Disruption of kinesthesia and position sense in the ankle joint is an independent predictor of falls in elderly patients undergoing hemodialysis

Nihal Sumeyye Ulutas[a], Recep Bentli[b], Ilhami Berber[b], Ozkan Ulutas[b,*]

[a]Malatya Turgut Ozal University, Faculty of Medicine, Department of Anatomy, Malatya, Türkiye
[b]Inonu University, Faculty of Medicine, Department of Internal Medicine, Malatya, Türkiye

Abstract

Aim: Patients receiving HD are more prone to accidental falls than elderly individuals not undergoing HD, leading to higher morbidity and mortality in this group. In this study, we hypothesized that senior HD patients with a history of falls may have impaired ankle kinesthetic position sense.

Materials and Methods: This study included 63 hemodialysis patients aged 65 and older. Baseline Timed Up and Go (TUG) test durations and ankle joint inclinometric deviation measurements were assessed in all participants, who were then monitored for fall events over a 12-month period. Patients who experienced one or more falls were classified as the faller group, while the rest were categorized as the non-faller group. Demographic data, laboratory values, TUG test durations, and ankle joint inclinometric deviations were compared between the two groups.

Results: Among the 63 patients, 25 (39.7%) were classified as fallers. The mean inclinometric deviation for the entire study population was 4.1±1.9 degrees. Notably, patients in the faller group had a significantly higher deviation (5.5±1.9) compared to those in the non-faller group (3.1±1.2, p=0.000). Age, serum albumin levels, TUG test duration, inclinometric deviation of patients have been included in the logistic regression analysis. Of these parameters, only inclinometric deviation (OR=2.627, p=0.003) was determined as an independent predictor of falls.

Conclusion: Falls are prevalent among elderly hemodialysis patients, and impairment of ankle kinesthetic position sense is evident in those who have experienced falls.

Introduction

As the number of elderly patients undergoing hemodialysis (HD) in recent years continues to rise, the number of the geriatric complaints experienced by these patients also increases. Patients maintained on HD have numerous functional and cognitive problems leading to fraility of these patients and, consequently, causing increase in mortality, hospital admissions and dialysis-related complications. A major issue that arises with aging involves accidental falls [1]. The aging process contributes to gait and balance impairments, diminished postural reflexes, neurosensory disorders, neurological and cardiovascular comorbidities, osteoarthritis, and reduced muscle strength [2]. In hemodialysis patients, the risk of falling is heightened due to dialysis-related factors, underlying causes of end-stage renal failure, and declining kidney function [3]. Compared to elderly individuals not on hemodialysis, HD patients experience a higher incidence of accidental falls, leading to increased morbidity and mortality in this population [4].

Functional mobility was assessed through the Timed Up and Go (TUG) test. Kinesthesia and position sense are components of proprioception and consciously or unconsciously effective on balance, as it senses lower extremity movements and the position of the joints [5]. In normal ambulation, ankle dorsiflexion is about 10 degrees and sensed by proprioceptors [6]. In this study, we investigated whether basal TUG test durations and ankle joint inclinometric deviation representing disruption in proprioceptive sensation differ in fallers and non-fallers.

Materials and Methods

This study aims to reveal that ankle kinesthetic position sense may be impaired in hemodialysis patients older than 65 years. Based on a theoretical power analysis conducted

*Corresponding author:
Email address: drozkanulutas@yahoo.com (Ozkan Ulutas)

using the G*Power 3.1 program, a minimum sample size of 50 patients (25 per group) was required to detect a significant difference between the two groups using an independent two-sample t-test. This calculation was performed with a Type I error rate (alpha) of 0.05, a test power (1-beta) of 0.80, an effect size of 0.81 (large effect), an alternative hypothesis (H1) assuming a two-tailed distribution, and a group allocation ratio of 1:1 [7]. All patients aged 65 years or older undergoing outpatient hemodialysis at Malatya Education and Research Hospital were eligible for inclusion in the study. Patients were excluded if they were unable or unwilling to provide informed consent. Additionally, individuals with amputations or those using a wheelchair were not included.

Sixty-three patients on hemodialysis aged 65 or more included to the present study. Approval for the ethics of the study was granted by the Malatya Regional Research Ethics Board (File No. 2018/162).

Medical history, cause of ESKD, and laboratory values were obtained from electronic computer records. Patients' TUG test and ankle joint inclinometric measurements were performed at the beginning of the study and noted. TUG tests and inclinometric measurements were done before the HD session. Fall is defined as, unintentionally coming to rest on the ground, floor, or other lower level [8]. All patients were questioned for falling events every Mondays and Tuesdays during the study period. Those who fell at least once during the study period were considered as fallers. Laboratory values, inclinometric deviations and TUG test durations of fallers and non-fallers were compared.

Kinesthesia and position sense of the ankle was measured using a simple digital inclinometer instrument on the dominant side. While the patients were in supine position, and their eyes were closed, their ankles were brought to 10 degrees of dorsiflexion by the help of study nurse. Afterwards, the patients were asked to come back to the starting point, and actively return to the set angle 3 times without help [5] (Figure 1). All patient attempts were recorded, and the deviation of the error angle from the set angle was used as the outcome measure. The test result was determined as the average of three recorded values.
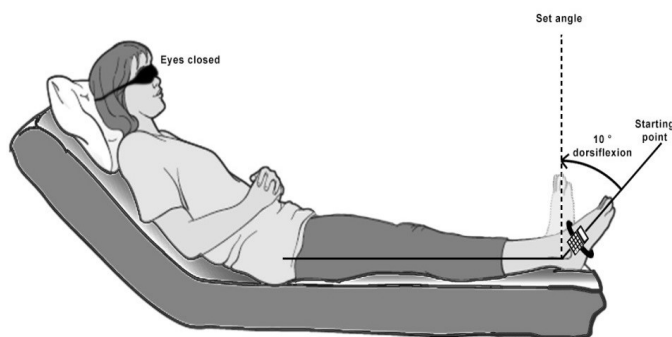

Figure 1. Inclinometric measurement of ankles.

In the TUG test, participants were instructed to rise from a chair, walk 3 meters, and return to a seated position. The completion time was recorded, with scores below 10 seconds considered normal. Patients scoring between 10–15 seconds were classified as having 'slowed mobility,' while those exceeding 15 seconds were categorized as having 'impaired mobility' [9].

Descriptive data were presented as mean and standard deviation (SD) or median and quartiles for continuous variables, as appropriate, and as frequency for ordinal or nominal data. The normality of continuous variables was assessed using the Shapiro-Wilk test. Group differences were analyzed using either the Mann–Whitney U test or Student's t-test, depending on the distribution of the data. A logistic regression analysis was performed to determine the independent predictors of falls. All probability values were reported two tailed and p value <0.05 was considered statistically signifcant. Analyses were performed using IBM SPSS software (ver. 23.0; SPSS Inc., Chicago, IL, USA).

Results

Of the 63 patients included in the present study, 49.2% were male. Etiology of kidney disease was diabetes mellitus (DM) in 22 (34.9%), hypertension (HT) in 20 (31.7%), glomerulonephritis (GN) in 7 (11.1%), and other causes (polycystic kidney disease, amyloidosis, renovascular diseases, kidney stones, and postrenal diseases) in 6 (9.5%) of the patients. Renal disease was of unknown origin in 8 (12.7%) of the patients. Among 63 patients, 25 (39.7%) patients were fallers. Median predialysis medical treatment duration was 2 (0-240) months, and median HD therapy duration was 26 (3-217) months. Mean hemoglobin (Hg) concentration was 11.1±1.5 g/dL, mean creatinin (cre) level was 5.3±1.8 mg/dL, mean 25-Hydroxyvitamin D level was 19.8±16.1 ng/mL, and mean parathormone (PTH) level was 421.3±401.1 pg/mL in study population. Mean hemoglobin, creatinine, 25-Hydroxyvitamin D, and PTH levels were similar among fallers and non-fallers. Both faller (11, 10-14.3) and non-fallers (10.7, 9-12) had slowed mobility according to TUG times, However, fallers had significantly longer (p=0.018) test durations .

The mean age of the study population was 73.9±7.5 years, with a significantly higher mean age of 76.8±7.2 years in the faller group (p=0.003). Serum albumin concentration was notably lower in the faller group, averaging 3.3±0.4 g/dL (p=0.018). The mean inclinometric deviation for the overall study population was 4.1±1.9 degrees, which was significantly greater in the faller group (5.5±1.9 degrees) compared to the non-faller group (3.1±1.2 degrees, p<0.001) (Table 1).

In the univariate analysis, age, serum albumin levels, TUG test duration, and p values of patients' inclinometric deviation were lower than 0.05 and were included in the logistic regression analysis. Inclinometric deviation was obtained as an independent significant risk factor in both univariate and multivariate analyses. Although age, albumin and TUG duration were significant in the univariate analysis, they were not significant in the multivariate analysis. According to the univariate analysis, when the Inclinometric deviation value increases, the risk of falling increases by 3.17 times (OR = 3.167, p<0.001). On the other hand, according to the multivariate analysis, even when other variables (age, albumin, TUG duration, etc.) are controlled, the risk of falling increases by 2.63 times in individuals with high Inclinometric deviation (OR = 2.627, p=0.003). Therefore, as the Inclinometric deviation value increases

Table 1. Baseline characteristics of study population.

	Study population (n=63)	Fallers (n=25) (39.7%)	Non-Fallers (n=38) (60.3%)	P value
Age (years)	73.9±7.5	76.8±7.2	72±7.1	**0.003***
Sex (% of males)	31(49.2%)	11 (44%)	20 (52.6%)	0.680
Etiology				
DM	22 (34.9%)	10 (40%)	12 (31.6%)	
HT	20 (31.7%)	6 (24%)	14 (36.8%)	
GN	7 (11.1%)	3 (12%)	4 (10.5%)	0.813
Others	6 (9.5%)	2 (8%)	4 (10.5%)	
Unknown	8 (12.7%)	4 (16%)	4 (10.5%)	
Median duration of RRT in months (range)	26 (3-217)	23 (12-217)	36 (3-203)	0.246
Number of antihypertensive medication (range)	0 (0-2)	0 (0-2)	0 (0-2)	0.706
Mean creatinin level (mg/dL)	5.3±1.8	5.4±1.6	5.3±1.9	0.908
Hemoglobin (g/dL)	11.1±1.5	11.1±1	11±1.7	0.752
Albumin (g/dL)	3.4±0.4	3.3±0.4	3.5±0.3	**0.018***
25-Hydroxyvitamin D (ng/mL)	19.8±16.1	19±16.8	20.3±15.9	0.373
PTH (pg/mL)	421.3±401.1	413±398.7	426±388.8	0.385
Median TUG test time (sn)	10.8 (9-14.3)	10.7 (9-12)	11(10-14.3)	**0.018***
Inclinometric deviation (degree)	4.1±1.9	5.5±1.9	3.1±1.2	**<0.001***
Number of falls (range)	0 (0-10)	1 (1-10)	0 (0-0)	**<0.001***
Number of falls with fracture (range)	0 (0-2)	0 (0-2)	0 (0-0)	**<0.001***

DM: Diabetes Mellitus, HT: Hypertension, GN: Glomerulonephritis, PTH: Parathormone, TUG: Timed up and go test, RRT: Renal replacement therapy, NS: Not significant *: Statistically significant.

Table 2. Independent predictors of falls.

	Univariate		Multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.096 (1.016-1.183)	**0.003***	1.103 (0.993-1.225)	0.066
Albumin	0.162 (0.034-0.772)	**0.022***	0.110 (0.007-1.691)	0.113
TUG duration	2.364 (1.211-4.616)	**0.012***	2.195 (0.839-5.747)	0.109
Inclinometric deviation	3.167 (1.730-5.799)	**<0.001***	2.627 (1.382-4.993)	**0.003***

TUG: Timed up and go test, OR: Odds ratio, CI: Confidence Interval, *: Statistically significant.

in individuals who have fallen, the risk of falling increases significantly (Table 2).

Discussion

This study shows that in elderly HD patients, the frequency of falls is high, TUG test durations are longer, and increased inclinometric deviation of the ankle is an independent determinant of the risk of falling. This study is the first study, that demonstrates proprioceptive sensory loss in HD patients with simple inclinometric measurements and shows that inclinometric deviation increases more in falling patients and is an independent determinant of the risk of falling.

Among many geriatric problems, falls are associated with severe morbidity and mortality in elderly patients who undergo hemodialysis and who do not. In addition to the difficulties of aging, many additional risk factors trigger

falls in hemodialysis patients. Neuropathies related to diabetes mellitus (DM), uremia or atherosclerosis in patients on HD are common. In addition to neuropathies, muscle and bone pain, muscle atrophies due to immobility, rapid electrolyte and hemodynamic changes due to HD session, and disruptions in the leukomotor system appear as additional risks in HD patients [10-11-12]. A retrospective study conducted by Cook and Jassal reported that while 27% of senior HD patients fell during the last one year, an additional another 16% fell during the previous year [13]. Roberts at al. demonstrated that, with a rate of 1.76 falls/patient year, 38% of HD patients fell within the one year period [14]. This rate was 1.60 falls/patient year in the study reported by Cook et al. [15]. In correlation with such prior studies, in the present study 39.7% of patients were fallers.

The dynamic balance and functional mobility of the pa-

tients included in the present study were assesed by means of TUG test. TUG test durations were significantly longer in fallers, and both fallers and non-fallers demonstrated slowed mobility. Zanotto et al. reported that falls were associated with longer duration of TUG tests and also showed that longer duration of TUG tests were independent predictors of falls in HD patients [16]. Nevertheless, TUG test durations were not independent predictors of falls in the logistic regression analyses of the present study.

Proprioception is defined as the perception of position and movement of the joints and the application of force in space [17-18]. Proprioceptive receptors and mechanoreceptors located on tendons, ligaments and joint capsules, percive the signals that are transmitted to central nervous system (CNS) via afferent sensory pathways and that ultimately culminate in the formation of proprioception. Signals from proprioceptive receptors and mechanoreceptors are integrated and processed in the CNS, and a response is sent to relevant tissues [19]. Maintaining balance, controlling body posture, and ensuring the stability of the body during static and dynamic activities are the main tasks of proprioception. If proprioception fails to function adequately, risk of falling increases [20]. The role of proprioception in falling is a topic that is mentioned very little in geriatric patient groups. Moreover, the role of proprioception in falling has never been studied in geriatric patients also receiving HD. Basic inclinometric deviation measurements of the ankle are indicative of proprioceptive sensation.

In the present study, inclinometric deviation of ankles was significantly higher in the falling group ($p<0.001$). In the logistic regression analysis, which included the patients' age, TUG test durations, ankle inclinometric deviation measurements, as well as albumin levels, high ankle inclinometric deviation appeared as the independent determinant of the falls (OR=2,627, p=0.003). The data obtained by the present study shows proprioceptive sensation is more impaired in fallers. There are many reasons for falls in HD patients. HD patients are prone to neuropathy due to etiological reasons and uremia-related causes. Diabetic polyneuropathy and uremic polyneuropathy are common in dialysis patients. In the present study, the number of patients diagnosed with diabetic nephropathy was 22 (34.9%). A comparison of the number of falls reported by patients diagnosed with diabetic nephropathy and the number of falls documented for patients suffering from nephropathy of other etiological causes, there was no significant difference in terms of the number of falls. Uremic polyneuropathy is a frequent finding and is demonstrated in more than 60% of chronic kidney disease patients [21]. Although the cause of uremic polyneuropathy is unknown, it is thought to be caused by thiamine, zinc and biotin deficiencies, or by the toxicity of middle molecular weight uremic toxins that are more difficult to remove by hemodialysis [22]. Uremic polyneuropathy is a distal symmetrical sensorymotor neuropathy. The afferent pathway of proprioception is also transmitted to CNS via sensory nerves. Proprioception pathways may be more affected in the falling group of HD patients. Although there are no studies showing receptor activities in HD patients, it is possible to hypothesize that mechanoreceptor and proprioceptive receptor activities in falling HD patients may

be more impaired. We also do not know whether there are changes in the proprioceptive interpretation of the CNS in uremic patients.

Small study population is a limitation of our study. Performing EMG of patients would be helpful to demonstrate whether there were basal neuropathies. Comparing the patients with healthy controls would show the effect of uremia on proprioceptive sensation more clearly.

The present study also has some strengths. Firstly, it is important to note that this is the first study examining the relationship between proprioception and falls in hemodialysis patients. Additionally, the fact that all inclinometric measurements were made by the same study nurse is also of great significance. Finally, that both TUG tests and inclinometric measurements were performed 3 times and averages were accepted as test results adds to the strengths of the present study.

In summary, falls are common in elderly hemodialysis patients, and disruption of ankle proprioception is evident in HD patients who fell. Exercise programs for increasing the proprioceptive inflow may be beneficial to prevent subsequent falls.

Conflict of Interest

The authors declare that they have no conflicts of interest that are directly relevant to the content of this article.

Ethics Committee Approval

This study was conducted on human participants. The study was approved by the Malatya Regional Research Ethics Board, Malatya, Turkey. File number: 2018/162.

Informed Consent

Informed consent was obtained from all participants included in the study.

Explanation

The English in this document has been checked by at least two professional editors, both native speakers of English.

References

1. van Loon IN, Joosten H, Iyasere O, Johansson L, Hamaker ME, Brown EA. The prevalence and impact of falls in elderly dialysis patients: Frail elderly Patient Outcomes on Dialysis (FEPOD) study. *Arch Gerontol Geriatr.* 2019;83:285–291. doi:10.1016/j.archger.2019.05.015.

2. Plantinga LC, Patzer RE, Franch HA, Bowling CB. Serious Fall Injuries Before and After Initiation of Hemodialysis Among Older ESRD Patients in the United States: A Retrospective Cohort Study. *Am J Kidney Dis.* 2017;70(1):76–83. doi:10.1053/j.ajkd.2016.11.021.

3. Farragher J, Rajan T, Chiu E, et al. Equivalent Fall Risk in Elderly Patients on Hemodialysis and Peritoneal Dialysis. *Perit Dial Int.* 2016;36(1):67–70. doi:10.3747/pdi.2014.00163.

4. Farragher J, Chiu E, Ulutas O, Tomlinson G, Cook WL, Jassal SV. Accidental falls and risk of mortality among older adults on chronic peritoneal dialysis. *Clin J Am Soc Nephrol.* 2014;9(7):1248–1253. doi:10.2215/CJN.11001013.

5. Ha SY, Han JH, Sung YH. Effects of ankle strengthening exercise program on an unstable supporting surface on proprioception and balance in adults with functional ankle instability. *J Exerc Rehabil.* 2018;14(2):301–305. Published 2018 Apr 26. doi:10.12965/jer.1836082.041.

6. Weir J, Chockalingam N. Ankle joint dorsiflexion: Assessment of true values necessary for normal gait. *International Journal of Therapy and Rehabilitation.* Vol. 14, No. 2.76-82, https://doi.org/10.12968/ijtr.2007.14.2.23518.

7. Buchner A, Erdfelder E, Faul F, Lang A. G* Power 3.1 manual. Düsseldorf, Germany: Heinrich-Heine-Universitat Dusseldorf. 2017.

8. Buchner DM, Hornbrook MC, Kutner NG, et al. Development of the common data base for the FICSIT trials. *J Am Geriatr Soc.* 1993;41(3):297–308. doi:10.1111/j.1532-5415.1993.tb06708.x.

9. Botolfsen P, Helbostad JL, Moe-Nilssen R, Wall JC. Reliability and concurrent validity of the Expanded Timed Up-and-Go test in older people with impaired mobility. *Physiother Res Int.* 2008;13(2):94–106. doi:10.1002/pri.394.

10. 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. doi:10.1046/j.1523-1755.2000.00178.x

11. Soangra R, Lockhart TE, Lach J, Abdel-Rahman EM. Effects of hemodialysis therapy on sit-to-walk characteristics in end stage renal disease patients. *Ann Biomed Eng.* 2013;41(4):795–805. doi:10.1007/s10439-012-0701-6.

12. Erken E, Ozelsancak R, Sahin S, et al. The effect of hemodialysis on balance measurements and risk of fall. *Int Urol Nephrol.* 2016;48(10):1705–1711. doi:10.1007/s11255-016-1388-7.

13. Cook WL, Jassal SV. Prevalence of falls among seniors maintained on hemodialysis. Int Urol Nephrol. 2005;37(3):649–652. doi:10.1007/s11255-005-0396-9.

14. Roberts R, Jeffrey C, Carlisle G, Brierley E. Prospective investigation of the incidence of falls, dizziness and syncope in haemodialysis patients. *Int Urol Nephrol.* 2007;39(1):275–279. doi:10.1007/s11255-006-9088-3.

15. Cook WL, Tomlinson G, Donaldson M, et al. Falls and fall-related injuries in older dialysis patients. *Clin J Am Soc Nephrol.* 2006;1(6):1197–1204. doi:10.2215/CJN.01650506.

16. Zanotto T, Mercer TH, van der Linden ML, et al. The relative importance of frailty, physical and cardiovascular function as exercise-modifiable predictors of falls in haemodialysis patients: a prospective cohort study. *BMC Nephrol.* 2020;21(1):99. Published 2020 Mar 14. doi:10.1186/s12882-020-01759-z.

17. Westlake KP, Culham EG. Sensory-specific balance training in older adults: effect on proprioceptive reintegration and cognitive demands. Phys Ther. 2007;87(10):1274–1283. doi:10.2522/ptj.20060263.

18. Ribeiro F, Oliveira J. Aging effects on joint proprioception: the role of physical activity in proprioception preservation. Eur Rev Aging Phys Act. 2007; 4(2): 71-76. https://doi.org/10.1007/s11556-007-0026-x.

19. Myers JB, Lephart SM. The role of the sensorimotor system in the athletic shoulder. *J Athl Train.* 2000;35(3):351–363.

20. Ferlinc A, Fabiani E, Velnar T, Gradisnik L. The Importance and Role of Proprioception in the Elderly: a Short Review. Mater Sociomed. 2019;31(3):219–221. doi:10.5455/msm.2019.31.219-221.

21. Baumgaertel MW, Kraemer M, Berlit P. Neurologic complications of acute and chronic renal disease. *Handb Clin Neurol.* 2014;119:383–393. doi:10.1016/B978-0-7020-4086-3.00024-2.

22. Guolo M, Stella AM, Melito V, Parera V, Del C Batlle AM. Altered 5-aminolevulinic acid metabolism leading to pseudoporphyria in hemodialysed patients. *Int J Biochem Cell Biol.* 1996;28(3):311–317. doi:10.1016/1357-2725(95)00133-6.