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Dynamic Analysis of Kidney Function and Its Correlation with Nutritional Indicators in a Large Sample of Hospitalized Elderly Patients

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Statistical Analysis C
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Background: The aim of this study was to analyze changes in kidney function and its correlation with nutritional metabolism indicators in hospitalized elderly patients in a large medical center over the past 7 years.

Material/Methods: The renal function of patients over 60 years old in the Chinese PLA General Hospital in 2008, 2011, and 2014 were comparatively analyzed. The hemoglobin, serum albumin, triglycerides, cholesterol, uric acid, and urea nitrogen data were collected and used as the nutritional metabolism indicators. In addition, the correlation between these indicators and the eGFR was analyzed.

Results: The numbers of patients who received kidney function assessments in the 3 years were 15 752, 23 539, and 49 828; their mean ages were 69.97±6.99, 69.51±7.11, and 69.45±7.74 years. The median values of serum creatinine were 75.4, 76.5, and 77.5 μmol/L in the men and 59.6, 60.7, and 62.1 μmol/L in the women. The eGFR in both sexes demonstrated a gradual decreasing trend over the 3 years. According to the CKD staging method, analysis of the different percentages of eGFR intervals in the patients showed that the percentages of the 3 groups with an eGFR lower than 60 mL/min/1.73 m^2 exhibited a rising trend annually. Correlational analysis of the nutritional indicators showed that the correlations between Hb, ALB, TG, TC, Ur, and BUN with an eGFR lower than 60 mL/min/1.73 m^2 were 0.582, 0.780, 1.219, 1.364, 2.180, and 3.677, respectively.

Conclusions: Serum creatinine showed a gradually increasing trend over the 3 study years. The CKD-EPI equation calculation results showed that the eGFR in elderly people of both sexes gradually decreased. Reduction of hemoglobin and albumin was a risk factor for decreased kidney function, while increases in uric acid and blood lipids affected the progression of renal insufficiency.

MeSH Keywords: Aged • Glomerular Filtration Rate • Nutritional Status • Renal Insufficiency, Chronic

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Background

The populations of developed countries are gradually becoming older, and developing countries are facing a trend of accelerated population aging. The percentage of the population over 60 years of age has exceeded 13% in mainland China [1]. At present, more than 500 million people worldwide have different kidney injury conditions (*www.worldkidneyday.org*). The prevalence of chronic kidney diseases (CKD) in China is 10.8% [2], and the percentage of elderly people who have CKD is even higher. It has been reported that the CKD prevalence in the population over 70 years of age is over 20% [3]. Elderly people usually have many types of underlying diseases, such as cardiovascular disease, tumors, chronic obstructive pulmonary disease (COPD), and diabetes mellitus. These elderly patients take a wide variety of medications and have a high chance of receiving surgical, invasive, and radiological examinations. Therefore, in the clinic, kidney function assessments that particularly target hospitalized elderly patients are especially important. Additionally, because of the influence of CKD and changes in diet in Chinese residents, elderly patients usually have nutrition- and metabolism-related problems. Patients with stage 3 and stage 4 CKD have a higher percentage of nutritional metabolism issues, which can even reach 75% in end-stage renal disease (ESRD) patients [4]. However, studies with large sample size and longitudinal comparative comprehensive kidney function analysis targeting elderly people are currently lacking. The present study targeted a large sample of hospitalized elderly patients in the Chinese PLA General Hospital in 3 different years for analysis.

Material and Methods

Subjects

This study used a cross-sectional analysis. The selected subjects were patients who were hospitalized in our hospital in the years 2008, 2011, and 2014, had measured serum creatinine values, and were over 60 years of age (patients who received temporary and regular hemodialysis were excluded). A total of 89 119 patients (2008: 15 752 patients; 2011: 23 539 patients; 2014: 49 828 patients) were enrolled. For the analysis of nutritional metabolism, a total of 57 519 patients (2008: 12 421 patients; 2011: 18 797 patients, and 2014: 26 301 patients) who also were tested for hemoglobin, serum albumin, blood uric acid, blood urea nitrogen, triglycerides, and cholesterol were selected.

Methods

Hemoglobin was detected using a Sysmex XS automatic analyzer. Serum creatinine and other biochemical indicators were measured using the Roche Cobas 8000 automatic biochemical detection system in the Department of Biochemistry in our hospital when the patients were hospitalized. The detection of serum creatinine in this biochemical system used the enzymatic method.

The hemoglobin, serum albumin, blood uric acid, blood urea nitrogen, triglycerides, and cholesterol levels were described using quartile statistics, which were used for grade classification. The eGFR calculation results were used for dichotomous classification using 60 mL/min/1.73 m^2 as the limit. Next, a dichotomous logistic regression analysis was performed.

Assessment of kidney function

The measurement unit of eGFR was mL/min/1.73 m^2. In the CKD-EPI equation, the unit of serum creatinine was mg/dl, and the unit of the serum creatinine values detected by the biochemical analyzer was μmol/L; the conversion was accomplished using the value obtained by the equation divided by the constant value 88.4.

CKD-EPI equation:
Male:
Scr ≤0: 9: $eGFR=141\times(Scr/0.9)^{-0.411}\times0.993^{Age}$
Scr >0: 9: $eGFR=141\times(Scr/0.9)^{-1.209}\times0.993^{Age}$
Female:
Scr ≤0: 7: $eGFR=144\times(Scr/0.7)^{-0.329}\times0.993^{Age}$
Scr >0: 7: $eGFR=144\times(Scr/0.7)^{-1.209}\times0.993^{Age}$

Statistical methods

Quantitative data are expressed as a quartile difference (expressed in terms of age using the mean), and qualitative data are expressed as a percentage. In different years, the quantitative analysis of different age and different age groups was analyzed by rank sum test. The eGFR ratio was calculated according to the KDIGO-CKD stage in different years, different sexes, and different ages. The χ^2 test was used to compare the groups. The relationship between hemoglobin, serum albumin, triglyceride, cholesterol, urea nitrogen, and uric acid and renal function was analyzed by logistic regression and SPSS 19.0 was used for statistical analysis.

Results

Analysis of the general condition of the patients in each year

This study enrolled 89 119 patients in total (2008: 15 752; 2011: 23 539; 2014: 49 828). Women accounted for 40.9%, 42.6%, and 36.9% of the patients (in 2008, 2011, and 2014,

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Table 1. The year of serum creatinine comparison.

Years	Gender	n	Proportion	Scr (μmol/L)				
				2.5%	25%	50%	75%	97.5%
2008	M	9303	59.1%	47.6	64.9	75.4	90.5	250.2*
	F	6449	40.9%	36.9	51.0	59.6	72.2	235.6
2011	M	13522	57.4%	48.8	66.1	76.5	91.2	256.9*&
	F	10017	42.6%	37.9	52.3	60.7	72.6	251.7&
2014	M	31464	63.1%	49.2	66.2	77.5	92.6	268.9*&@
	F	18364	36.9%	38.7	53.2	62.1	73.8	288.3&@

M – Male; F – Female. * Compared with the same year women, $P<0.05$; & compared with same sex in 2008, $P<0.05$; @ compared with same sex in 2011, P<0.05.

respectively). The mean ages of all patients in each year were 69.97±6.99 years, 69.51±7.11, years, and 69.45±7.74 years. The percentage of each age group was as follows: in 2008, 60–69 years was 51.5%, 70–79 years was 38.3%, 80–89 years was 9.6%, and 90 years and above was 0.6%; in 2011, 60–69 years was 54.4%, 70–79 years was 34.9%, 80–89 years was 10.2%, and 90 years and above was 0.5%; in 2014, 60–699 years was 58.1%, 70–79 years was 28.7%, 80–89 years was 12.3%, and 90 years and above was 1.0%.

Analysis of serum creatinine

The median values of serum creatinine in men and women showed a gradual rising trend in 2008, 2011, and 2014. Within each year, the value in men was higher than in women (Table 1).

Analysis of eGFR using the CKD-EPI equation

Intra-year comparison of the eGFR between men and women showed that the median kidney function in women was slightly higher than in men at the 2 age groups of 60–69 years and 70-79 years; however, this trend was reversed in the age groups of 80–89 years and 90 years and above. The longitudinal comparison showed that the median eGFR at different age groups in these 3 years gradually decreased in both men and women (Table 2).

The percentages were calculated according to the eGFR staging standard recommended in the KDIGO guideline. The longitudinal comparison of eGFR at the stages equivalent to CKD stages 3, 4, and 5 showed a gradual rising trend. This trend was present in both male and female elderly patients (Figure 1).

Analysis of nutritional metabolism indicators

In the above samples, patients who were tested for all 6 nutritional metabolism-related indicators were selected. The indicators included hemoglobin, serum albumin, urea nitrogen, uric acid, triglycerides, and total cholesterol. Analysis of their correlation with eGFR was performed. The statistical significance of the above indictors is shown in Table 3.

The eGFR was used for dichotomous classification using 60 mL/min as the limit. The 6 indicators were classified into 4 grades using the description of quartile statistics. Next, a dichotomous logistic regression analysis between the above indicators and eGFR was performed. The results showed that these 6 indicators were correlated with an eGFR lower than 60 mL/min/1.73 m^2. Hemoglobin and serum albumin were negatively correlated with decreased kidney function, while the other 4 indicators showed positive correlations (Table 4).

Discussion

CKD has gradually become an important public health problem that threatens human health worldwide. It has been reported that the world-wide prevalence of CKD is 8–16% [5], and this percentage is even higher in the elderly population [3]. The 2010 Global Burden of Kidney Disease Study showed that CKD was 18th among the global causes of death [6].

In this study, a comparative analysis was performed to show that the serum creatinine concentrations in 2008, 2011, and 2014 exhibited a gradual rising trend in both men and women. In addition, the serum creatinine values in men were higher than those in women; this trend was similar in different age groups in elderly patients. In addition to affecting kidney function, the plasma creatinine concentration also was correlated with muscle metabolism and body mass index (BMI) [7]. Therefore, it was more scientifically rigorous to use the eGFR equation to perform the assessment of kidney function. The calculation results using the CKD-EPI equation showed that the eGFR in elderly men and women gradually

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Table 2. Different age groups, different years eGFR statistics.

Age	Gender	Years	eGFR (mL/min/1.73 m²) 2.5%	25.0%	50.0%	75.0%	97.5%
60–69	Male	2008	26.1	84.0	93.4	99.2	111.6*
		2011	34.5	83.2	92.8	98.2	110.6*&
		2014	28.0	79.6	91.9	97.4	111.2*&@
	Female	2008	21.3	82.7	94.0	99.5	122.8
		2011	21.0	80.2	93.4	98.8	108.6&
		2014	22.8	78.0	92.6	97.6	108.1&@
70–79	Male	2008	18.6	68.2	84.0	90.3	103.9*
		2011	19.1	67.0	83.6	90.2	102.5*&
		2014	19.4	66.9	83.1	89.9	104.1*&@
	Female	2008	14.5	66.7	85.0	91.4	108.4
		2011	19.0	69.4	84.4	90.7	101.1&
		2014	10.9	65.7	83.5	89.9	100.8&@
80–89	Male	2008	17.6	56.6	74.8	83.2	97.9*
		2011	14.4	56.3	72.3	82.8	96.3*&
		2014	10.7	51.4	70.3	83.5	106.9*&@
	Female	2008	14.3	54.2	70.8	82.7	96.7
		2011	15.3	53.8	67.5	82.2	94.5&
		2014	7.4	46.2	65.9	81.5	94.0&@
90–	Male	2008	27.7	55.7	66.3	76.9	90.4*
		2011	9.2	47.9	64.2	73.8	93.9*&
		2014	8.5	44.3	62.2	79.3	97.2*&@
	Female	2008	12.7	35.6	65.0	83.0	129.6
		2011	13.6	33.6	63.8	78.3	104.6&
		2014	12.1	36.2	61.4	77.3	94.6&@

* Compared with the same year femal, $P<0.05$; & compared with same sex in 2008, $P<0.05$; @ compared with same sex in 2011, P<0.05.

decreased with age. In the age groups 60–69 years and 70–79 years, eGFR in women was higher than in men, but in the 2 age groups of 89–89 years and 90 years and above, eGFR in men was higher. In addition, the longitudinal comparison of the 3 years 2008, 2011, and 2014 showed that kidney function in the different age groups in men and women exhibited a gradual decreasing trend. Comparison of the eGFR stages showed that in the 3 groups with an eGFR lower than 60, the percentages gradually increased, and the trends in men and women were similar. Previous studies already showed that age itself was an independent factor of CKD progression [8]. However, under physiological status, the eGFR decreased at a rate of 6.3 mL/min/1.73 m² for every 10 years [9]. Therefore, CKD diagnosis for elderly patients should be made cautiously. Correspondingly, their kidney function reserve was also worse, and the risk of development of various kidney injuries was also higher. The elderly patients took more types of drugs, and their chances of receiving surgery and angiography were also higher. Some studies have already shown that the chances of development of drug-induced kidney injury, postoperative kidney injury, and contrast-associated nephropathy in the elderly population are significantly higher than those in other age groups [10–12]. Analysis of the general health condition showed that the mean ages of elderly people in the 3 different years were relatively close, and the differences in the sex ratio were not obvious; however, the number of hospitalized people increased annually, and the results of the assessment of kidney function showed a decreasing trend. These results suggest that more elderly patients had renal dysfunction. Therefore, the assessment of kidney function targeting hospitalized elderly patients is important.

In the fields of geriatrics and nephrology, nutritional status is always of great research interest. Low dietary nutrient intake

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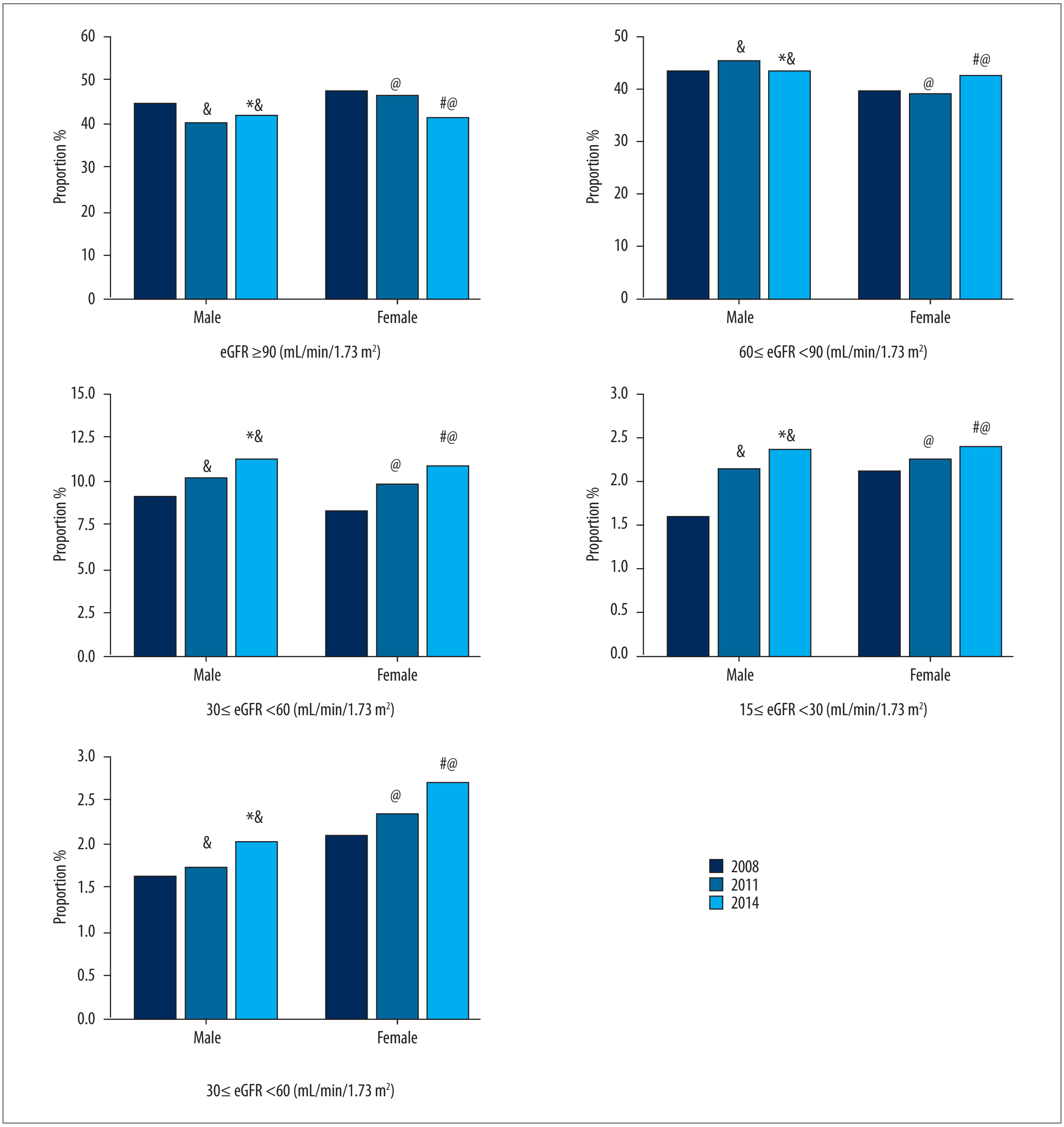

Figure 1. Different sex eGFR grouping ratio. [&] compared with 2008 male, *P*<0.05; * compared with 2011 male, *P*<0.05; [@] compared with 2008 female, *P*<0.05; [#] compared with 2011 female, *P*<0.05.

caused by renal dysfunction, the catabolic effects of renal replacement therapy, systemic inflammation, and metabolic and hormonal disorders and their complications (such as diabetes mellitus and depression) can all affect the nutritional status of patients [13]. In addition, nutritional status also affects the progression or even outcome of CKD [14]. Our study performed an analysis targeting hemoglobin, serum albumin, urea nitrogen, uric acid, triglycerides, and total cholesterol. The results showed that the first 2 indicators were negatively correlated with reduction of kidney function and that the other 4 indicators had positive correlations. Renal anemia is a common complication of ESRD. However, some studies confirmed that hemoglobin increased when kidney function decreased slightly [15]. Some basic studies also showed that the increase of hemoglobin expression was a protective factor for delaying disease progression during diabetic nephropathy and renal insufficiency [16] and had protective roles in kidney function after kidney transplantation, by correcting anemia [17]. As an

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Table 3. Nutritional metabolism indicators of the patients.

Indicators	2.5%	25%	50%	75%	97.5%
Hb (g/L)	82.5	112.5	126.0	138.5	160.0
ALB (g/L)	28.2	35.1	38.2	41.0	46.2
BUN (μmol/L)	2.9	4.5	5.5	6.9	15.8
Ur (μmol/L)	120.9	225.0	283.1	348.7	507.3
TG (mmol/L)	0.5	0.9	1.2	1.7	3.6
TC (mmol/L)	2.4	3.5	4.2	4.9	6.6

Hb – hemoglobin; ALB – serum albumin; BUN – blood urea nitrogen; Ur – uric acid; TG – triglycerides; TC – total cholesterol.

Table 4. Correlation between nutritional metabolism indicators and an eGFR of less than 60 mL/min/1.73 m^2.

Indicators	OR	*P*	95% CI
Hb	0.582	<0.01	0.564–0.600
ALB	0.780	<0.01	0.756–0.804
BUN	3.677	<0.01	3.532–3.828
Ur	2.180	<0.01	2.113–2.249
TG	1.219	<0.05	1.184–1.254
TC	1.364	<0.01	1.312–1.416

Hb – hemoglobin; ALB – serum albumin; BUN – blood urea nitrogen; Ur – uric acid; TG – triglycerides; TC – total cholesterol.

important indicator of nutritional status, low serum albumin is important in affecting the progression of renal insufficiency. Albumin is an oxidant scavenger of many endogenous and exogenous compounds and is an abundant carrier protein [18]. Some studies have shown that hypoalbuminemia could be a risk factor for predicting mortality in CKD patients [19]. Urea nitrogen and uric acid are important indicators reflecting kidney function; they gradually increase with an increase in eGFR. However, serum uric acid alone cannot be used to evaluate for kidney injury. The concentration of serum uric acid does not correspond to the level of the decrease in kidney function [19]. However, kidney injury caused by hyperuricemia and its close relationship with metabolic syndrome are important factors causing decreased kidney function. The association between blood lipid metabolism and kidney diseases, especially CKD, has already received extensive attention. Triglyceride level is a risk factor of the progression of renal insufficiency. Some scholars already proposed the hypothesis of the common mechanism of glomerular sclerosis and arteriosclerosis [20]. The serum cholesterol levels, including the increase of low-density lipoprotein (LDL) and the decrease of high-density lipoprotein (HDL), all participate in the progression of CKD, which involves mechanisms such as cholesterol transport in the body, inflammatory status mediated by lipid toxicity in dyslipidemia, and increased cardiovascular risks [21]. The 2013 KIDIGO blood lipid management guideline recommends using all blood lipid indicators for the assessment of abnormal blood lipid profile conditions in patients; in addition, appropriate treatment intervention should be performed according to age and the level of kidney function [22].

Conclusions

In summary, the kidney function of enrolled hospitalized elderly patients in our center showed a gradual decreasing trend in the 3 study years, which, no doubt, increased the risk of adverse reactions when these patients received treatment and surgical and invasive examinations, and increased the chance of acute kidney injury. In addition, reductions in hemoglobin and albumin were risk factors for decreased kidney function, whereas increases in uric acid and blood lipids affected the progression of renal insufficiency.

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