Review

Falls in elderly hemodialysis patients

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Summary

The elderly, (age ≥65 years) hemodialysis (HD) patient population is growing rapidly across the world. The risk of accidental falls is very high in this patient population due to multiple factors which include aging, underlying renal disease and adverse events associated with HD treatments. Falls, the most common cause of fatal injury among elderly, not only increase morbidity and mortality, but also increase costs to the health system. Prediction of falls and interventions to prevent or minimize fall risk and associated complications will be a major step in helping these patients as well as decreasing financial and social burdens. Thus, it is vital to learn how to approach this important problem. In this review, we will summarize the epidemiology, risk factors, pathophysiology and complications of falls in elderly HD patients. We will also focus on available methods to assess and predict the patients at higher risk of falling and will provide recommendations for interventions to reduce the occurrence of falls in this population.

Introduction

The elderly population has grown rapidly during the 20th century across the world and continues to grow.¹ This trend is mirrored in the elderly patients with end stage renal disease (ESRD).²,³ As a result of aging and other factors, elderly patients are at increased risk of accidental falls.⁴ This problem is magnified further in elderly patients with ESRD treated with hemodialysis (HD) due to the added risks of the kidney disease burden as well as the HD technique itself.⁵,⁶ Falls can result in multiple complications. These complications include injuries, disability and loss of independence, poor quality of life, nursing home placement and high cost to the health system.⁵,⁶ More importantly, falls can be markers of poor health and declining function, and are often associated with significant morbidity and mortality.⁶,⁷ Although the complications and impact of falls on the elderly have been addressed and are the subject of clinical guidelines,⁸ falls in the growing population of elderly on chronic HD have received little attention.

In this article, we will review the epidemiology, risk factors, pathophysiology and complications of falls in elderly ESRD patients on HD. We will focus on available methods to assess and predict the patients at higher risk of falling and will provide recommendations for interventions to reduce the occurrence of falls in this population.

Epidemiology

Approximately 27% of community-dwelling people over the age of 65 years fall at least once per year.
and this proportion increases in correlation with aging.\textsuperscript{9–11} There is a paucity of epidemiological information about falls in elderly (age \( \geq 65 \) years) HD patients. Though most studies showed high incidence of fall in elderly patients on HD, there was wide variation in the published data. Desmet et al.\textsuperscript{12} noted an incidence of fall of 12.7\% of HD patients over an 8-week study period. In a cross-sectional interview based survey to determine the one year prevalence of falls among elderly patients on HD, Cook and Jassal found that 27\% of the patients surveyed have fallen over the 12 month period, with an additional 16\% having fallen prior to that time.\textsuperscript{13} In a prospective study, Cook et al.\textsuperscript{5} followed 162 elderly HD patients for a median of 468 days, 76 patients fell one or more times with a fall incidence rate of 1.60 falls/person-year. In a recent study, Fleming et al.\textsuperscript{14} found an incidence of 2.8 falls/person-year in HD patients. More recently, we reported an incidence of falls of 38.2\% in our elderly HD population over a 12-month period. That incidence of falls in our elderly HD population was significantly higher than the incidence of falls in our younger HD population (16.7\%, \( P = 0.034 \)).\textsuperscript{7}

**Pathophysiology**

The median age of incident HD patients is now 64.4 years and this population has a high risk for falls as outlined in Table 1.\textsuperscript{15} The pathophysiology of falls in elderly patients on HD can be divided into several causes: (i) related to aging, (ii) related to the predisposing cause of ESRD, (iii) related to the loss of kidney function and (iv) related to the HD treatment.

### Related to aging

Several risk factors contribute to fall in older subjects and were outlined in the guidelines for the prevention of falls in older persons published by the American Geriatrics Society, British Geriatrics Society and American Academy of Orthopedic Surgeons Panel on Falls Prevention\textsuperscript{16,17} (Table 1).

### Related to the predisposing cause of ESRD

The multiple co-morbid factors that can lead to kidney failure and ESRD can also act as risk factors leading to falls. Diabetes mellitus, the commonest cause of ESRD in the US, is often associated with microvascular and macrovascular complications like autonomic neuropathy, peripheral neuropathy, retinopathy and decreased visual acuity that can increase the susceptibility to falls. Peripheral vascular disease, cardiovascular problems and hypertension with hypotensive episodes related to overmedication may also contribute to the high prevalence of falls in this population (Table 1).

### Related to the loss of kidney function

The burden of kidney disease in patients with chronic kidney disease (CKD) can contribute to fall in this population (Table 1). These burdens include severe functional limitations, such as low cardio-respiratory fitness, symptoms of tiring easily and fatigue, we

<table>
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<tr>
<th>Table 1</th>
<th>Common risk factors for falls in elderly HD patients</th>
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<tr>
<td><strong>Related to aging</strong></td>
<td><strong>Related CKD co-morbidities</strong></td>
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<tr>
<td>Gait deficit</td>
<td>Diabetes mellitus, with microvascular and macrovascular sequelae</td>
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<tr>
<td>Decreased mobility</td>
<td>Peripheral vascular disease</td>
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<tr>
<td>Cognitive impairment</td>
<td>Cardiovascular problems</td>
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<td>Postural hypotension</td>
<td>Hypertension with hypotensive episodes</td>
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<td>Multiple medications</td>
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<td>Inner ear impairments</td>
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<td>Visual impairments</td>
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<td>Cardio-vascular diseases</td>
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<td>Neurologic diseases</td>
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<tr>
<td>Impaired posture control</td>
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<td>Impaired muscle</td>
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<td>strength and tone</td>
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<td>Balance deficits</td>
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<tr>
<td>Arthritis</td>
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<td>Impaired ADL</td>
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<td>Depression</td>
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ADL: activities of daily living.
muscular irritability and myoclonus. Other problems associated with kidney disease include disturbances of mineral metabolism as seen in CKD bone mineral disease (CKD-BMD).

Vitamin D deficiency and osteoporosis have been reported to affect predominantly the weight-bearing antigravity muscles of the lower limb and are necessary for postural balance and walking, and a significant correlation between serum 25 (OH) D3 concentration and the occurrence of falls in elderly people has been reported. Renneboog et al. showed that hyponatremia even mild can affect attention and gait that could cause falls in the elderly. Kengne et al. investigated the association between bone fracture after incidental fall and hyponatremia in the ambulatory elderly. According to results of this study hyponatremia was found be a major risk factor for bone fracture in this population. Kinsella et al. also evaluated whether hyponatremia is associated with fracture occurrence and osteoporosis in women. According to results of this study, patients with fractures had significantly higher incidence of hyponatremia than those without (8.7 vs. 3.2%), patients with hyponatremia were older and had slightly lower bone density and hyponatremia was also found a major risk factor for the development of fracture with an odds ratio of 2.25 even after adjustment for age, bone density, CKD and other risk factors. In a recent study, Hoorn et al. also found similar results with the latter one.

In a meta-analysis, digoxin, type IA antiarrhythmic and diuretic use (the pooled odds ratio (95% confidence interval) was 1.08 (1.02–1.16) for diuretic use, 1.06 (0.97–1.16) for thiazide diuretics, 0.90 (0.73–1.12) for loop diuretics, 0.93 (0.77–1.11) were found to be weakly associated with falls in older adults. Possible explanation of falls associated with diuretic use include dizziness as a consequence of orthostatic hypotension.

Anemia, which is an extremely prevalent condition in older age and is common in the setting of declining kidney function, correlates with reduced muscle strength, poor physical performance and disability. Finally, acidosis, a common complication of ESRD, is associated with negative nitrogen balance and can cause patients to lose lean body mass by preventing the activation of adaptive responses that maintain protein stores, thus contributing to falls.

Thus, many factors related to the burden of kidney disease could explain the increasing incidence of falls in this population.

Related to HD treatment

The marked reduction in exercise tolerance observed in patients receiving HD is attributed to various central and peripheral factors such as anemia, metabolic disturbances, impairment of cardiac autonomic control, cardiac dysfunction, very low cardio-respiratory fitness, defect of muscle oxidative metabolism and skeletal muscle atrophy, and as a result of uremic myopathy and neuropathy. Moreover, a sedentary lifestyle and psychological dysfunction because of both renal failure and
inactivity are factors reported to influence physical fitness in these patients on HD.\textsuperscript{45,46}

Other risk factors for falls are related to complications or adverse effects of dialysis treatments. Intradialytic hypotension or hypotension occurring shortly after HD treatments is a common problem in 15–30\% of patients in general and probably more so in elderly patients.\textsuperscript{47} In a study by Roberts et al.,\textsuperscript{48} 47 HD patients aged \(\geq 70\) years were interviewed. Twenty patients reported syncope/pre-syncope episodes, 34 reported dizziness and 14 recalled at least one fall in the previous year. Around 8 out of 23 patients (34.8\%) had orthostatic hypotension pre-dialysis as compared to 16 out of 23 patients (69.6\%) having orthostatic hypotension post-dialysis, highlighting the high incidence of hypotensive symptoms and their squeal between dialysis episodes.\textsuperscript{48} A number of causal factors are involved in the pathogenesis of intradialytic hypotension partly related to the dialysis technique itself (ultrafiltration, dialysate sodium and temperature, membrane) and partly related to the patient (hydration, anemia and cardiovascular pathologies).\textsuperscript{49} The high interdialytic weight gains necessitating higher ultrafiltration rates, concomitant use of antihypertensive agents, autonomic dysfunction and less biocompatible membranes are also factors that contribute to significant hypotension.\textsuperscript{50,51}

Arrhythmia in HD patients can contribute to the falls noted in these patients. Arrhythmia can occur as a result of several disorders of serum ion balance, anemia and water retention. Age, duration of HD and acetate dialysis also have close relation with occurrence of arrhythmias among HD patients.\textsuperscript{52} Left ventricular hypertrophy leads to ventricular arrhythmias and is an independent risk factor for cardiac disease in dialysis patients.\textsuperscript{53} A high calcium phosphate product predialysis may also correlate with increased incidence of ventricular arrhythmias.\textsuperscript{52}

We further showed that the HD treatment itself influenced strength and mobility of patients (i.e. comparing post- to pre-dialysis, patients demonstrated weaker strength and slower mobility after the dialysis) suggesting that post-HD fatigue plays a role in falls in this population.\textsuperscript{17,55} Thus, problem of fall in elderly HD patients is unique with variable factors contributing to their falls.

Plasma potassium levels are generally maintained at 3.5–5 mEq/l in adults. Hyperkalemia, not an uncommon finding in the dialysis patients,\textsuperscript{56} can lead to significant hemodynamic and neurologic consequences, as well as abnormal heart (arrhythmia) and skeletal muscle function (muscle weakness) by lowering cell-resting action potential and preventing repolarization. These abnormalities can potentially cause falls. Hypokalemia was also demonstrated to be associated with falls.\textsuperscript{57} During a dialysis treatment, 50–80 mmol of potassium are removed,\textsuperscript{58} and this potassium depletion can cause several complications, with the elderly being more likely to suffer from hypokalemia-related complications.\textsuperscript{59} Hypokalemia can predispose to the development of arrhythmia\textsuperscript{60} and muscles abnormalities. Potassium depletion can impair muscle contractility, reduce blood flow to skeletal muscles, predisposing patients to rhabdomyolysis, with resulting muscle weakness, and myalgia, and rarely leading to paralysis.\textsuperscript{61} Furthermore, abnormal potassium levels in patients with ESRD on dialysis can cause uremic neuropathy.\textsuperscript{62} All these potassium-related abnormalities, cardiac, muscular and neurological, can contribute to falls in this population with ESRD on dialysis.

### Complications of falls

Nearly, two-thirds of the more than 10 000 fatal accidents each year among elderly result from falls, making falls the most common source of fatal injury among elderly. For those subjects of ages 70–79 years, 27.7\% of injury-related deaths are attributable to falling. This proportion increases to 46.4 and 64.8\% for those of ages 80–89 and 90–99 years, respectively.\textsuperscript{63} An increase in the total fall-induced injuries as well as an increase in the rate of fall-induced injuries per 100 000 patient by 284 and 183\% over a 25 years period between 1970 and 1995 has been shown in patients aged 50 years and older.\textsuperscript{64}

Fractures in elderly are an outcome of the interaction between bone fragility and trauma force, more often a ‘fall’. In the nondialedged older adults, fall prevalence is correlated with fracture prevalence. Parkkari et al.\textsuperscript{65} showed that in 98\% of the hip fracture patients, the fracture was a result of a fall. Kohlmeier et al.\textsuperscript{66} confirmed the magnitude of this problem in HD patients. In their study, during a 4-year follow up of 219 HD patients, one in seven patients suffered at least one fracture. Many of these were fractures of major bones which required hospitalization and lead to a serious decline of some of the patients’ health status. Hip fractures remain an important cause of morbidity and mortality associated with a 20\% increase in mortality at 1 year.\textsuperscript{67} The economic burden of hip fracture is estimated to be more than $20 billion per year.\textsuperscript{68}
Hip fractures are particularly common among ESRD patients. Reports suggest a 4.4 relative risk for hip fracture for HD patients compared to age, race and gender matched control in the normal population.69 The one year mortality from hip fracture event is nearly 2.5 times greater in the dialysis patients compared with general population.70 Though, the higher incidence of hip fracture in the HD patients’ population may be due to renal bone disease, it is probably also related to the increased incidence of falls.

Falls can also be a major financial and social burden. The health care costs of falls are substantial. In one study, it was shown that incurring one or more injurious falls was associated with increased total health cost by $ 19,440 annually.71 Tinetti et al.,72 further showed in a prospective trial among older patients living in the community that falls are a strong predictor of placement in a skilled-nursing facility with additional social and economic burden.

**Assessing the risk of falling**

Prediction of falls and interventions to prevent or minimize fall risk and its associated complications will be a major step in helping these patients as well as decreasing the financial and social burdens (Table 2). In 2008, Centers for Medicare/Medicaid Services (CMS) implemented new coverage rules for preventable hospital-acquired adverse events including falls-related injuries. According to these rules, reimbursements about preventable events might be withheld even in high risk patients.73 Therefore, identifying patients who are at higher risk of developing complications with the help of active quality assurance and performance improvement (QAPI) programs may improve patients’ quality of life and possibly survival as well as reducing the staggering costs associated with these complications.

<table>
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<tr>
<th>General</th>
<th>ESRD patients on HD</th>
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<td>Vital signs</td>
<td>Routine questioning about falls risks/occurrences</td>
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<tr>
<td>Mental status testing</td>
<td>Measure pre- and post-BP</td>
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<tr>
<td>Cardiac</td>
<td>Routine assessment of ultrafiltration rate and target weight</td>
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<td>Musculoskeletal</td>
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<td>Neurological</td>
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<td>Proprioception</td>
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<tr>
<td>Vision</td>
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<td>Hearing</td>
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<td>Gait and balance testing</td>
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Murphy et al.\textsuperscript{76} studied fallers vs. nonfallers among the general population in the community setting, and showed that the 5 min Walk, the five-step test and the functional reach tool all reached sensitivity and specificity values >70. However, a Canadian study\textsuperscript{77} stated that these tools while having good construct validity, they do not have predictive validity in the general population. Therefore, the choice of a tool in a clinical context needs to reflect the purpose for which the tool is to be applied. For screening of high-risk population, a tool that is quick and easy to apply with good sensitivity and specificity will be required. On the other hand, for risk reduction, a tool that can reliably identify remediable factors on which interventions can be focused would be of great benefit. These different purposes of fall-assessment tools that make selection of an appropriate tool difficult is further complicated by the lack of consistency in methods of reporting and interpreting the comparative properties of these tools in the published literature.

Psychological history is crucial in the assessment of risks of falling. Depression and social isolation may result in unintentional- or possibly intentional-falls as ways to gain attention or end one’s life. Additionally, depression may contribute to falls because depressed people may be less attentive to environmental hazards.\textsuperscript{78} The potential for confusion, also associated with depression in the elderly, can result in reduced ability to perceive and respond to environmental hazards.

**Specific to patients with ESRD on HD**

Given the high prevalence of falls in the patients with ESRD on HD and the associated morbidity and mortality in this population, it is imperative that adequate assessment tools should be used to detect the risk and prevent falls in the elderly on dialysis.

An easy first approach is to ensure that the dialysis staff caring for these patients routinely assess for fall risk factors and question any patient who reports a recent fall. Adequate monitoring of the blood pressure, following monthly laboratories with special emphasis at correcting the predisposing problems associated with falls such as anemia, metabolic acidosis and bone-mineral parameters are highly recommended.

Assessing gait characteristics that are traditionally done in a gait laboratory and/or with a wearable device are cumbersome especially for elderly patients with ESRD already burdened with the need to go to a dialysis unit three times per week for HD treatments and are rarely done. We recently tested a new wireless wearable device, the TEMPO (Technology-Enabled Medical Precision Observation) and were able to obtain precise gait and posture data continuously and noninvasively, which will help us study the relationship between gait disorders and fall risk.\textsuperscript{54}

**Intervention**

Several actions need to go hand-in-hand to decrease risk of falling in the elderly population. In a recent review of several randomized clinical trials dealing with falls intervention in elderly and published between 2003 and 2010, Michael et al.\textsuperscript{79} reviewed 54 trials with a total of 26 102 participants using different falls intervention approaches. These approaches included multifactorial assessment and management strategies, exercise/physical therapy interventions and vitamin D supplementations. While some of these interventions (vitamin D supplementation and exercise) were successful in reducing falls, the trials addressing multifactorial assessments and management showed contradictory results. Clinical education and behavioral counseling about the prevention of falls in high-risk geriatric population constitute an important but usually undertaken point. Clemson et al.\textsuperscript{80} also studied the effects of behavioral counseling on the prevention of falls in high-risk older adults, and showed that programs that encourage behavioral changes can be beneficial in decreasing falls.

**General**

Elderly patients with several co-morbid conditions are on multiple drug regimens. Minimizing the number of medications and avoiding drug interactions can be very helpful to prevent falls in the elderly.

Physical improvement of the patient’s condition can be attained through routine physical examination of visual, auditory, muscular and cardiovascular functions of the patient. Once an abnormality is identified, immediate intervention is warranted. Improvement of the environment of the patients, removing obstacles, adding aiding and safety tools to the surrounding environment can be helpful. Physical therapy and exercise are crucial in maintaining and improving the muscular-skeletal system. While the benefit of physical therapy and exercise are becoming more evident in patients with ESRD, it is still underutilized. Johansen\textsuperscript{81} argues that nephrologists should not cite the paucity of published position statements about exercise or the lack of randomized data on outcomes as survival as reasons for the underutilization of these measures in ESRD population. In fact, the Kidney Disease Outcomes
Quality Initiative (K/DOQI) clearly endorses exercise and physical therapy in patients with ESRD.82

**Specific for patients with ESRD on HD**

In addition to the general guidelines aimed at preventing falls in the elderly, special intervention should be addressed applied for the elderly patients with ESRD on HD.

Vitamin D supplementation was shown to decrease incidence of falls. In a study by Pfeifer et al., vitamin D supplementation was given for 8 week with vitamin D and calcium in 148 elderly women with a serum 25 (OH) D3 concentration <50 nmol/l resulted in a decrease (9%; P<0.05) in body sway and fewer falls per subject over 1 year of follow-up as compared with calcium mono therapy (0.24 compared with 0.45; P<0.05). In contrast, supplementation in an elderly Dutch population (≥70 years of age) with 10 g (400 IU) vitamin D3/day for 2 years did not result in significantly fewer falls than in a placebo group.9 In addition, supplementation in a healthy elderly (≥65 years of age) Boston population with vitamin D and calcium for 3 years did not result in a significantly lower incidence of falls than in a placebo group.84

In a recent double blinded study, Gallagher et al.85 studied 415 women aged 65–77 years. They were randomized to receive calcitriol 0.25 mcg twice daily, estrogen and progestin therapy with or without calcitriol or to placebo. Follow-up at 3 years showed that calcitriol treatment decreased the number of falls and of those who fell. In a subgroup with renal impairment with creatinine clearance <60 ml/min, while calcitriol monotherapy reduced the rate of falls by 53%, it decreased it by 61% when combined with estrogen and progestin. Estrogen and progestin without calcitriol decreased falls by 25%. Furthermore, Michael et al.79 showed that Vitamin D with or without calcium was associated with a 17% (CI, 11 to 23%) reduced risk for falling during 6 to 36 months of follow-up.

Studies in the field of renal rehabilitation have shown that exercise training in HD patients improves the aerobic capacity, muscle strength, cardiac parasympathetic activity, lipid profile, the mood and also the quality of life.41–43 Aerobic training usually activates glycolytic as well as oxidative fibers, and, therefore, may improve muscle endurance.43 A combined program of aerobic training and strength building during HD can be carried out safely with proper supervision and patient education, and it improves the physical and mental well-being of patients with ESRD.

Special care as using a wheelchair and staff assistance with transfers and pre- and post dialysis weight checks has to be applied the patients with frequent and recurrent falls as they are more prone to further falls and subsequent morbidity and mortality.17

**Conclusion**

Falls in the elderly patients with ESRD on HD are highly prevalent, and associated with severe morbidity risks and high mortality. In spite of that, little emphasis has been placed on identifying, preventing and adequately managing these patients in terms of fall risk. For the clinicians who are caring this patient population, it is vital to consider the risk of falls as important as other important complications associated with ESRD. Various fall prevention programs have been shown to be effective in the general population and such programs should be developed for elderly dialysis population. Heung et al.17 recently developed a fall-risk assessment tool to identify patients at high risk for falls and fall related complications. A routine brief simple questionnaire (Appendix 1) may be included in the nurse assessment protocols for each patient at the beginning of each dialysis session. Promoting more physical therapy and exercise in the dialysis facility could be of great help in this population.

*Conflict of interest:* None declared.

**References**


**Appendix 1**

Did you experience any falls during this month?

If yes then:

1. How many times did you fall?
2. Anything preceding falls: dizziness, irregular heartbeat, smell, auditory, tripping, room spinning, others.
3. Any outcome from the fall: loss of conscience, fracture, hospitalization, ER visit, temporary disability, permanent disability, NH placement, physical therapy, others.
4. Fall in relation to dialysis: same day (before or after), nondialysis day.