tissue. Real-time shearwave elastography (SWE) can also be used in patients with diabetic

nephropathy to deform or displace the target tissue in the region of interest for estimation of its elasticity and hardness from the dynamic displacement of the target tissue. Qiu et al. [10] studied and analyzed the difference and correlation between Young's modulus of SWE parameter and 99m Tc DTPA renal dynamic imaging in detecting renal function in 62 patients with diabetic nephropathy, and found that SWE had high diagnostic significance in the diagnosis of renal function impairment in patients with diabetic nephropathy. It is feasible and reliable to be used in diagnosis of diabetic nephropathy and evaluation of renal function. It has important clinical significance for the early diagnosis and treatment of diabetic nephropathy.

2.5 Evaluation of Diabetic Kidney with Contrast-Enhanced Ultrasound

Contrast-enhanced ultrasound (CEUS) imaging technology is widely used in the diagnosis and treatment of all kinds of kidney diseases. It can display the blood flow of tiny vessels and even capillaries, and can quantitatively, objectively and accurately analyze the renal cortical microcirculation blood perfusion. Li et al. selected 78 subjects for ultrasound and contra-enhanced ultrasound examination to study the feasibility and clinical application value of relevant parameters in the evaluation of early renal function changes in diabetic nephropathy patients. It has been found that CEUS can accurately evaluate the early renal cortical microcirculation blood perfusion in diabetic patients, and can sensitively reflect the early renal hemodynamics and renal function changes in diabetic nephropathy patients[11].In the future, ultrasonic imaging technology may be applied for prediction of early diabetic nephropathy blood flow ultrafiltration, and evaluation of the technology in the middle-late stage of diabetic nephropathy perfusion and ultrasonic technology has greater potential than others. With the continuous development of modern medical technology, the emergence of all kinds of ultrasound machines, as well as the development and application of ultrasound contrast agents, contrast-enhanced ultrasound technology will also play an increasingly important role in the early diagnosis of diabetic nephropathy and the assessment of disease progression [12].

2.6 Evaluation of Diabetic Kidney by Color Doppler Energy Map

Color Doppler Energy Imaging (CDEI) is the scattered signal of flowing red blood cells, integral processing, again pseudo Color coding, it is related to the number of flowing cells, which not only show the large artery and vein branches in the kidney blood vessels. The arcuate artery and interlobular artery of renal parenchyma are also very clear. Patients with diabetic nephropathy have high glomerular filtration rate, high glomerular perfusion and high internal pressure. With the development of the disease, the glomerular capillary basement membrane was diffusely thickened, the vascular wall endothelial was damaged and proliferated, the lumen was occluded and sclerosis, and the renal arteries and branches developed atherosclerosis. The renal artery injury caused renal blood supply insufficiency, which could reflect the corresponding changes of different degrees on CDEI images. Color doppler energy diagram can be used to analyze renal blood flow in patients with diabetic nephropathy in patients with renal blood flow, grade assessment and grading Ⅰ level: in patients with renal blood flow signal distribution is normal, at all levels within the kidney blood vessels dendritic distribution from the renal hilum trunk branching step by step, rich network of small blood vessels around the envelope, rich blood flow signal. Grade Ⅱ : slight reduction of fine vessels, partial reduction of interlobular arteries, continuous dendritic appearance of main renal arteries, segmental arteries, interlobular arteries and arcuate arteries, with clear display, obvious defect of subcapsular vascular network, no blood flow signal; Ⅲ grade: With the deterioration of the hyperperfusion, the damage of renal arterioles is aggravated, and the decrease of renal blood supply signal in patients is less than that in other grades. The main renal artery, renal interlobular artery and renal segmental artery are all shown. The visible part of arcuate artery is reduced, and no interlobular artery is significantly reduced or disappeared. It can be seen that the renal blood supply of the patient is significantly reduced, with discontinuous and significantly reduced blood flow in the distal side of the main renal artery, interlobar artery and main renal artery, and uneven thickness of renal segment arteries. The overall distribution of renal artery blood flow signals is diffuse, with

rare blood flow signals visible, and sudden "interruption" of renal artery blood flow appears [13].

2.7 Evaluation of Diabetic Kidney by Ultrasonic Backscattering Integral Technique

Ultrasonic backscattering integral technology (IBS) is mainly used to measure the scattered signals of tiny particles with a diameter smaller than their own wavelength to help accurately analyze the specific pathological changes in the relevant tissue structures of patients. Theoretically speaking, the change of various factors in human tissue will affect the change of tissue backscattered signal to a certain extent, and then cause the change of IBS value. The glomeruli, renal tubules and renal interstitium are the main sources of scattering in normal renal parenchyma, and the change of any structure will affect the integral value of backscattering. Therefore, this technique can be used for early assessment, diagnosis and quantitative analysis of the disease progression of diabetic nephropathy [14].However, ultrasound retroreflex integral technique also has limitations, because it is susceptible to many external factors, and it needs to be further improved before it can be widely used in the early diagnosis of diabetic nephropathy.

3. Summary and Prospect

In conclusion, ultrasound technology plays a very important role in the treatment of diabetic nephropathy, which can help early diagnosis and staging of the disease of diabetic nephropathy. With the continuous development and progress of new ultrasound technology, ultrasound will undergo a more long-term development in the diagnosis of diabetic nephropathy.

References

[1] Xie Zechan, Wu Jiaxiang, Huang Tingting.The value of color Doppler ultrasonography in the diagnosis of early diabetic nephropathy[J]. World Complex Medicine, 2020, 6(09):117-119.

[2] Luo Lin, Huang Zijuan, Wu Juan, Wang Jianting, Luo Yanping.Ultrasonography in the diagnosis of diabetic nephropathy [J]. Continuity Medical Education, 2018, 32(11):143-145. (in Chinese)

[3]Schwieger J, Fine LG.Nephropathy in Renal hypertrophy, Nephropathy, diabetes mellitus [J].Semin Nephrol, 1990, 10:160.

[4] Wang Yan, Xing Keying et al.Clinical study of diabetic nephropathy with two-dimensional and color Doppler ultrasonography [J].Chinese Journal of Medical Imaging, 1999,15 (3): 213-214.

[5] Liu Yuchun, Gu Minqi, Wang Haiyan, Tian Shaorong.Study on measurement of renal volume with B-type ultrasound [J]. Journal of Beijing Medical University, 1990(03):168.

[6]Kim Hyun Cheol, Yang Dal Mo, Jin Wook, et al. Relation between total renal volume and renal function: Usefulness of 3D sonographic measurements with a matrix array transducer.. 2010, 194(2):W186-92

[7] Li Nan, Tang Jie, Wang Yiru, Tian Xiaoqi, Liang Shuyuan, Lin Lin, Li Qiuyang, Fei Xiang, Luo Yukun.Diagnosis and prediction model of diabetic nephropathy based on three-dimensional ultrasound [J]. Chin J Med Ultrasonography, 2019, 16(09):702-708. (in Chinese)

[8] Lu JB. Comparison of color ultrasound and contrast-enhanced ultrasound in the diagnosis of diabetic nephropathy [J].New World Diabetes Mellitus, 2018, 21(21):173-174.

[9]Felix Stoperka, Claudia Karger, Joachim Beige.Limited Accuracy of Colour Doppler Ultrasound Dynamic Tissue Perfusion Measurement in Diabetic Adults[J]. PLoS One, 2016,11 (12): e0168905.

[10] Qiu Siying, Jiang Zewen, Wu Chiqiu, Chen Duoduo.Clinical significance of real-time shear wave elastography in the evaluation of renal function in diabetic nephropathy [J].Chinese Journal of Hospital Statistics,2020,27(03):202-206.

[11] Li Feng, Chen Tongqing, Huang Weijun, Cao Yunqing, Zhang Weilan.The value of ultrasound

and contrast-enhanced ultrasound in the evaluation of early renal function impairment in diabetic nephropathy [J].Hainan Medical Journal,2019,30(05):610-612.

[12] Zhao Li, Li Mingxing, Chen Yuanyuan, Luo Zhijian, Chen Kewen.Journal of Clinical Imaging, 2016, 27(10):732-735. (in Chinese with English abstract) [J]. Journal of Clinical Imaging, 2016,27(10):732-735.

[13] WANG Haiyan, WANG Yan, WANG Juan.The effect of color Doppler energy imaging on renal hemodynamics in diabetic patients [J]. Chinese Journal of Ultrasonography, 1999(07):3-5.

[14] Shi Chaohui, Zhang Shuhua, Kan Yanmin, Ma Lin.Clinical evaluation of diabetic nephropathy by ultrasonic backscattering technique [J].Guangxi Medical Journal,2015,37(08):1106-1109.