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# Value of serum β-trace protein combined with E-Cadherin in early diagnosis of diabetic kidney disease

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**Abstract: Objective** To explore the level of serum β-trace protein (βTP) and E-Cadherin in patients with diabetic kidney disease (DKD), and to evaluate the value of both alone and in combination for the early diagnosis of DKD. **Methods** A total of 150 patients with DKD treated in the Affiliated Changsha Hospital of Hunan University from January 2024 to August 2024 were prospectively selected (DKD group), and 150 patients with simple diabetes mellitus (DM) were selected according to the ratio of 1∶1 principle during the same period (DM group). According to urinary albumin-to-creatinine ratio (UACR), the patients in DKD group were further divided into early group (30 mg/g ≤ UACR <300 mg/g, $n$=84) and clinical group (UACR≥300 mg/g, $n$=66). The clinical data of the subjects were collected, and serum βTP and E-Cadherin levels were detected by enzyme-linked immunosorbent assay (ELISA). Multivariate logistic curves were plotted to assess the predictive value of serum βTP and E-Cadherin levels alone and in combination for DKD. **Results** There were significant differences in systolic blood pressure (SBP), total cholesterol (TC), triglyceride (TG), glycosylated hemoglobin ($HbA_{1c}$) and urinary albumin excretion rate (UAER) between DKD group and DM group ($P$<0.01). Compared with the DM group, the serum βTP level in the DKD group was higher [ (0.99±0.43) mg/L *vs* (0.57±0.19) mg/L, t=10.857, $P$<0.01], and the serum E-Cadherin level was lower [ (14.80±4.36) ng/mL *vs* (23.60±7.30) ng/mL, t=12.685, $P$<0.001]. Compared with the early group, the serum βTP level in the clinical group was higher [ (1.24±0.38) mg/L *vs* (0.79±0.36) mg/L, t=7.333, $P$<0.001], and the serum E-Cadherin level was lower [ (12.54±3.28) ng/mL *vs* (16.57±4.29) ng/mL, t=6.328, $P$<0.001]. Multivariate logistic regression analysis showed that high$HbA_{1c}$, high UAER, high βTP and low E-Cadherin levels were independent risk factors for DKD ($P$<0.05). ROC results showed that the area under curve (AUC) of serum βTP combined with E-Cadherin in predicting DKD was 0.904 (sensitivity 0.847, specificity 0.807), which was better than the two diagnoses alone. **Conclusion** Abnormal levels of serum βTP and E-Cadherin are independent risk factors for the development of DKD, and the combined detection of βTP and E-Cadherin is effective for the early diagnosis of DKD.

**Keywords:** Diabetic kidney disease; Diabetes mellitus; β-trace protein; E-Cadherin; Urinary albumin-to-creatinine ratio

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Diabetic kidney disease (DKD), as a severe chronic complication of diabetes, is a leading cause of end-stage renal disease (ESRD) globally [1]. The pathological progression of DKD is insidious, and early-stage clinical manifestations are often non-specific. By the time patients exhibit obvious proteinuria or renal function impairment, the disease is typically already at an irreversible stage, imposing significant physical and mental burdens on patients and substantially increasing medical costs and societal expenses [2]. However, early diagnosis of DKD in clinical practice remains challenging, and traditional diagnostic indicators are often inadequate in providing accurate information during the early stages of the disease [3]. In recent years, the potential value of serum β-trace protein (βTP) and E-cadherin in kidney diseases has attracted increasing attention. βTP, a sensitive marker for tubular injury, has been found to be abnormally expressed in various kidney diseases, potentially being closely related to kidney damage and dysfunction [4-5]. E-cadherin, an important cell-cell adhesion molecule, plays a key role in maintaining the normal structure and function of the kidneys, and changes in its expression levels are also thought to be associated with the progression of kidney diseases [6]. This study aims to explore the combined diagnostic value of serum βTP and E-cadherin for the early diagnosis of DKD, providing scientific evidence for early screening, diagnosis, and intervention of DKD.

## 1 Materials and Methods

### *1.1 General Data*

A total of 150 patients with DKD were prospectively selected from the Third Hospital of Changsha between January 2024 and August 2024.

(1) Inclusion Criteria:

① Diagnosed with DKD according to the *China Type 2 Diabetes Prevention and Treatment Guidelines (2020 edition)* [7] and the *2021 Clinical Practice Guidelines for Diabetic Kidney Disease in China* [8], and newly diagnosed DKD.

② Aged from 18 to 80 years old.

③ No use of medications that affect blood glucose or renal function within 2 months prior to admission.

④ Informed and consented to participate in the study.

(2) Exclusion Criteria:
① Other kidney diseases or urinary system diseases.
② Severe systemic diseases, such as malignancies or cirrhosis.
③ Infectious diseases or recent use of immunosuppressive drugs.
④ Hematological disorders or other inflammatory diseases.
⑤ Kidney disease caused by other etiologies.
⑥ Severe psychiatric conditions preventing participation.
⑦ Pregnant or lactating women.

An additional 150 patients with simple diabetes mellitus were selected as DM group. Furthermore, according to the urinary albumin to creatinine ratio (UACR), the DKD group was divided into an early-stage group ($n$=84, with 30 mg/g ≤ UACR <300 mg/g) and a clinical-stage group ($n$=66, with UACR ≥ 300 mg/g) [8]. The study was approved by the Medical Ethics Committee of the Third Hospital of Changsha [Ethical approval number: KY-EC (kuaishen)-2024-015].

### *1.2 Collection of Clinical Baseline Data*

Clinical data were collected, including gender, age, body mass index (BMI), diabetes duration, history of kidney disease, smoking, alcohol consumption, systolic blood pressure (SBP), diastolic blood pressure (DBP), total cholesterol (TC), triglycerides (TG), glycated hemoglobin ($HbA_{1C}$), urinary albumin excretion rate (UAER), serum creatinine (SCr), estimated glomerular filtration rate (eGFR), urea nitrogen, and platelet microparticles (PMPs).

### *1.3 Measurement of Serum βTP and E-Cadherin Levels*

Enzyme-linked immunosorbent assay (ELISA) was used to detected the serum level of βTP (Catalog number: ml038479, Shanghai Enzyme-Linked Biotechnology) and E-cadherin (Catalog number: 1531217389, Jianglai Bio). The specific procedure was as follows:

(1) 3 mL of fasting peripheral venous blood from patients were collected, and centrifuged at 1,500 rpm for 10 minutes to separate the serum, and the serum was diluted with dilution buffer at a 1:5 ratio. (2) 100 μL of diluted serum and an equal amount of antigen standard were added to pre-coated microplates, incubated at 37°C for 2 hours. (3) The plate was washed 5 times with 300 μL of washing buffer, leaving a 1-minute interval between washes to remove unbound substances. (4) 100 μL of detection antibody was added to each well and incubated at room temperature for 1 hour to further promote the formation of the antigen-antibody complex. (5) After another wash, 100 μL of substrate solution was added to each well, and incubated at 37°C in the dark for 15-30 minutes for color development. And 50 μL of stop solution was added to terminate the reaction. (6) The absorbance at 450 nm was measured by microplate reader (Model: E0226, Beyotime Biotechnology), and the serum βTP or E-cadherin level was calculated by analyzing standard curve.

### *1.4 Statistical Analysis*

Statistical analysis was performed using SPSS 22.0 software. Count data were expressed as cases (%), and comparisons were made using the Chi-square test. Ordinal data were analyzed using the Mann-Whitney $U$ test. For continuous data, normality was first tested using the Shapiro-Wilk test. Data that followed a normal distribution were presented as x ± s, and comparisons between two groups were made using the independent sample t-test. Non-normally distributed data were expressed as M(P25, P75), and comparisons were made using the Mann-Whitney U test. Logistic regression analysis was used to determine the independent risk factors for the occurrence of DKD. Receiver operating characteristic (ROC) curves were used to evaluate the predictive value of serum βTP and E-cadherin levels, both separately and in combination, for DKD. $P$<0.05 was considered statistically significant.

## 2 Results

### *2.1 Comparison of General Clinical Baseline Data Between DKD Group and DM Group*

There was no significant difference between the two groups in terms of gender, age, BMI, duration of diabetes, history of kidney disease, smoking, drinking, DBP, SCr, eGFR, BUN, and PMPs levels ($P$>0.05). However, there were statistically significant differences in SBP, TC, TG, $HbA_{1C}$, and UAER levels between the two groups ($P$<0.01). See **Table 1**.

### *2.2 Comparison of Serum βTP and E-Cadherin Levels Between DKD Group and DM Group*

Compared with DM group, he serum βTP level was significantly higher and E-Cadherin level was significantly lower in the DKD group ($P$<0.01). See **Table 1**.

### *2.3 Comparison of Serum βTP and E-Cadherin Levels in DKD Patients at Different Stages*

Based on the UACR, DKD patients were further divided into an early-stage group ($n$=84) and a clinical-stage group ($n$=66). The results showed that the serum βTP level in the clinical-stage group was significantly higher than that in the early-stage group, and the serum E-Cadherin level was significantly lower in the clinical-stage group compared to the early-stage group ($P$<0.01). See **Table 2.**

### *2.4 Multivariate Logistic Regression Analysis of Independent Risk Factors for DKD*

The group (0=DM group, 1=DKD group) was set as the dependent variable, with SBP, TC, TG, $HbA_{1C}$, UAER, βTP, and E-Cadherin levels as independent variables (all continuous variables, with original values substituted). These were included in the multivariate logistic regression, and "backward" for variable selection was used. The results indicated that high $HbA_{1C}$, high UAER, high βTP, and low E-Cadherin levels were independent risk factors for DKD ($P$<0.05). See **Table 3**.

### *2.5 Diagnostic Performance of Serum βTP Combined with E-Cadherin for Early Diagnosis of DKD*

The ROC curve results showed that the AUC for serum βTP, E-Cadherin levels, and their combined prediction were 0.804, 0.855, and 0.904, respectively, indicating certain predictive value for DKD. At the cutoff values, the sensitivity of each was 0.673, 0.767, and 0.847, and the specificity was 0.887, 0.827, and 0.807, respectively. The combination of serum βTP and E-Cadherin detection for early diagnosis of DKD was superior to the individual tests. See **Table 4, Figure 1**.

**Tab.1** Comparison of general clinical data between two groups ($n$=150, $\bar{x}\pm s$)

| Indicators | DKD group | DM group | $\chi^2/t$ value | $P$ value |
|---|---|---|---|---|
| **Gender** | | | 0.121 | 0.728 |
| **Male** | 82(54.67) | 79(52.67) | | |
| **Female** | 68(45.33) | 71(47.33) | | |
| **Age(years)** | 57.29±4.00 | 57.38±4.14 | 0.184 | 0.854 |
| **BMI(kg/m²)** | 22.81±2.20 | 23.07±2.20 | 1.007 | 0.315 |
| **Duration of diabetes (years)** | 4.22±1.18 | 4.22±1.07 | 0.031 | 0.975 |
| **History of kidney disease** | 27(18.00) | 25(16.67) | 0.093 | 0.760 |
| **Smoking history** | 53(35.33) | 49(32.67) | 0.238 | 0.626 |
| **Drinking history** | 56(37.33) | 51(34.00) | 0.363 | 0.547 |
| **SBP(mmHg)** | 109.81±10.98 | 105.83±10.92 | 3.143 | 0.002 |
| **DBP(mmHg)** | 76.12±5.60 | 76.33±5.55 | 0.321 | 0.748 |
| **TC(mmol/L)** | 3.91±1.19 | 3.13±1.10 | 5.905 | <0.001 |
| **TG(mmol/L)** | 1.30±0.36 | 1.13±0.31 | 4.360 | <0.001 |
| **$HbA_{1C}$(%)** | 7.97±1.41 | 6.17±1.52 | 10.664 | <0.001 |
| **UAER(μg/min)** | 35.79±21.36 | 17.34±4.59 | 10.343 | <0.001 |
| **SCr(μmol/L)** | 95.38±10.91 | 93.82±10.08 | 1.288 | 0.199 |
| **eGFR[mL/(min·1.73m²)]** | 55.99±13.42 | 54.73±13.90 | 0.799 | 0.425 |
| **BUN(mmol/L)** | 7.60±1.43 | 7.48±1.34 | 0.750 | 0.454 |
| **PMPs(×10⁹/L)** | 6.33±2.13 | 6.27±2.09 | 0.247 | 0.805 |
| **βTP(mg/L)** | 0.99±0.43 | 0.57±0.19 | 10.857 | <0.001 |
| **E-Cadherin(ng/mL)** | 14.80±4.36 | 23.60±7.30 | 12.685 | <0.001 |

**Tab.2** Comparison of serum βTP and E-Cadherin levels in DKD patients with different disease severities ($\bar{x}\pm s$)

| Group | βTP(mg/L) | E-Cadherin(ng/mL) |
|---|---|---|
| **Clinical group ($n$=66)** | 1.24±0.38 | 12.54±3.28 |
| **Early group ($n$=84)** | 0.79±0.36 | 16.57±4.29 |
| ***t* value** | 7.333 | 6.328 |
| ***P* value** | <0.001 | <0.001 |

**Tab.3** Multivariate logistic regression analysis of independent risk factors for DKD

| Independent Variable | *β* | *SE* | *Wald* | *P* value | *OR*(95%*CI*) |
|---|---|---|---|---|---|
| **SBP** | 0.011 | 0.019 | 0.356 | 0.551 | 1.011(0.975-1.049) |
| **TC** | 0.087 | 0.186 | 0.218 | 0.640 | 1.091(0.757-1.572) |
| **TG** | 1.116 | 0.702 | 2.528 | 0.112 | 3.053(0.771-12.085) |
| **$HbA_{1C}$** | 0.545 | 0.145 | 14.122 | <0.001 | 1.724(1.298-2.291) |
| **UAER** | 0.086 | 0.023 | 13.584 | <0.001 | 1.090(1.041-1.140) |
| **βTP** | 3.083 | 0.706 | 19.077 | <0.001 | 21.814(5.470-86.990) |
| **E-Cadherin** | -0.233 | 0.043 | 29.748 | <0.001 | 0.792(0.729-0.861) |

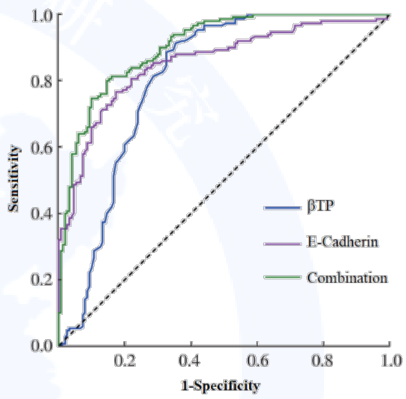


**Fig.1** Efficacy of serum βTP combined with E-Cadherin detection in early diagnosis of DKD

**Tab. 4** Efficacy of serum βTP combined with E-Cadherin detection in early diagnosis of DKD

| Variable | AUC | *P* value | 95%*CI* | Cut-off value | Youden index | Sensitivity | Specificity |
|---|---|---|---|---|---|---|---|
| **βTP** | 0.804 | <0.001 | 0.751-0.857 | 0.795 mg/L | 0.56 | 0.673 | 0.887 |
| **E-Cadherin** | 0.855 | <0.001 | 0.812-0.898 | 18.32 ng/mL | 0.594 | 0.767 | 0.827 |
| **Combination** | 0.904 | <0.001 | 0.871-0.937 | 0.460 | 0.654 | 0.847 | 0.807 |

## 3 Discussion

DKD is one of the most important microvascular complications in diabetes patients and is also one of the main causes leading to ESRD [9]. The continuous rise in the global incidence of diabetes has led to an increasing number of DKD patients each year, constituting a significant public health issue [10]. Early diagnosis and intervention of DKD are crucial to reduce renal damage and delay the progression of the disease to ESRD. Currently, DKD diagnosis relies on renal biopsy or UACR, but the former is an invasive procedure with the risk of complications, and the latter is delayed and unable to reflect early glomerular function damage [11]. Therefore, finding safer, more sensitive, and specific biomarkers for early diagnosis of DKD has become a research hotspot. Serum βTP is a glycoprotein that reflects early renal tubular damage and decline in kidney function with high sensitivity [12]. E-Cadherin, as an intercellular adhesion molecule, may reflect the damage to the glomerular basement membrane and the process of extracellular matrix remodeling when its level is abnormal [13]. Thus, this study measured serum βTP and E-Cadherin levels to evaluate their combined value in the early diagnosis of DKD and to provide new ideas for early identification and intervention. At the same time, it analyzed the relationship between the levels of the two and disease progression, exploring their potential as independent risk factors and providing reference for DKD prevention and treatment.

The results of this study showed that the serum βTP level in the DKD group was significantly higher than in the DM group, while the serum E-Cadherin level was significantly lower than in the DM group, suggesting that changes in serum βTP and E-Cadherin levels may be closely related to the occurrence and development of DKD. Meanwhile, with the worsening of DKD, the serum βTP level gradually increased, while the serum E-Cadherin level gradually decreased, further reinforcing the potential of serum βTP and E-Cadherin as biomarkers for the progression of DKD. Further logistic regression analysis showed that high $HbA_{1C}$, high UAER, high βTP, and low E-Cadherin levels were independent risk factors for DKD. $HbA_{1C}$ is an indicator reflecting the average blood glucose level over the past 2-3 months. Previous studies have shown that high $HbA_{1C}$ levels indicate poor long-term blood sugar control and are one of the key factors in the occurrence and development of DKD [14]. High blood glucose leads to microvascular damage in the kidneys, promotes oxidative stress and inflammation, and thus triggers or accelerates the progression of DKD [15]. UAER is a sensitive indicator for assessing early kidney damage, and studies have shown that when the glomerular filtration membrane is damaged, the excretion of urinary microalbumin increases [16-17]. High UAER levels not only reflect abnormalities in glomerular filtration function but may also be a marker of impaired renal tubular reabsorption [18], making it an important indicator for early diagnosis and disease monitoring of DKD. In recent years, many studies have found that βTP shows potential application value in kidney function assessment and in monitoring DM and its complications [19-20]. Changes in βTP levels may reflect changes in renal filtration function. In DKD, as the glomerular filtration rate decreases, the kidneys' ability to clear βTP is reduced, leading to elevated serum βTP levels [21]. Furthermore, Costa *et al.* [22] found that βTP may also be involved in renal inflammation and oxidative stress processes, which play an important role in the pathogenesis of DKD. Studies have reported that E-Cadherin is an important molecule for maintaining the integrity and polarity of epithelial cells [23-24]. In DKD, due to the effects of factors such as hyperglycemia, oxidative stress, and inflammation, renal tubular epithelial cells are damaged, leading to downregulation of E-Cadherin expression. Low E-Cadherin levels may reflect damage and dysfunction of renal tubular epithelial cells, thus promoting the progression of DKD [25]. ROC analysis showed that the AUC of serum βTP and E-Cadherin levels for the early diagnosis of DKD were 0.804 and 0.855, respectively. However, when both were tested together, the AUC increased to 0.904, indicating that the combined detection of serum βTP and E-Cadherin was significantly more effective for the early diagnosis of DKD than the individual tests. The combination detection showed a sensitivity of 0.847 and specificity of 0.807, suggesting that the combination detection, while maintaining high specificity, could more accurately identify DKD patients and reduce the occurrence of missed and misdiagnoses. This suggests that the combined detection of serum βTP and E-Cadherin holds significant value in the early diagnosis of DKD and has the potential to become a more effective diagnostic tool in clinical practice.

In conclusion, abnormal serum βTP and E-Cadherin levels are independent risk factors for the occurrence of DKD, and their combined detection has high early diagnostic value for DKD. However, this study still has limitations. The single-center design may lead to sample bias, and future multi-center large-sample studies are needed for validation. Subsequent research will further explore the molecular mechanisms by which serum βTP and E-Cadherin levels regulate the occurrence and development of DKD, aiming to provide scientific evidence for the diagnosis and treatment strategies of DKD.

**Conflict of Interest** None

## References

[1] Feng YL, Yin Y, Wu JY, et al. Application value of urinary neutrophil gelatinase-associated lipocalin in the diagnosis of diabetic nephropathies[J]. Pract J Card Cereb Pneumal Vasc Dis, 2024, 32(8): 127-130. **[In Chinese]**
[2] Cui BK, Liu JQ, Feng R, et al. The value of combined detection of serum CHI3L1 and NLR in diagnosis of diabetes nephropathy[J]. Lab Med Clin, 2024, 21(10): 1401-1405. **[In Chinese]**
[3] Zhao LZ, Li WM, Jiang RX. Clinical value of systemic immune-inflammation index in the diagnosis of diabetic kidney disease in community-dwelling elderly patients with type 2 diabetes[J]. Chin Gen Pract, 2023, 26(18): 2227-2231. **[In Chinese]**
[4] Zhang K, Zheng S, Wu JS, et al. Human umbilical cord mesenchymal stem cell-derived exosomes ameliorate renal fibrosis in diabetic nephropathy by targeting Hedgehog/SMO signaling[J]. FASEB J, 2024, 38(7): e23599.
[5] Zhang XR, Tanwar VS, Jose CC, et al. Transcriptional repression of E-cadherin in nickel-exposed lung epithelial cells mediated by loss of Sp1 binding at the promoter[J]. Mol Carcinog, 2022, 61(1): 99-110.
[6] Russo GC, Crawford AJ, Clark D, et al. Correction: E-cadherin interacts with EGFR resulting in hyper-activation of ERK in multiple models of breast cancer[J]. Oncogene, 2024, 43(19): 1488.
[7] Chinese Diabetes Society. Guideline for the prevention and treatment of type 2 diabetes mellitus in China (2020 edition) [J]. Chin J Diabetes Mellitus, 2021,13(4)： 315-409. **[In Chinese]**
[8] Expert Group of Chinese Society of Nephrology. Chinese guidelines for diagnosis and treatment of diabetic kidney disease[J]. Chin J Nephrol, 2021(3): 255-304. **[In Chinese]**
[9] Wei J, Zhou DM, Li PP, et al. Diagnostic value of triglyceride/cystatin C ratio combined with three indexes in diabetic nephropathy[J]. Chin J Lab Med, 2022, 45(1): 58-64. **[In Chinese]**
[10] Xu J. Diagnostic prediction formula for diabetic nephropathy based on serum TFF3, SFRP5, Gal-3 and NES-1[J]. Int J Biomed Eng, 2022, 45(1): 47-51. **[In Chinese]**
[11] Zhang S, Li YY, Liu XQ, et al. Carnosine alleviates kidney tubular epithelial injury by targeting NRF2 mediated ferroptosis in diabetic nephropathy[J]. Amino Acids, 2023, 55(9): 1141-1155.
[12] Peng JY, Jin J, Xiang MJ, et al. Serum and urinary biochemical indexes in early diagnosis of diabetic nephropathy[J]. Zhejiang Med J, 2022, 44(13): 1397-1401, 1466. **[In Chinese]**
[13] Liu DD, Zheng YJ, Chen ZX. Value analysis of serum NGAL combined with TG/Cys-C in early diagnosis of diabetic nephropathy[J]. J Harbin Med Univ, 2024, 58(2): 162-166. **[In Chinese]**
[14] Zhao TT, Cheng F, Zhan DD, et al. The Glomerulus multiomics analysis provides deeper insights into diabetic nephropathy[J]. J Proteome Res, 2023, 22(6): 1779-1789.
[15] Ge K, Li CM, Bai N, et al. Diagnostic value of combined detection of urinary albumin/creatinine ratio, urinary α1- microglobulin and urinary transferrin in early diabetic nephropathy[J]. Shaanxi Med J, 2022, 51(12): 1536-1539. **[In Chinese]**
[16] Li MX, Ding RF, Yang JJ, et al. Value of α1-MGU, TG/Cys-C and renal arterial hemodynamics parameters in early diagnosis of diabetic nephropathy[J]. J Clin Exp Med, 2024, 23(7): 752-756. **[In Chinese]**
[17] Hussein HR, Abdulkareem AA, Milward MR, et al. Ability of gingival crevicular fluid volume, E-cadherin, and total antioxidant capacity levels for predicting outcomes of nonsurgical periodontal therapy for periodontitis patients[J]. J Periodontal Res, 2024, 59(2): 289-298.
[18] Zhao LL, Yao YL, Lin LJ, et al. Value of neutrophils-to-lymphocyte ratio combined with urine albumin to creatinine ratio in diagnosis of diabetic nephropathy[J]. China J Mod Med, 2023, 33(11): 92-96. **[In Chinese]**
[19] Xing SJ, Chen BB, Zhang L, et al. The relationship between serum markers β-trace protein, transthyretin and non-esterified fatty acids and the severity of hypertensive disorder complicating pregnancy, and the value of combined diagnosis in predicting adverse pregnancy outcome[J]. Chin J Hypertens, 2023, 31(3): 273-278. **[In Chinese]**
[20] Kazem NM, Abdulkareem AA, Milward MR. Salivary E-cadherin as a biomarker for diagnosis and predicting grade of periodontitis[J]. J Periodontal Res, 2023, 58(4): 715-722.
[21] Gao J, Liang Z, Zhao F, et al. Relationship between serum levels of E-cadherin and β-catenin and calcium phosphorus metabolism and carotid artery calcification in patients with diabetic nephropathy[J]. Int J Lab Med, 2024, 45(12): 1469-1473. **[In Chinese]**
[22] Costa E Silva VT, Gil LA Jr, Inker LA, et al. Glomerular filtration rate estimation using β2-microglobulin and β-trace protein in adults with solid tumors: a prospective cross-sectional study[J]. Am J Kidney Dis, 2024, 84(3): 339-348.
[23] Costa e Silva VT, Gil LA, Inker LA, et al. GFR estimation using β2-microglobulin and β-trace protein in adults with solid tumors: a prospective cross-sectional study: SA-PO121[J]. J Am Soc Nephrol, 2022, 33(11S): 634.
[24] Chen XW, Li H, Liao XP, et al. TGF-β1 induces the proliferation and migration of renal tubular epithelial cells by regulating BMP7 expression through miR-21d-5p[J]. Chin J Integr Tradit West Nephrol, 2024, 25(4): 330-333. **[In Chinese]**
[25] Tan HB, Zhao Q, Chen L. Penehyclidine hydrochloride suppresses inflammation response and reduces podocyte injury in diabetic nephropathy by targeting fibrinogen-like protein 2[J]. Int Immunopharmacol, 2022, 107: 108680.

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·论　著·

# 血清β-痕迹蛋白联合E-钙黏蛋白对糖尿病肾病的早期诊断价值

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**摘要：目的**　探究糖尿病肾病（DKD）患者血清β-痕迹蛋白（βTP）和E-钙黏蛋白（E-Cadherin）的水平，评估二者单独或联合对DKD的早期诊断价值。**方法**　前瞻性选取2024年1月至2024年8月长沙市第三医院诊治的DKD患者150例（DKD组），另按1∶1比例选取同期单纯糖尿病（DM）患者150例（DM组）。根据尿白蛋白/尿肌酐比值（UACR）将DKD组患者分为早期组（30 mg/g≤UACR<300 mg/g，$n$=84）和临床组（UACR≥300 mg/g，$n$=66）。收集研究对象临床资料，采用酶联免疫吸附法（ELISA）检测血清βTP和E-Cadherin水平。采用多因素logistic回归分析筛选DKD发生的危险因素。绘制受试者工作特征曲线（ROC）评估血清βTP和E-Cadherin水平单独及联合对DKD的预测价值。**结果**　DKD组和DM组患者收缩压（SBP）、总胆固醇（TC）、三酰甘油（TG）、糖化血红蛋白（$HbA_{1C}$）、尿白蛋白排泄率（UAER）水平比较，差异有统计学意义（$P$<0.01）。与DM组比较，DKD组患者血清βTP水平高［（0.99±0.43）mg/L *vs*（0.57±0.19）mg/L，$t$=10.857，$P$<0.001］，血清E-Cadherin水平低［（14.80±4.36）ng/mL *vs*（23.60±7.30）ng/mL，$t$=12.685，$P$<0.001］。与早期组比较，临床组患者血清βTP水平高［（1.24±0.38）mg/L *vs*（0.79±0.36）mg/L，$t$=7.333，$P$<0.001］，血清E-Cadherin水平低［（12.54±3.28）ng/mL *vs*（16.57±4.29）ng/mL，$t$=6.328，$P$<0.001］。多因素logistic回归分析结果显示，高$HbA_{1C}$、高UAER、高βTP和低E-Cadherin水平为DKD的独立危险因素（$P$<0.05）。ROC结果显示，血清βTP联合E-Cadherin预测DKD的曲线下面积（AUC）为0.904（灵敏度为0.847，特异度为0.807），优于两者单独诊断。**结论**　血清βTP、E-Cadherin水平异常是DKD发生的独立危险因素，且二者联合检测对DKD的早期诊断效能较高。

**关键词：** 糖尿病肾病；糖尿病；β-痕迹蛋白；E-钙黏蛋白；尿白蛋白/尿肌酐比值

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# Value of serum β-trace protein combined with E-Cadherin in early diagnosis of diabetic kidney disease

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**Abstract：Objective**　To explore the level of serum β-trace protein（βTP）and E-Cadherin in patients with diabetic kidney disease（DKD），and to evaluate the value of both alone and in combination for the early diagnosis of DKD. **Methods**　A total of 150 patients with DKD treated in the Third Hospital of Changsha from January 2024 to August 2024 were prospectively selected（DKD group），and 150 patients with simple diabetes mellitus（DM）were selected according to the ratio of 1∶1 during the same period（DM group）. According to urinary albumin-to-creatinine ratio（UACR），the patients in DKD group were further divided into early group（30 mg/g≤UACR<300 mg/g，$n$=84）and clinical group（UACR≥300 mg/g，$n$=66）. The clinical data of the subjects were collected，and serum βTP and E-Cadherin levels were detected by enzyme-linked immunosorbent assay（ELISA）. Multivariate logistic regression

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analysis was used to screen the independent risk factors of DKD. Receiver operating characteristic (ROC) curves were plotted to assess the predictive value of serum βTP and E-Cadherin levels alone and in combination for DKD. **Results** There were significant differences in systolic blood pressure (SBP), total cholesterol (TC), triglyceride (TG), glycosylated hemoglobin ($HbA_{1C}$) and urinary albumin excretion rate (UAER) between DKD group and DM group ($P<0.01$). Compared with the DM group, the serum βTP level in the DKD group was higher [(0.99±0.43) mg/L *vs* (0.57±0.19) mg/L, $t$=10.857, $P<0.01$], and the serum E-Cadherin level was lower [(14.80±4.36) ng/mL *vs* (23.60±7.30) ng/mL, $t$=12.685, $P<0.001$]. Compared with the early group, the serum βTP level in the clinical group was higher [(1.24±0.38) mg/L *vs* (0.79±0.36) mg/L, $t$=7.333, $P<0.001$], and the serum E-Cadherin level was lower [(12.54±3.28) ng/mL *vs* (16.57±4.29) ng/mL, $t$=6.328, $P<0.001$]. Multivariate logistic regression analysis showed that high $HbA_{1C}$, high UAER, high βTP and low E-Cadherin levels were independent risk factors for DKD ($P<0.05$). ROC results showed that the area under curve (AUC) of serum βTP combined with E-Cadherin in predicting DKD was 0.904 (sensitivity was 0.847, and specificity was 0.807), which was better than the two diagnoses alone. **Conclusion** Abnormal levels of serum βTP and E-Cadherin are independent risk factors for the development of DKD, and the combined detection of βTP and E-Cadherin is effective for the early diagnosis of DKD.

**Keywords**: Diabetic kidney disease; Diabetes mellitus; β-trace protein; E-Cadherin; Urinary albumin-to-creatinine ratio

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糖尿病肾病(diabetic kidney disease, DKD)作为糖尿病的一种严重慢性并发症,是全球范围内导致终末期肾病(end-stage renal disease, ESRD)的主要原因[1]。其病理进展隐匿,早期缺乏特异性临床表现,待患者出现明显蛋白尿或肾功能损害时,往往已进展至不可逆阶段,给患者带来极大的身心负担,并显著增加医疗经济支出和社会成本[2]。然而,当前临床上对于DKD的早期诊断仍面临诸多挑战,传统的检测指标往往难以在疾病早期阶段提供准确的诊断信息[3]。近年来,血清β-痕迹蛋白(β-trace protein, βTP)和E-钙黏蛋白(E-Cadherin)在肾脏疾病中的潜在价值逐渐受到关注。βTP作为肾小管功能损伤的敏感指标,被发现在多种肾脏疾病中表达异常,可能与肾脏损伤和功能障碍密切相关[4-5]。而E-Cadherin作为一种重要的细胞间连接分子,在维持肾脏正常结构和功能中发挥着关键作用,其表达水平的变化也被认为与肾脏疾病的进展有关[6]。本研究旨在探讨血清βTP与E-Cadherin联合对DKD的早期诊断价值,为DKD的早期筛查、诊断及干预提供科学依据。

## 1 资料与方法

1.1 一般资料 前瞻性选取2024年1月至2024年8月长沙市第三医院诊治的DKD患者150例,将其纳入DKD组。(1)纳入标准:①符合《中国2型糖尿病防治指南(2020年版)》[7]及《2021年版糖尿病肾脏疾病临床诊疗中国指南》[8]诊断,且为首次确诊DKD;②年龄18~80岁;③入院前2个月未使用过影响血糖及肾功能的药物;④对本研究知情且同意。(2)排除标准:①存在其他肾脏疾病及泌尿系统相关疾病;②存在严重的全身性疾病,如恶性肿瘤、肝硬化等;③存在感染性疾病或近期接受过免疫抑制剂治疗;④存在血液系统疾病或其他炎症性疾病;⑤其他诱因导致肾脏疾病者;⑥有严重精神疾病,无法配合研究;⑦孕妇或哺乳期妇女。另按1:1原则选取同期单纯糖尿病患者150例(DM组)。并进一步根据尿白蛋白/尿肌酐比值(urinary albumin-to-creatinine ratio, UACR)[8]将DKD组患者分为早期组($n$=84, 30 mg/g≤UACR<300 mg/g)和临床组($n$=66, UACR≥300 mg/g)。本研究符合《赫尔辛基宣言》伦理准则,经长沙市第三医院医学伦理委员会批准[伦理审批号:KY-EC(快审)-2024-015]。

1.2 临床基线资料 收集受试者的临床基线资料,包括性别、年龄、身体质量指数(body mass index, BMI)、糖尿病病程、肾脏疾病史、吸烟、饮酒、收缩压、舒张压、总胆固醇(total cholesterol, TC)、三酰甘油(triglycerides, TG)、糖化血红蛋白(glycated hemoglobin, $HbA_{1C}$)、尿白蛋白排泄率(urinary albumin excretion rate, UAER)、血肌酐、估算肾小球滤过率(estimated glomerular filtration rate, eGFR)、血尿素氮、血小板微粒(platelet microparticles, PMPs)等。

1.3 血清βTP和E-Cadherin水平测定 采用酶联免疫吸附测定法(enzyme-linked immunosorbent assay, ELISA)检测血清βTP(货号:ml038479,上海酶联生物

科技）和E-Cadherin（货号：1531217389，江莱生物科技）水平，具体步骤为：采集患者3 mL空腹外周静脉血，3 000 r/min（离心半径15 cm）离心10 min分离血清，使用稀释缓冲液将血清按1∶5比例稀释。将100 μL稀释血清和等量抗原标准品加入预包被微孔板，37 °C温育2 h。用300 μL洗涤液清洗5次，间隔1 min，去除未结合物质。每孔加入100 μL，室温孵育1 h，进一步促进抗原抗体复合物的形成。再次进行洗涤后，每孔加入100 μL底物溶液，37 °C避光显色15~30 min进行显色反应。为终止反应，加入50 μL终止液。使用酶标仪（型号：E0226，碧云天生物技术）在450 nm波长下测量吸光度值，通过标准曲线分析计算出血清βTP或E-Cadherin水平。

1.4　统计学分析　采用SPSS 22.0软件进行统计分析。计数资料用例（%）表示，比较采用$\chi^2$检验；等级资料采用Mann-Whitney $U$检验。计量资料先采用Shapiro-Wilk检验验证正态性，符合正态分布的数据用$\bar{x}\pm s$表示，两组比较行独立样本$t$检验；反之则以$M(P_{25}, P_{75})$表示，比较采用Mann-Whitney $U$检验。采用logistic回归分析DKD发生的独立危险因素。受试者工作特征（receiver operating characteristic, ROC）曲线评估血清βTP和E-Cadherin水平单独及联合对DKD的预测价值。$P<0.05$为差异有统计学意义。

## 2　结　果

2.1　一般临床基线资料对比　DKD组和DM组患者在性别、年龄、BMI、糖尿病病程、肾脏疾病史、吸烟、饮酒、舒张压、血肌酐、eGFR、血尿素氮和PMPs水平比较差异无统计学意义（$P>0.05$）；而两组的收缩压、TC、TG、$HbA_{1C}$、UAER水平差异有统计学意义（$P<0.01$）。见表1。

2.2　DKD组和DM组患者血清βTP及E-Cadherin水平比较　DKD组患者血清βTP水平显著高于DM组，血清E-Cadherin水平显著低于DM组（$P<0.01$）。见表1。

2.3　不同期别的DKD患者血清βTP和E-Cadherin水平比较　根据UACR，进一步将DKD组患者分为早期组（$n$=84）和临床组（$n$=66），结果发现，临床组患者血清βTP水平显著高于早期组，血清E-Cadherin水平显著低于早期组（$P<0.01$）。见表2。

2.4　多因素logistic回归分析DKD的独立危险因素　将组别（0=DM组，1=DKD组）设为因变量，收缩压、TC、TG、$HbA_{1C}$、UAER、βTP和E-Cadherin水平作为自变量（均为连续变量，原值代入），纳入多因素logistic回归模型中，变量筛选方式为“后退法”，结果显示，高$HbA_{1C}$、高UAER、高βTP和低E-Cadherin水平为DKD的独立危险因素（$P<0.05$）。见表3。

2.5　血清βTP联合E-Cadherin检测对DKD的诊断效能　ROC曲线结果显示，血清βTP、E-Cadherin水平及联合预测的AUC分别为0.804、0.855、0.904。当取截断值时，各自灵敏度分别为0.673、0.767、0.847，特异度分别为0.887、0.827、0.807。血清βTP联合E-Cadherin检测对DKD的诊断效能优于两者单独检测。见表4、图1。

**表1　两组一般临床资料对比　（$n$=150，$\bar{x}\pm s$）**

**Tab.1　Comparison of general clinical data between two groups （$n$=150，$\bar{x}\pm s$）**

| 项目 | DKD组 | DM组 | $\chi^2$/$t$值 | $P$值 |
|---|---|---|---|---|
| 性别[例（%）] | | | | |
| 男 | 82（54.67） | 79（52.67） | 0.121 | 0.728 |
| 女 | 68（45.33） | 71（47.33） | | |
| 年龄（岁） | 57.29±4.00 | 57.38±4.14 | 0.184 | 0.854 |
| BMI（kg/m²） | 22.81±2.20 | 23.07±2.20 | 1.007 | 0.315 |
| 糖尿病病程（年） | 4.22±1.18 | 4.22±1.07 | 0.031 | 0.975 |
| 肾脏疾病史[例（%）] | 27（18.00） | 25（16.67） | 0.093 | 0.760 |
| 吸烟史[例（%）] | 53（35.33） | 49（32.67） | 0.238 | 0.626 |
| 饮酒史[例（%）] | 56（37.33） | 51（34.00） | 0.363 | 0.547 |
| 收缩压（mmHg） | 109.81±10.98 | 105.83±10.92 | 3.143 | 0.002 |
| 舒张压（mmHg） | 76.12±5.60 | 76.33±5.55 | 0.321 | 0.748 |
| TC（mmol/L） | 3.91±1.19 | 3.13±1.10 | 5.905 | <0.001 |
| TG（mmol/L） | 1.30±0.36 | 1.13±0.31 | 4.360 | <0.001 |
| $HbA_{1C}$（%） | 7.97±1.41 | 6.17±1.52 | 10.664 | <0.001 |
| UAER（μg/min） | 35.79±21.36 | 17.34±4.59 | 10.343 | <0.001 |
| 血肌酐（μmol/L） | 95.38±10.91 | 93.82±10.08 | 1.288 | 0.199 |
| eGFR[mL/(min·1.73m²)] | 55.99±13.42 | 54.73±13.90 | 0.799 | 0.425 |
| 血尿素氮（mmol/L） | 7.60±1.43 | 7.48±1.34 | 0.750 | 0.454 |
| PMPs（$\times10^9$/L） | 6.33±2.13 | 6.27±2.09 | 0.247 | 0.805 |
| βTP（mg/L） | 0.99±0.43 | 0.57±0.19 | 10.857 | <0.001 |
| E-Cadherin（ng/mL） | 14.80±4.36 | 23.60±7.30 | 12.685 | <0.001 |

**表2　不同期别的DKD患者血清βTP和E-Cadherin水平比较 （$\bar{x}\pm s$）**

**Tab.2　Comparison of serum βTP and E-Cadherin levels in DKD patients with different stage （$\bar{x}\pm s$）**

| 组别 | βTP（mg/L） | E-Cadherin（ng/mL） |
|---|---|---|
| 临床组（$n$=66） | 1.24±0.38 | 12.54±3.28 |
| 早期组（$n$=84） | 0.79±0.36 | 16.57±4.29 |
| $t$值 | 7.333 | 6.328 |
| $P$值 | <0.001 | <0.001 |

**表3　多因素logistic回归分析DKD的独立危险因素**

**Tab.3　Multivariate logistic regression analysis of independent risk factors for DKD**

| 自变量 | $\beta$值 | $SE$ | Wald | $P$值 | $OR$（95%$CI$） |
|---|---|---|---|---|---|
| 收缩压 | 0.011 | 0.019 | 0.356 | 0.551 | 1.011（0.975~1.049） |
| TC | 0.087 | 0.186 | 0.218 | 0.640 | 1.091（0.757~1.572） |
| TG | 1.116 | 0.702 | 2.528 | 0.112 | 3.053（0.771~12.085） |
| $HbA_{1C}$ | 0.545 | 0.145 | 14.122 | <0.001 | 1.724（1.298~2.291） |
| UAER | 0.086 | 0.023 | 13.584 | <0.001 | 1.090（1.041~1.140） |
| βTP | 3.083 | 0.706 | 19.077 | <0.001 | 21.814（5.470~86.990） |
| E-Cadherin | −0.233 | 0.043 | 29.748 | <0.001 | 0.792（0.729~0.861） |

**表4** 血清βTP联合E-Cadherin检测对DKD的早期诊断效能

**Tab.4** Efficacy of serum βTP combined with E-Cadherin detection in early diagnosis of DKD

| 变量 | AUC | *P*值 | 95%*CI* | 截断值 | 约登指数 | 灵敏度 | 特异度 |
|---|---|---|---|---|---|---|---|
| βTP | 0.804 | <0.001 | 0.751~0.857 | 0.795 mg/L | 0.560 | 0.673 | 0.887 |
| E-Cadherin | 0.855 | <0.001 | 0.812~0.898 | 18.32 ng/mL | 0.594 | 0.767 | 0.827 |
| 两项联合 | 0.904 | <0.001 | 0.871~0.937 | | 0.654 | 0.847 | 0.807 |

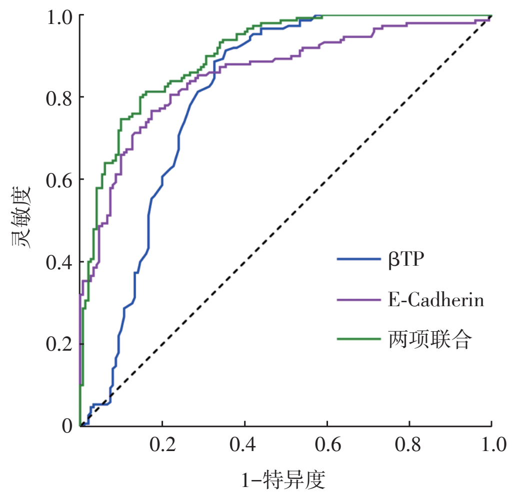


**图1** 血清βTP联合E-Cadherin检测对DKD的早期诊断效能

**Fig.1** Efficacy of serum βTP combined with E-Cadherin detection in early diagnosis of DKD

## 3 讨论

DKD是糖尿病患者重要的微血管并发症之一，也是ESRD的主要原因之一[9]。全球糖尿病发病率的持续攀升，使得DKD的患者数量也在逐年增加，构成了重大的公共卫生问题[10]。早期诊断和干预DKD对减少肾功能损害、延缓疾病向ESRD进展至关重要。当前DKD诊断依赖肾活检或UACR，但前者作为侵入性检查有并发症风险，后者有滞后性，无法在早期反映肾小球功能受损[11]。因此，寻找更安全、更敏感特异的生物标志物对DKD进行早期诊断成为研究的热点。血清βTP是一种糖蛋白，能早期反映肾小管损伤及肾功能下降，且敏感性高[12]。而E-Cadherin作为细胞间黏附分子，其水平异常则可能反映肾小球基底膜损伤及细胞外基质重构的过程[13]。鉴于此，本研究检测了血清βTP和E-Cadherin水平，并评估了二者联合在DKD早期诊断中的价值，为早期识别和干预提供新思路。同时，分析两者水平与疾病进展的关系，探讨其作为独立危险因素的可能性，为DKD防治提供参考。

本研究结果显示，DKD组患者血清βTP水平显著高于DM组，而血清E-Cadherin水平显著低于DM组，提示血清βTP和E-Cadherin水平的变化可能与DKD的发生和发展密切相关。与此同时，随着DKD病情的加重，血清βTP水平逐渐升高，而血清E-Cadherin水平则逐渐降低，这进一步强化了血清βTP和E-Cadherin作为DKD病情进展标志物的潜力。进一步logistic回归分析结果显示，高$HbA_{1C}$、高UAER、高βTP和低E-Cadherin水平为DKD的独立危险因素。$HbA_{1C}$是反映过去2~3个月平均血糖水平的指标。既往研究表明，高$HbA_{1C}$水平表明长期血糖控制不佳，是DKD发生和发展的关键因素之一[14]。高血糖状态会导致肾脏微血管损伤，促进氧化应激和炎症反应，进而引发或加速DKD的进展[15]。UAER是评估肾脏早期损伤的敏感指标，有报道指出，当肾小球滤过膜受损时，尿微量白蛋白的排泄量会增加[16-17]。高UAER水平不仅反映了肾小球滤过功能的异常，还可能是肾小管重吸收功能受损的标志[18]，是DKD早期诊断和病情监测的重要指标。近年来诸多研究发现了βTP在肾功能评估和对糖尿病及其并发症的监测中展现出潜在的应用价值[19-20]。βTP水平的变化可能反映了肾脏滤过功能的改变。在DKD中，随着eGFR的下降，肾脏对βTP的清除能力降低，导致血清中βTP水平升高[21]。此外，Cota等[22]研究发现，βTP还可能参与肾脏内的炎症反应和氧化应激过程，这些因素在DKD的发病机制中起重要作用。E-Cadherin是维持上皮细胞完整性和极性的重要分子[23-24]。在DKD中，由于高血糖、氧化应激、炎症反应等多种因素的作用，导致肾小管上皮细胞受损，进而导致E-Cadherin水平降低。而低E-Cadherin水平可能反映了肾小管上皮细胞的损伤和功能障碍，进而促进DKD的进展[25]。ROC分析显示，血清βTP和E-Cadherin水平对DKD早期诊断的AUC分别为0.804和0.855。然而，当二者联合检测时，其AUC提升至0.904，表明血清βTP和E-Cadherin联合检测对DKD的早期诊断效能明显优于两者单独检测。且二者联合检测的灵敏度为0.847，特异度为0.807，表明二者联合诊断在保持较高特异度的同时，能够更准确地识别出DKD患者，减少漏诊和误诊的发生。提示血清βTP联合E-Cadherin检测在DKD的早期诊断中具有重要价值，有望成为临床更有效的诊断工具。

综上所述，血清βTP、E-Cadherin水平异常是DKD发生的独立危险因素，且二者联合检测对DKD具有较高的早期诊断价值。然而，本研究仍存在局限，单

中心研究可能导致样本偏倚,未来需多中心大样本研究验证。后续将深入探究血清βTP和E-Cadherin水平参与调控DKD发生发展的分子机制,旨在为DKD的诊治策略提供科学依据。

**利益冲突**　无

**参考文献**

[1] 冯艳莉, 尹一, 吴金银, 等. 尿中性粒细胞明胶酶相关脂质运载蛋白在糖尿病肾病诊断中的应用价值[J]. 实用心脑肺血管病杂志, 2024, 32(8): 127-130.

[2] 崔博坤, 刘静芹, 冯然, 等. 血清CHI3L1、NLR联合检测对糖尿病肾病的诊断价值[J]. 检验医学与临床, 2024, 21(10): 1401-1405.

[3] 赵丽珍, 李卫民, 姜瑞霞. 系统免疫炎症指数对社区老年2型糖尿病患者并发糖尿病肾病的临床诊断价值研究[J]. 中国全科医学, 2023, 26(18): 2227-2231.

[4] Zhang K, Zheng S, Wu JS, et al. Human umbilical cord mesenchymal stem cell-derived exosomes ameliorate renal fibrosis in diabetic nephropathy by targeting Hedgehog/SMO signaling[J]. FASEB J, 2024, 38(7): e23599.

[5] Zhang XR, Tanwar VS, Jose CC, et al. Transcriptional repression of E-cadherin in nickel-exposed lung epithelial cells mediated by loss of Sp1 binding at the promoter[J]. Mol Carcinog, 2022, 61(1): 99-110.

[6] Russo GC, Crawford AJ, Clark D, et al. Correction: E-cadherin interacts with EGFR resulting in hyper-activation of ERK in multiple models of breast cancer[J]. Oncogene, 2024, 43(19): 1488.

[7] 中华医学会糖尿病学分会. 中国2型糖尿病防治指南(2020年版)[J]. 中华糖尿病杂志, 2021, 13(4): 315-409.

[8] 中华医学会肾脏病学分会专家组. 糖尿病肾脏疾病临床诊疗中国指南[J]. 中华肾脏病杂志, 2021,37(3): 255-304.

[9] 魏晶, 周冬梅, 李培培, 等. 甘油三酯/胱抑素C比值联合3项指标对糖尿病肾病的诊断价值[J]. 中华检验医学杂志, 2022, 45(1): 58-64.

[10] 徐婧. 基于血清TFF3、SFRP5、Gal-3和NES-1的糖尿病肾病诊断预测公式[J]. 国际生物医学工程杂志, 2022, 45(1): 47-51.

[11] Zhang S, Li YY, Liu XQ, et al. Carnosine alleviates kidney tubular epithelial injury by targeting NRF2 mediated ferroptosis in diabetic nephropathy[J]. Amino Acids, 2023, 55(9): 1141-1155.

[12] 彭健韫, 金菊, 项美娟, 等. 血清及尿液生化指标对糖尿病肾病的早期诊断价值分析[J]. 浙江医学, 2022, 44(13): 1397-1401, 1466.

[13] 刘丹丹, 郑元杰, 陈正徐. 血清NGAL联合TG/Cys-C在糖尿病肾病早期诊断中的价值分析[J]. 哈尔滨医科大学学报, 2024, 58(2): 162-166.

[14] Zhao TT, Cheng F, Zhan DD, et al. The Glomerulus multiomics analysis provides deeper insights into diabetic nephropathy[J]. J Proteome Res, 2023, 22(6): 1779-1789.

[15] 葛恺, 李春梦, 白妮, 等. 尿白蛋白/肌酐比、尿α1-微球蛋白、尿转铁蛋白联合检测对早期糖尿病肾病的诊断价值[J]. 陕西医学杂志, 2022, 51(12): 1536-1539.

[16] 李梦旭, 丁锐锋, 杨静静, 等. α1-MGU、TG/Cys-C及肾动脉血流动力学参数早期诊断糖尿病肾病的价值[J]. 临床和实验医学杂志, 2024, 23(7): 752-756.

[17] Hussein HR, Abdulkareem AA, Milward MR, et al. Ability of gingival crevicular fluid volume, E-cadherin, and total antioxidant capacity levels for predicting outcomes of nonsurgical periodontal therapy for periodontitis patients[J]. J Periodontal Res, 2024, 59(2): 289-298.

[18] 赵玲玲, 姚勇利, 林丽君, 等. 中性粒细胞与淋巴细胞比值联合尿白蛋白与肌酐比值诊断糖尿病肾病的临床价值[J]. 中国现代医学杂志, 2023, 33(11): 92-96.

[19] 邢素娟, 陈贝贝, 张丽, 等. 血清标志物β-痕迹蛋白、转甲状腺素蛋白和非酯化脂肪酸与妊娠期高血压疾病严重程度的关系及联合诊断预测不良妊娠结局的价值[J]. 中华高血压杂志, 2023, 31(3): 273-278.

[20] Kazem NM, Abdulkareem AA, Milward MR. Salivary E-cadherin as a biomarker for diagnosis and predicting grade of periodontitis[J]. J Periodontal Res, 2023, 58(4): 715-722.

[21] 高剑, 梁铮, 赵飞, 等. 血清β-catenin、E-cadherin水平与糖尿病肾病患者钙磷代谢、颈动脉钙化的关系[J]. 国际检验医学杂志, 2024, 45(12): 1469-1473.

[22] Chou CH, Huang TH, Hsieh PC, et al. Quantitative lateral flow immunoassay for rapid detection and monitoring of cerebrospinal fluid leakage following incidental durotomy[J]. Anal Chim Acta, 2022, 1196:339544.

[23] Costa E Silva VT, Gil LA Jr, Inker LA, et al. Glomerular filtration rate estimation using $\beta_2$-microglobulin and β-trace protein in adults with solid tumors: a prospective cross-sectional study[J]. Am J Kidney Dis, 2024, 84(3): 339-348.

[24] 陈香文, 李惠, 廖湘平, 等. TGF-β1通过miR-21d-5p调控BMP7表达诱导肾小管上皮细胞增殖及迁移[J]. 中国中西医结合肾病杂志, 2024, 25(4): 330-333.

[25] Tan HB, Zhao Q, Chen L. Penehyclidine hydrochloride suppresses inflammation response and reduces podocyte injury in diabetic nephropathy by targeting fibrinogen-like protein 2[J]. Int Immunopharmacol, 2022, 107: 108680.

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