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Review article

Assessment of kidney functions in diabetic patients: A mini review

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Abstract: Diabetes mellitus is a metabolic disorder characterized by chronic hyperglycemia resulting from insufficient insulin production, impaired insulin action, or both. In autoimmune-mediated diabetes, pancreatic β-cells are progressively destroyed, leading to disrupted glucose metabolism. Prolonged hyperglycemia causes damage to small blood vessels and contributes to serious complications, including diabetic nephropathy, which may progress to end-stage renal disease requiring dialysis or kidney transplantation. The reported incidence of kidney failure ranges from 30-40% in patients with type 1 diabetes and 10-40% in those with type 2 diabetes. Early and accurate assessment of renal function is therefore essential for reducing morbidity and mortality among diabetic patients. This mini review focuses on the commonly used methods for evaluating kidney function in diabetes, with particular emphasis on glomerular function. Various biochemical and clinical approaches are discussed, including renal function tests, urine analysis, albumin-to-creatinine ratio (ACR), and estimation of glomerular filtration rate (GFR) using endogenous and exogenous markers such as inulin. Blood-based assays assessing protein concentrations and urine-based measurements of solute clearance, combined with mathematical models, remain fundamental tools for estimating GFR. Early detection of renal impairment through appropriate diagnostic strategies can significantly reduce the risk of renal complications in diabetic patients and improve long-term clinical outcomes.

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Introduction

Chronic diabetes results in elevated blood sugar levels and alterations in the metabolic processes of lipids and proteins, among other symptoms. A lack of insulin secretion from the pancreas and cells that cannot utilize insulin given by the pancreas contribute to elevated blood glucose levels [1]. Diabetes has 3 types: Type 1 diabetes, type 2 diabetes and type 3 diabetes. In type 1, the pancreas does not produce insulin; in type 2 cases, the body's cells become insulin-resistant, and with time, insulin production gradually decreases. Similarly, in the case of gestational diabetes, which occurs during pregnancy and at birth, complications may arise and increase the risk of type 2 diabetes in the mother and obesity among her children [2, 3]. Diabetes mellitus is a significant metabolic condition. The multi-system consequences of Diabetes are Stroke, Ischemic heart disease, and peripheral vascular disease. Diabetes prevalence has risen in recent decades, fueled by global obesity prevalence. Early morbidity, mortality, shortened life expectancy, and financial and other expenses to patients, caregivers, and the health system are caused by diabetes [4]. Diabetes classification and diagnosis are difficult and subject to decades of discussion and revision [5]. Polyuria, polydipsia, weight loss, often accompanied by polyphagia, and blurred vision is all signs of severe hyperglycemia, according to the American Diabetes Association. Chronic hyperglycemia may also be associated with growth retardation and increased susceptibility to certain diseases [6].

In the last two decades, the number of persons who have Diabetes has more than doubled from its previous level. Given this quick increase, one of the most concerning developments is the increase in the Prevalence of type 2 diabetes among children, adolescents, and young adults [7]. However, the most remarkable incidence cultures show a male excess, while the lowest risk populations assessed, largely non-European, show a female skew [8]. In Asians, type 2 diabetes is becoming more prevalent in the home country and among migrant communities. In this way, Asian groups are more prone than other cultures to develop Diabetes earlier in life. The condition's complications are more common in young Asian individuals than in elderly Asian individuals [9]. Without regard to the age of the people affected, it was predicted that Diabetes will be present in 2.8% of the world's people in 2000 and 4.4% by the year 2030. It is anticipated that the number of people with Diabetes will rise from 171 million in 2000 to 366 million by 2030 by studies. Even though Diabetes is more likely to be diagnosed in males, women are more likely to develop the condition. Between 2000 and 2030, it is expected that the urban population in emerging countries will more than double [10]. The most extraordinary significant rise is projected in the fastest-growing developing countries [11].

Biochemical markers are critical in making an accurate diagnosis, assessing risk, and selecting the treatment to enhance the patient's clinical result [12]. To accurately detect the levels of venous plasma glucose and HbA1c, only standardized and quality-certified laboratory methods must be used. Diabetes is currently diagnosed by measuring glucose levels in venous plasma, which is considered the gold standard [13]. Diabetes, it is undeniably true, can result in renal disease. Diabetic people have an increased chance of developing hypertension, a risk factor for renal damage. Diabetic nephropathy, a kidney condition brought on by high blood sugar levels, is thought to be aided by the renin-angiotensin system, which is also thought to be involved in blood pressure regulation [14]. For the most part, renal function tests are performed to diagnose renal disease, select the best course of treatment, and prevent further renal function deterioration. Other indications for renal disease testing in patients who have been diagnosed include determining the stage or type of renal disease, monitoring the progression of renal disease to ensure that optimal management occurs, and monitoring response to interventions in patients who have been diagnosed with renal disease [15].

Renal function tests

An estimated $23 billion is spent yearly in the United States on health care for people with end-stage renal disease (ESRD) caused by chronic kidney disease (CKD) [16]. The following signs and symptoms may point to a problem with your kidneys, infrequent urination because of the high blood pressure, or the presence of urine with blood in its enlargement of the hands and feet due to fluid retention in the body. Single symptoms may not indicate more severe conditions [17, 18]. However, if you have both of these symptoms simultaneously, it may signify that your kidneys aren't functioning well. Having a kidney function test can help you figure out what's wrong. Numerous clinical laboratory tests can be performed when studying and analyzing kidney function. The most practical techniques to perform to assess renal function in the clinic are obtaining an estimate of the glomerular filtration rate (GFR.) and screening for proteinuria (Albuminuria) [19, 20]. Glomerular proteinuria can be produced by changing the glomerular capillary wall's permeability to usually filtered proteins in various renal diseases. An individual's 24-hour proteinuria might range from less than 1 gram to more than 30 grams [21]. The glomerular filtration rate (G.F.R.) is often the most significant overall marker for kidney health and sickness since it considers functional, clinical, pathological, and prognostic factors. The "positive" glomerulotubular balance and the "negative" tubuloglomerular feedback are critical to the relationship between G.F.R. and nephron function. G.F.R. measures are used by the National Renal Foundation to diagnose and treat CKD [20].

CKD testing can be used in public health and clinical contexts without knowing about the patient's underlying medical condition, which is a significant advantage of the technique [22]. The function of the kidney can also be assessed through the use of blood testing. Various tests are available to measure kidney function and seek for signs of aberrant kidney function. Kidney health is assessed by the GFR. The most often used biomarker of renal function is serum creatinine, but it is not a direct measurement [23]. Other tests that can help determine kidney function include assessing electrolyte levels like potassium and phosphate, measuring bicarbonate levels from a vein, and checking for anaemia in a complete blood count. More accurately, changes in blood creatinine concentration can estimate GFR than changes in serum urea concentrations [24]. GFR determines most creatinine levels in the blood, and the rate at which Creatinine develops is constant. There are a lot of factors that influence urea production, including liver function and protein intake [25]. An independent risk factor for

patients with ESRD was blood albumin levels, commonly accepted as renal function indicators [26].

Urine analysis

Urine and its contents are measured as part of the evaluation of kidney function. Pee production may be affected by abnormal kidney function, resulting in too much or too little urine being excreted. Urine albumin or urine protein levels are common indicators of the kidneys' ability to filter protein. It is possible to detect protein and blood in the urine with a urinalysis. Having protein in your urine does not necessarily mean an illness. Urine protein levels are increased by infection, but so is a strenuous workout. If the results are the same after a few weeks, your doctor may order a follow-up test. Your doctor may also request a 24-hour urine collection sample. Doctors can use this to monitor the rate at which a waste product known as Creatinine leaves your system [27].

Albumin to creatinine ratio

Albumin has lately been recommended as a marker of kidney impairment due to the standardization of this test and the fact that albumin is the most common protein lost in the urine of persons with chronic kidney disease. When analyzing urine albumin, the ACR. (albumin-to-creatinine ratio) is the most frequently utilized statistic [28]. This urine test's an ACR. Albumin-to-creatinine ratio is abbreviated as ACR. The urine will be tested for albumin. A protein is an albumin. Protein is a nutrient that every cell in your body needs to function correctly.

Nevertheless, it should be found in the blood rather than the urine. You may be experiencing renal failure if you notice protein in your urine. This could be a symptom of renal disease in its earliest stages. You should repeat a urine test if the findings are "positive" for protein in your urine. Kidney disease is detected when three consecutively positive tests are performed over three months or longer [29].

Serum creatinine test

A decent estimate of renal function can be obtained by measuring serum creatinine and calculating creatinine clearance. If you collect all your urine, you can get a more accurate reading of your creatinine clearance [30]. This blood test looks to see if you're accumulating creatinine levels. In most people, the kidneys can remove all Creatinine from their blood. Abnormally high creatinine levels indicate an issue with the kidneys [31]. Women with a creatinine level of 1.2 mg/dL or higher and males with a level of 1.4 mg/dL or higher are considered to be at risk for kidney disease, according to the National Kidney Foundation (NKF) [32].

Blood test to estimate GFR

The glomerular capillaries filter fluid into the Bowman's capsule is the rate at which the kidney's GFR. The GFR in an average adult male is around 125 ml/min. GFR. is 10% lower in the typical adult female. An average of 180 ml of fluid is filtered per 24 hours with this GFR. However, the daily output of urine is only 1 to 2 litres. Assuming these values are accurate, the renal tubules must reabsorb 99 percent of the glomerular filtrate [33].

GFR using creatinine

A blood test to estimate your G.F.R. Using creatinine clearance, one can approximate the GFR. by determining how much Creatinine is removed from the blood per unit time [34]. Due to creatinine excretion, creatinine clearance exceeds G.F.R., which can be prevented with cimetidine. Excessive urinary retention (eGFR) and excess urea nitrogen (eC_{cr}) can be accurately measured utilizing comparisons between blood and urine samples (eGFR). The findings of these tests are used to evaluate kidney excretion [35]. The creatinine level in your blood will be checked because it is a consequence of cellular metabolism and measured. Creatine is a byproduct of the metabolism of muscular tissue.

The creatinine test is just the beginning. The GFR is then calculated from your creatinine result using a mathematical procedure (GFR) [36]. Your doctor can tell how well your kidneys operate by looking at your GFR. Make an appointment with your doctor to get a GFR test. This test measures the efficiency of your kidneys in removing waste from your bloodstream. The rate is determined by looking at various aspects, such as multiple data points, including creatinine levels and other demographic information. If your kidney function is below 60 milliliters/minute/1.73 square feet, you may be at risk for developing renal disease. It is common to use GFR equations to evaluate renal function [37].

$$GFF = \frac{\text{Urine Concentration} \times \text{Urine Flow}}{\text{Plasma Concentration}}$$

The glomerular filtration rate can be calculated or estimated using various methods GFR. Only when the Clearance Rate is equal to the GFR does the preceding formula apply.

Serum creatinine

Many primary care physicians use serum creatinine (SCr) levels as a screening test for renal impairment.

However, SCr values may remain within normal ranges even if renal function is severely impaired [38]. When determining renal function, a patient's serum creatinine levels are tested. The reference range is 53–115 mol/L or 0.6–1.3 mg/dL. Serum creatinine is the most often used measure of renal function, and it is a simple test. When nephrons are severely damaged, blood creatinine levels rise as a late indicator. As a result, this test is useless for detecting kidney disease in its earliest stages [39].

GRF using Inulin

The GFR can be determined by injecting Inulin or inulin-analogue sinistrin into the bloodstream. The vast majority of potential donors are screened using very reliable renal function tests, such as G.F.R. and effective renal plasma flow (ERPF) assessments based on inulin clearances [40]. This means that the excretion rate of Inulin and sinistrin is directly related to the rate at which the kidney filters water and solutes through the glomerular filter. Inulin concentrations in the blood and urine are measured using an enzymatic technique. For this test, Inulin is hydrolyzed with inulinase, and the native Glucose is simultaneously oxidized with H_2O_2, followed by the measurement of fructose. This time-saving approach can achieve high specificity, sensitivity, and accuracy with tiny sample volumes. [41]. Inulin clearance measurements are frequently tainted by incomplete urine collection [42].

G.R.F. using Cystatin C

The cystatin C level in a type 2 diabetes patient is a more sensitive marker for determining G.F.R. than the patient's creatinine level [43]. At 13kDa, CysC is the most negligible cysteine proteinase inhibitor. It's a member of the cysteine proteinase inhibitors. All nucleated cells result from a "housekeeping" gene that is expressed and generated at a steady rate [44]. Cystatin C is a biomarker for the early diagnosis of kidney illness that has only recently been found [45]. In addition to the fact that it is produced uniformly throughout the body and filtered out, it is brought back into the body by the tubular cells, where it is digested. Because of this, cystatin C levels in the blood rise as G.F.R. drops, which is harmful. According to some research, the levels of cystatin C in the blood are more constant than the levels of serum creatinine in the general population. Proximal tubular cells are monitored by urinary cystatin C [46]. The urine levels of cystatin C in healthy people are nearly undetectable. Cystatin C excretion can be increased if the proximal tubular cells are damaged, reducing the reabsorption of cystatin C [47]. There have been specific issues with Creatinine (variable muscle mass, recent meat-eating, etc.) that have necessitated examining other G.F.R. measurement methods. According to researchers, the endogenous marker of G.F.R., Cystatin C (CysC), is unaffected by body composition [48]. There are many more proteins than cystatin C, which is secreted by most cells in the body (it is an inhibitor of cysteine protease). Cystatin C is filtered out at the glomerulus. After filtration, it is reabsorbed and destroyed by tubular epithelial cells, with only trace amounts excreted in the urine. As a result, Cystatin C levels are evaluated in the bloodstream rather than in the urine. GFR estimation and serum cystatin C levels have been linked mathematically. (Sex, Age, and Race) Adjusted Cystatin C and Creatine have lately been integrated in certain proposed formulae Cystatine-C alone is slightly less accurate than Cystatine-C combined with (adjusted for) creatinine (adjusted for) age, gender, and race [49].

Blood urea nitrogen (BUN)

The determination of BUN and creatinine levels in the laboratory is "standard fare" in evaluating renal function. This testing is not unreasonably expensive for most patients because most hospitals have the necessary equipment and experience to carry out the tests [50]. To begin examining kidney function, blood urea nitrogen (BUN) levels in the serum or plasma were first measured [51]. Because the kidneys eliminate more than 90% of the urea produced, it is considered a significant consequence of protein metabolism. The glomerulus does not secrete urea; instead, it filters it out of the bloodstream.

Given that some of the urea excreted into the bloodstream is passively reabsorbed from the renal tubules, its concentration in the blood will underestimate GFR in conditions of reduced renal perfusion. Furthermore, nutritional consumption, liver function, and a wide range of disorders can all impact the levels of the hormone in the blood [52]. Additionally, waste materials in your blood can be detected with the BUN test. BUN tests are used to determine the blood's nitrogen content. Protein degradation produces urea nitrogen as a byproduct. While the renal disease is a common cause of increased BUN levels, it is not the only one. BUN levels can be elevated by various common drugs, including high dosages of aspirin and certain antibiotics. Your doctor should know about any medications or supplements you take daily. Certain medications may need to be stopped for a few days before the test. A BUN level of 7 to 20 mg/dL is considered normal. The greater the value, the more likely it is to indicate various health issues. The BUN test determines the amount of nitrogen present in the blood.

BUN levels and renal function degradation are inversely linked [53].

Albuminuria

Albuminuria is yet another marker of renal microvascular dysfunction that should be taken seriously [54]. Its Prevalence has increased over the previous two decades, coinciding with the rise in the Prevalence of high blood pressure, diabetes, and obesity [55]. Three-quarters of patients with diabetes are diagnosed by the time they are 60–69 years old. The term "albuminuria" refers to urine that contains abnormally high albumin levels. The presence of Albuminuria aids the detection of incipient nephropathy in diabetics. It is an independent marker for cardiovascular disease because it indicates increased endothelial permeability and chronic renal impairment. An albumin/creatinine ratio can be calculated from 24-hour urine samples or randomly selected specimens. In the absence of a urinary tract infection, the discovery of two episodes of Albuminuria points to glomerular dysfunction. Chronic renal disease is diagnosed when Albuminuria persists for more than three months [19].

Conclusion

Diabetic nephropathy remains one of the most serious and prevalent complications of diabetes mellitus, significantly contributing to morbidity and progression to end-stage renal disease. Regular and accurate assessment of kidney function is essential for the early identification of renal impairment in diabetic patients. The use of biochemical markers, renal function tests, urine analysis, albumin-to-creatinine ratio, and reliable estimation of glomerular filtration rate provides a comprehensive approach to evaluating glomerular function. Early diagnosis and timely intervention based on these assessments can substantially reduce the risk of renal complications, slow disease progression, and improve overall clinical outcomes in individuals with diabetes mellitus.

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