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ORIGINAL RESEARCH

The Relationship Between Fracture and Mortality in a Chinese Maintenance Hemodialysis Patients Cohort

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Background: Patients on maintenance hemodialysis have an increased risk of fracture. However, the relationship between fracture and poor prognosis is not clear.

Methods: A total of 182 maintenance hemodialysis patients were enrolled in the study. The relationship between fracture and poor prognosis (cardiovascular events, stroke, malignancy and 5-year all-cause mortality) were analyzed.

Results: 21 of 182 patients had a history of fracture at the time of enrollment. 26 patients had a new fracture after enrollment. A total of 57 fractures occurred in 47 patients, the most common fracture site was the rib. Patients with fracture group had a higher proportion of elderly and female, higher serum phosphorus and B-type natriuretic peptide and lower hemoglobin, albumin, and potassium compared with those without fracture. Age (*OR=3.809, 95% CI: 1.064–8.966, p=0.038*), hemoglobin (*OR=0.961, 95% CI: 0.925–0.997, p=0.035*), and serum phosphorus (*OR=3.325, 95% CI:1.104–10.019, p=0.033*) were the independent risk factors of new fractures in MHD patients. The incidence of malignancy and 5-year all-cause mortality in patients with fracture was higher than those without fracture ($p<0.05$). But there was no significant difference in the incidence of acute myocardial infarction or stroke.

Conclusion: 25.8% of maintenance hemodialysis patients had at least one fracture, with rib fractures accounting for the highest proportion. Age, hemoglobin and serum phosphorus were the independent risk factors of new fractures. The incidence of malignancy and 5-year all-cause mortality in patients with fracture was higher than those without fracture, but there was no significant difference in the incidence of acute myocardial infarction and stroke.

Plain Language Summary: To determine the incidence of fractures in hemodialysis patients, we conducted this single center, prospective observational study. 182 patients were enrolled. We also recorded the 5-year incidence of acute myocardial infarction-(AMI), stroke, malignancy, and mortality.

Our results showed that the incidence of fracture in hemodialysis patients was 25.8%. The most common fracture site was the rib. There were significant statistical differences in age, gender, hemoglobin, serum albumin, B-type natriuretic peptide, potassium and phosphorus between patients with and without fractures. Logistic regression analysis suggested that advanced age, anaemia and hyperphosphatemia were independent risk factors for new fractures in hemodialysis patients.

We followed 182 patients for 5 years and recorded the incidence of stroke, AMI and malignancy. The rates of AMI and stroke did not differ significantly between the two groups. However, the incidence of malignancy in patients with fractures is significantly higher than that in patients without fractures.

In our study, a total of 74 patients died, including 24 deaths in the fracture group and 50 deaths in the non-fracture group. The main causes of death in 74 cases were cardiovascular events. Our study provides some insight into the association between fractures and poor outcomes in hemodialysis patients.

Keywords: hemodialysis, fracture, mortality, anemia, hyperphosphatemia

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Introduction

Chronic kidney disease (CKD) is a major global public health problem. The prevalence of CKD in China is 8.2%~10.8%, that's about 100 million patients.[1,2] With the progression of CKD, renal function gradually declines. When the glomerular filtration rate (GFR) drops below 10mL/min, dialysis is often required. The main purpose of dialysis is to replace part of the function of the damaged kidney and remove toxins and excess fluid from the body to reduce uremia symptoms and improve the patient's quality of life. By the end of December 2022, the total number of patients registered for dialysis in mainland China had exceeded one million, bringing a heavy health burden to families and society.

There are many complications in dialysis patients, such as anemia, malnutrition, chronic kidney disease-mineral and bone disorder (CKD-MBD), resulting in significantly higher fracture rates than in the general population.[3,4] Fractures lead to reduced quality of life and increased mortality in dialysis patients.[5] The most common causes of death in maintenance hemodialysis (MHD) patients include cerebrovascular accidents, congestive heart failure and lung infections. To further clarify the incidence of fractures in MHD patients and the association between fractures and poor prognosis (cardiovascular events, stroke, malignancy and 5-year all-cause mortality), we performed this single center, prospective observational study.

Materials and Methods

This study was conducted at blood purification center of Tongji Hospital from January 2017 to December 2021.

Inclusion Criteria

The participants in the study were all HD patients aged >18 years who had received hemodialysis for more than 90 days.

Exclusion Criteria

1. Patients younger than 18 years old. 2. Patients who refuse to sign the consent. 3. Patients who have received hemodialysis for less than 90 days.

All enrolled patients underwent a routine chest CT and abdominal X-ray examinations once a year. Patients who have suffered a fall are examined by X-rays at the emergency department. Fractures were diagnosed radiologically using morphometry regardless of the presence of clinical symptoms. Patients were evaluated monthly for anemia and quarterly for CKD-MBD. Drugs to treat anemia include roxallistat, erythropoietin and iron. Drugs to treat CKD-MBD include sevelam, lanthanum carbonate and calcium acetate, calcitriol, paricalcitol and cinacase.

Data Analysis

The collected data were recorded and analyzed using the Statistical Product and Service Solutions (SPSS) version 26. Qualitative data were described as numbers and percentages, while quantitative data were expressed as mean±SD or median (quartile 1, quartile 3) for parametric and non-parametric data, respectively. The Kolmogorov–Smirnov test was used to test the normality of the continuous variables. Independent samples *t*-tests and Mann–Whitney *U*-tests were used to compare parametric and non-parametric variables between the two groups. The chi-square test was used to compare the qualitative variables between the two groups. Multivariate logistic regression analysis was used to identify significant predictors of fracture incidence. The level of significance was set at 5% ($p<0.05$).

Ethical Considerations

This study was approved by the Ethics Committee of Shanghai Tongji Hospital (approval number: 259-XZ-03) and conformed to the principles outlined in the Declaration of Helsinki. All subjects signed informed consent.

Results

The study enrolled 182 MHD patients, 61.0% males, with a mean age of 63.1±12.8 years. The leading cause of ESRD is glomerulonephritis (36.8%, 67/182), followed by diabetic nephropathy (27.5%, 50/182), hypertensive nephropathy (19.2%, 35/182) and polycystic kidney disease (8.8%, 16/182). Twenty-one of 182 patients had a history of fracture at

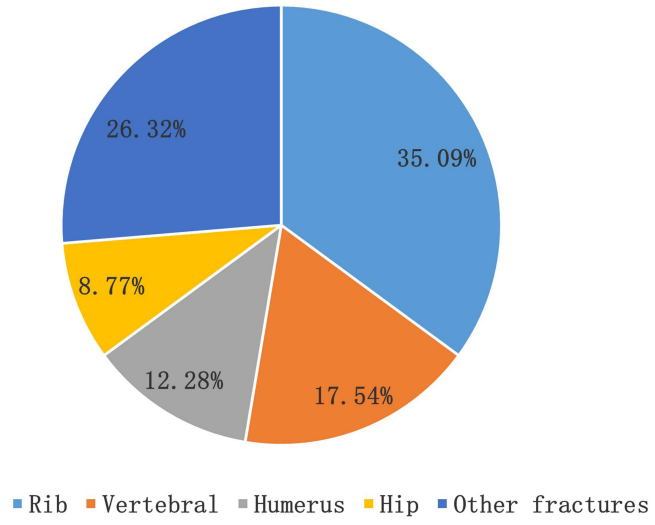

Figure 1 The proportion of fracture sites in MHD patients. A total of 57 fractures occurred in 47 patients, including 20 rib fractures (35.09%), 10 vertebral fractures (17.54%), 7 humeral fractures (12.28%), 5 Hip fractures (8.77%), and 15 other fractures (26.32%, including phalanx, metatarsal bone, ulna, etc).

the time of enrollment. Twenty-six patients had a new fracture after enrollment in the study. A total of 57 fractures occurred in 47 patients, including 20 rib fractures, 10 vertebral fractures, 7 humeral fractures, 5 hip fractures, and 15 other fractures (Figure 1). The proportion of fractures by age is shown in Figure 2. The risk of fracture increases with age and is higher in women than in men. In patients over 80 years of age, more than half of the females experienced fractures.

Table 1 shows the comparison of demographic and clinical parameters between the patients with or without fracture. Compared with the patients without fracture, patients with fracture had a higher proportion of elderly (66.0±13.6 vs 62.1 ±12.3 yrs.) and higher proportion female (53.2% vs 34.1%), higher serum phosphorus (1.85±0.52 vs 1.68±0.50 mmol/L) and higher B-type natriuretic peptide and lower hemoglobin (100.2±17.1 vs 104.4±15.1 g/L), lower albumin (36.86±3.93 vs 37.80±6.07 g/L), and lower potassium (3.93±0.79 vs 4.23±0.91 mmol/L). The patients with fracture had a greater

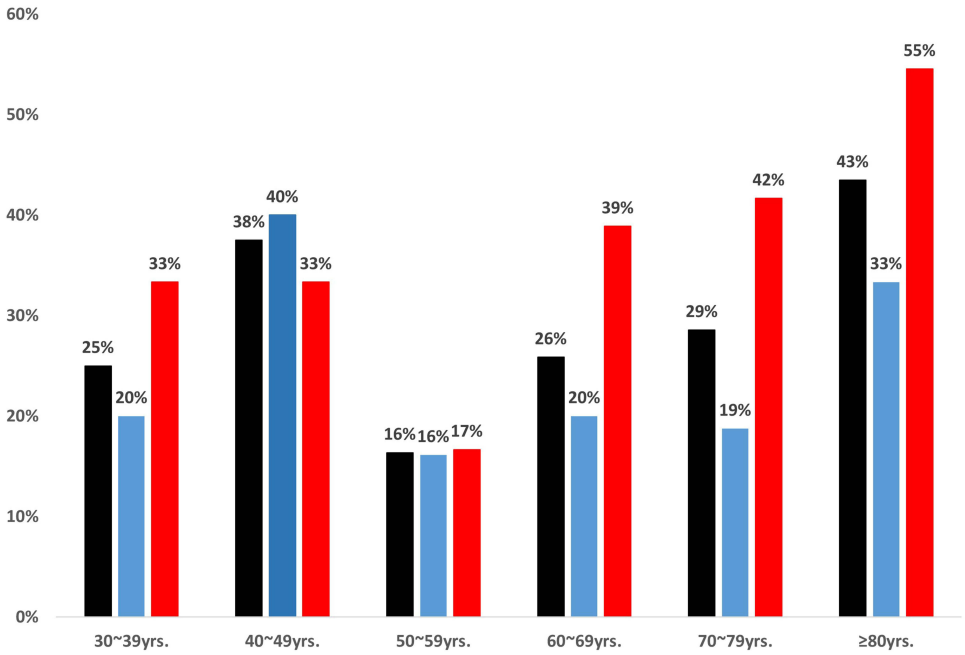

Figure 2 The prevalence of fractures by age (Black: Total; Blue: Male; Red: Female). In people over 50 years of age, the incidence of fractures increases with age and is higher in women than in men. More than half of all women over 80 experienced fractures.

Table 1 Demographic and Clinical Parameters of the Patients with and without Fractures

	Patients with Fracture (n=47)	Patients Without Fracture (n=135)	P value
Sex, women, n (%)	24(51.1)	47(34.8)	0.039
Age, years	66.0±13.6	62.1±12.3	0.002
Diabetic nephropathy (%)	34.0	25.2	
Chronic glomerulonephritis (%)	27.7	40.0	
Hypertensive nephropathy (%)	21.3	18.5	
Polycystic kidney disease (%)	10.6	6.7	
Duration of dialysis, (months)	(8.4, 111.6)	(11.8, 95.8)	0.903
CVC (%)	31.7	15.5	
AVF (%)	65.9	81.9	
AVG (%)	2.4	2.6	
Blood Flow (mL/min)	229±20	229±22	0.500
spKt/V	1.52±0.63	1.47±0.42	0.789
URR	69.21±8.51	70.02±9.36	0.607
Hemoglobin, g/L	100.2±17.1	104.4±15.1	0.016
CRP, mg/L	(2.61, 8.77)	(1.86, 6.98)	0.251
Albumin, g/L	36.86±3.93	37.80±6.07	0.017
Potassium, mmol/L	3.93±0.79	4.23±0.91	0.006
Calcium, mmol/L	2.19±0.20	2.19±0.29	0.745
Phosphorus, mmol/L	1.85±0.52	1.68±0.50	0.048
PTH, ng/L	(136.78, 387.53)	(113.88, 486.63)	0.761
Vitamin D, nmol/L	33.38±17.76	32.32±21.92	0.292
Fe, umol/L	13.35±7.70	12.27±4.68	0.806
Ferritin, μg/L	(197.20, 673.35)	(192.90, 632.28)	0.498
Uric acid, umol/L, umol/L	399.51±79.52	411.22±81.54	0.174
CO_2, mmol/L	21.95±2.79	21.85±3.05	0.075
BNP, ng/L	(199.30, 741.70)	(114.70, 575.33)	0.018

Abbreviations: CVC, Central Venous Catheter; AVF, Arteriovenous Fistula; AVG, Arteriovenous Graft; URR, urea reduction rate; CRP, C-reactive protein; PTH, Parathyroid Hormone; BNP, B-type natriuretic peptide.

proportion of patients with diabetes and a higher proportion of central venous catheter(CVC), but there was no statistical difference between the two groups. Multivariate logistic regression analysis showed age (≥65 yrs. vs < 65 years), anaemia and hyperphosphatemia were independent risk factors for new fractures in MHD patients, as shown in Table 2.

We followed 182 patients for 5 years and recorded the incidence of stroke, AMI and malignancy. The incidence of stroke was 8.5% in patients with fracture and 6.7% without fracture. AMI occurred in 23.4% of patients with fracture and 21.5% of patients without fracture. Malignancy developed in 8.5% (4/47) of patients with fracture, including two breast cancers, one prostate cancer, and one pancreatic cancer. Three patients (2.2%, 3/135) in patients without fracture developed malignancy, one colon cancer, kidney cancer, and lung cancer (Table 3).

Table 2 Independent Risk Factors for New Fractures in MHD Patients

	β	Sx	Waldx2	P value	OR	95% CI
Age	1.128	0.544	4.302	0.038	3.809	1.064~8.966
Albumin	−0.059	0.049	1.450	0.228	0.943	0.857~1.038
Hemoglobin	−0.04	0.019	4.428	0.035	0.961	0.925~0.997
Phosphorus	1.202	0.563	4.559	0.033	3.325	1.104~10.019
CO_2	0.100	0.105	0.916	0.339	1.106	0.900~1.358
PTH	0.000	0.001	0.002	0.960	1.000	0.999~1.001

Abbreviation: PTH, Parathyroid Hormone.

Table 3 Correlation Analysis Between Fracture and Poor Prognosis of Patients in MHD Patients

	Patients with Fracture (n=47)	Patients Without Fracture (n=135)	P value
Stroke (%)	8.5	6.7	0.280
AMI (%)	23.4	21.5	0.541
Malignancy (%)	8.5	2.2	<0.001
1-year mortality (%)	12.77	9.63	0.555
2-year mortality (%)	23.4	18.52	0.833
3-year mortality (%)	40.43	23.7	0.014
4-year mortality (%)	44.68	32.59	0.035
5-year mortality (%)	51.06	37.04	0.040

Abbreviations: MHD, Maintenance Hemodialysis; AMI, Acute Myocardial Infarction.

During 5 years of follow-up, 74 of 182 patients died, the all-cause mortality rate was significantly higher in patients with fracture (51.06%, 24/47) than that in patients without fracture (37.04%, 50/135). From the third year onwards, there was a statistically significant difference in all-cause mortality between the two groups, as shown in Table 3. The first leading cause of death was cardiovascular events (27.03%, 20/74), including heart failure, AMI and sudden cardiac death. The second cause was infection (18.92%, 14/74), followed by stroke (12.16%, 9/74) and respiratory failure (6.76%, 5/74), as shown in Figure 3.

Discussion

The incidence of fracture in dialysis patients is higher than that in the general population. Due to factors such as CKD-MBD, malnutrition, decreased exercise and cognitive function, osteoporosis is common in dialysis patients, with decreased bone quality and strength, leading to an increased risk of fracture. In previous studies, hip fractures were the most common type in dialysis patients, the incidence of hip fracture is about 4 to 5 times higher than that in the general population.[6] Our study showed that 11.5% of patients on maintenance hemodialysis had a history of fracture, and fractures occurred in 14.3% of patients during 5 years of follow-up. The most common fracture site was the rib, followed

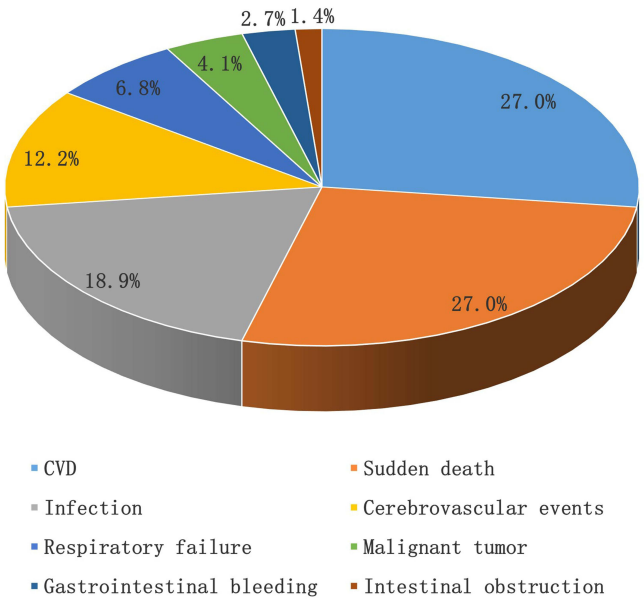

Figure 3 Analysis of 5-year death causes in MHD patients. During 5 years of follow-up, 74 of 182 patients died. The first leading cause of death was cardiovascular events (27.03%, 20/74), including heart failure, AMI and sudden cardiac death. The second cause was infection (18.92%, 14/74), followed by stroke (12.16%, 9/74) and respiratory failure (6.76%, 5/74).

by the vertebra, humerus and hip. The types of fractures are different in different populations, in people with type 1 diabetes, the most common fracture sites are carpal, clavicle, foot, humerus and tibia/fibula.[7] In our study, the higher proportion of rib fractures and vertebral fractures may be related to the routine chest CT and abdominal X-ray examinations performed in hemodialysis patients. Since a large proportion of hemodialysis patients are elderly patients with mobility difficulties, they often need to be carried between wheelchairs and beds, which is often done by family members who lack professional facilities, which may increase the chance of rib fractures.

To analyze risk factors for fracture in hemodialysis patients, we compared the differences between patients with or without fracture. The results showed that the fracture group had a higher proportion of elderly and female, in patients over 80 years of age, more than half of the female dialysis patients experienced fractures. Logistic regression analysis showed age, hemoglobin and surum phosphorus were independent risk factors for new fractures in MHD patients.

Anemia is a common complication of ESRD. The prevalences of anemia were 40.1% in patients with CKD stage 4 and 60.3% in patients with CKD stage 5.[8] Anemia is associated with cognitive impairment, physical function decline, muscle weakness, and low bone mineral density, leading to an increased risk of fractures.[9] EPO has been used clinically to treat anemia in end-stage renal disease. Data from the United States Renal Data System (USRDS) datasets shows EPO treatment as an independent risk factor for hip fractures in hemodialysis patients.[10] Therefore, the relationship between anemia and fracture in hemodialysis patients presents complex characteristics.

Hyperphosphatemia is highly prevalent in MHD patients and can lead to a variety of clinical manifestations, including cardiovascular calcification and fracture.[11] Serum phosphorus level is positively associated with fracture risk in male patients with CKD.[12] This association persisted even after correction for FGF23 and PTH levels.[13] In the LANDMARK study, among patients undergoing hemodialysis with hyperphosphatemia and at least 1 vascular calcification risk factor, treatment of hyperphosphatemia with lanthanum carbonate compared with calcium carbonate did not result in a significant difference in composite cardiovascular events and hip fracture.[14] In the COSMOS project, during a median follow-up of 24 months, 4% hemodialysis patients experienced at least one bone fragility fracture. Baseline serum phosphate > 6.1 mg/dL was significantly associated with a higher bone fragility fracture risk. Baseline serum calcium showed no association with bone fragility fracture risk. But the correlation between serum PTH and fracture was inconsistent.[15] In the EVOLVE study, bone fracture occurred in 19.2% of dialysis patients without hypocalcemia and 18.9%~21.1% of hemodialysis patients with hypocalcemia, indicating there was no significant correlation between hypocalcemia and the incidence of fracture.[16]

Hip fracture is associated with increased hospitalization and mortality. However, the relationship between other fracture types and patient outcomes is unclear. In our study, 182 hemodialysis patients were followed up for 5 years, a total of 7 of 182 patients developed malignancy, which was higher than in the general population. Hemodialysis patients have an increased risk of malignancy due to impaired immune system function, malnutrition, immunosuppressants or cytotoxic drugs and other factors.[17,18] In our study, malignancy appear to be more likely to occur in patients with fracture, for reasons that are not clear. One possible reason for this is that the patient had inadvertently suffered a pathological fracture before the diagnosis of malignancy was made. We also followed the hemodialysis patients for the occurrence of stroke and acute myocardial infarction. In a Korean nationwide population-based study, vertebral fracture is associated with myocardial infarction in incident hemodialysis patients.[19] In our study, the incidence of stroke and acute myocardial infarction was significantly higher in the hemodialysis patients, but there was no statistically significant difference between the two groups.

The main cause of death in MHD patients was cardiovascular disease.[20] In our study, 182 hemodialysis patients were followed up for 5 years and a total of 74 died, including 24 deaths in the fracture group and 50 deaths in the non-fracture group. The mortality in patients with fracture group (51.06%, 24/47) was significantly higher than that in patients without fracture (37.04%, 50/135) ($p<0.05$). The main causes of death in 74 cases were cardiovascular events, including heart failure, acute myocardial infarction and sudden cardiac death, followed by infection, stroke, and respiratory failure.

Our study has the following limitations: First, it is a single-center and small sample study, and the conclusions are not applicable to other ethnic groups; Second, we did not evaluate patients with SF-36 and other scales, so our study did not explore the impact of fractures on the quality of life of hemodialysis patients. Third, due to the inconsistent location of the fracture, we did not explore the effect of surgical and non-surgical treatment on patient outcomes in our study.

In conclusion, our study showed that the incidence of fracture in MHD patients was significantly increased, and the most common fracture was rib fracture. Advanced age, anemia and hyperphosphatemia were the independent risk factors of new fractures in MHD patients. Serum calcium and PTH levels had no significant correlation with fracture occurrence. The incidence of malignancy and 5-year all-cause mortality in patients with fracture was higher than those without fracture. But there was no significant difference in the incidence of acute myocardial infarction or stroke. Since our study was a single-center study with a small sample size, whether pathological fractures and elevated levels of inflammation were involved needs further study.

Data Sharing Statement

The data used to support the findings of this study are available from the corresponding author upon request.

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Disclosure

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, or publication of this manuscript.

References

1. Zhang L, Long J, Jiang W, et al. Trends in Chronic Kidney Disease in China. *N Engl J Med*. 2016;375(9):905–906. PMID: 27579659. doi:10.1056/NEJMc1602469
2. Wang L, Xu X, Zhang M, et al. Prevalence of chronic kidney disease in china: results from the sixth china chronic disease and risk factor surveillance. *JAMA Intern Med*. 2023;183(4):298–310. PMID: 36804760; PMCID: PMC9941971. doi:10.1001/jamainternmed.2022.6817
3. Wakasugi M, Kazama JJ, Wada A, Hamano T, Masakane I, Narita I. Hip fracture trends in japanese dialysis patients, 2008–2013. *Am J Kidney Dis*. 2018;71(2):173–181. PMID: 29162337. doi:10.1053/j.ajkd.2017.07.017
4. Iseri K, Carrero JJ, Evans M, et al. Secular trends in Hip fracture incidence and subsequent mortality in dialysis patients and the general population in Sweden. *Bone*. 2021;147:115909. PMID: 33716163. doi:10.1016/j.bone.2021.115909
5. Tentori F, McCullough K, Kilpatrick RD, et al. High rates of death and hospitalization follow bone fracture among hemodialysis patients. *Kidney Int*. 2014;85(1):166–173. PMID: 23903367; PMCID: PMC3910091. doi:10.1038/ki.2013.279
6. Alem AM, Sherrard DJ, Gillen DL, et al. Increased risk of Hip fracture among patients with end-stage renal disease. *Kidney Int*. 2000;58(1):396–399. PMID: 10886587. doi:10.1046/j.1523-1755.2000.00178.x
7. Rasmussen NH, Sarodnik C, Bours SPG, et al. The pattern of incident fractures according to fracture site in people with T1D. *Osteoporos Int*. 2022;33(3):599–610. PMID: 34617151. doi:10.1007/s00198-021-06175-z
8. Sofue T, Nakagawa N, Kanda E, et al. Prevalence of anemia in patients with chronic kidney disease in Japan: a nationwide, cross-sectional cohort study using data from the Japan Chronic Kidney Disease Database (J-CKD-DB). *PLoS One*. 2020;15(7):e0236132. PMID: 32687544; PMCID: PMC7371174. doi:10.1371/journal.pone.0236132
9. Maezawa K, Nozawa M, Maruyama Y, Sakuragi E, Sugimoto M, Ishijima M. Comparison of anemia, renal function, and nutritional status in older women with femoral neck fracture and older women with osteoarthritis of the Hip joint. *J Orthop Sci*. 2023;28(2):380–384. PMID: 35000815. doi:10.1016/j.jos.2021.12.009
10. Suresh S, Wright EC, Wright DG, Abbott KC, Noguchi CT. Erythropoietin treatment and the risk of Hip fractures in hemodialysis patients. *J Bone Miner Res*. 2021;36(7):1211–1219. PMID: 33949002; PMCID: PMC8360057. doi:10.1002/jbmr.4297
11. McCullough PA. Phosphate control: the next frontier in dialysis cardiovascular mortality. *Cardiorenal Med*. 2021;11(3):123–132. PMID: 34120113. doi:10.1159/000516286
12. Fusaro M, Holden R, Lok C, et al. Phosphate and bone fracture risk in chronic kidney disease patients. *Nephrol Dial Transplant*. 2021;36(3):405–412. PMID: 31620773. doi:10.1093/ndt/gfz196
13. González-Parra E, Bover J, Herrero J, et al. Control of phosphorus and prevention of fractures in the kidney patient. *Nefrologia*. 2021;41(1):7–14. PMID: 36165365. doi:10.1016/j.nefroe.2021.02.003
14. Ogata H, Fukagawa M, Hirakata H, Kagimura T, Fukushima M, Akizawa T; LANDMARK Investigators and Committees. Effect of treating hyperphosphatemia with lanthanum carbonate vs calcium carbonate on cardiovascular events in patients with chronic kidney disease undergoing hemodialysis: the LANDMARK randomized clinical trial. *JAMA*. 2021;325(19):1946–1954. PMID: 34003226; PMCID: PMC8132143. doi:10.1001/jama.2021.4807
15. Barrera-Baena P, Rodríguez-García M, Rodríguez-Rubio E, et al.; of COSMOS. Serum phosphate is associated with increased risk of bone fragility fractures in hemodialysis patients. *Nephrol Dial Transplant*. 2023;39(4):618–626. PMID: 37660283; PMCID: PMC10966329. doi:10.1093/ndt/gfad190
16. Floege J, Tsirtsonis K, Iles J, Drueke TB, Chertow GM, Parfrey P. Incidence, predictors and therapeutic consequences of hypocalcemia in patients treated with cinacalcet in the EVOLVE trial. *Kidney Int*. 2018;93(6):1475–1482. PMID: 29525393. doi:10.1016/j.kint.2017.12.014

17. Pyrża M, Głogowski T, Wieliczko M, et al. Malignancy prevalence in the dialyzed population and in waitlisted potential kidney transplant recipients. *Transplant Proc*. 2022;54(4):930–933. PMID: 35279304. doi:10.1016/j.transproceed.2022.01.025
18. Kwon SK, Han JH, Kim HY, et al. The incidences and characteristics of various cancers in patients on dialysis: a korean nationwide study. *J Korean Med Sci*. 2019;34(25):e176. PMID: 31243935; PMCID: PMC6597487. doi:10.3346/jkms.2019.34.e176
19. Kwon YE, Choi HY, Oh HJ, Ahn SY, Ryu DR, Kwon YJ. Vertebral fracture is associated with myocardial infarction in incident hemodialysis patients: a Korean nationwide population-based study. *Osteoporos Int*. 2020;31(10):1965–1973. PMID: 32394062. doi:10.1007/s00198-020-05423-y
20. Zhao X, Gan L, Niu Q, et al. Clinical outcomes in patients on hemodialysis with congestive heart failure. *Kidney Dis*. 2023;9(4):306–316. PMID: 37900002; PMCID: PMC10601911. doi:10.1159/000529802