Hyponatremia as a fall predictor in a geriatric trauma population

Katelyn J. Rittenhouse **, Tuc To, Amelia Rogers, Daniel Wu, Michael Horst, Mathew Edavetal, Jo Ann Miller, Frederick B. Rogers *

Lancaster General Health, Lancaster, PA, United States

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A B S T R A C T

Introduction: Approximately one in three older adults fall each year, resulting in a significant proportion of geriatric traumatic injuries. In a hospital with a focus on geriatric fall prevention, we sought to characterize this population to develop targeted interventions. As mild hyponatremia, defined as a serum sodium <135 meq/L, has been reported to be associated with falls, unsteadiness and attention deficits, we hypothesized that hyponatremia is associated with falls in our geriatric trauma population.

Methods: Gender, age, pre-existing conditions (cardiac disease, diabetes, hematologic disorder, liver disease, malignancy, musculoskeletal disorder, neurological disorder, obesity, psychiatric disorder, pulmonary disease, renal disease, thyroid disease), mechanism of injury and admitting serum sodium level were queried for all geriatric trauma admissions from 2008 to 2011. Mechanism of injury was coded as falls admissions and non-falls admissions. Admitting serum sodium levels were coded as hyponatremic (<135 mmol/L) and not hyponatremic (≥135 mmol/L).

Results: Of the 2370 geriatric trauma admissions during the study period, there were 1841 (77.7%) falls admissions and 293 (19.4%) patients who were hyponatremic. Gender, age, neurological disorder, hematologic disorder, and hyponatremia were found to be significant predictors of falls in both univariate and multivariable analyses.

Conclusion: Hyponatremic patients are significantly more likely to be admitted for a fall than non-hyponatremic patients, when adjusting for age, neurological disorder, and hematologic disorder. Consequently, hyponatremia identification and management should be an integral part of any geriatric trauma fall prevention programme. Additionally, if hyponatremia is found during a geriatric fall workup, it should be corrected prior to discharge and closely monitored by a primary care physician to prevent recurrent episodes of falls.

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Introduction

Hyponatremia is the most common electrolyte imbalance in the geriatric population [1,2]. This disorder can be attributed to many factors, including polypharmacy and conditions such as congestive heart failure, cirrhosis, chronic kidney disease or renal insufficiency, and syndrome of inappropriate antidiuretic hormone secretion (SIADH) [3–6]. The clinical significance of hyponatremia is not well-understood. Although some neurological disturbances have been found to be correlated with moderate to severe hyponatremia [7], mild hyponatremia has been traditionally identified as asymptomatic because symptoms are rather non-descript [8,9]. However, as a growing body of literature associates mild cases of this condition with unsteadiness, falls, attention deficits, and risk of fracture [10–13], the identification of mild hyponatremia as ‘asymptomatic’ is being challenged.

Although hyponatremia can affect all ages, it has been found to be most prevalent among older adults [14]. Further, as approximately 30% of elderly adults fall each year [15–17] and 20–30% of these falls result in moderate to severe injuries [18] with a mortality rate between 7% and 11% [18–20], falls are a significant concern in the geriatric population. As the elderly population expands nationwide [21] the proportion of geriatric admissions at our level II trauma centre increased from 23.3% in 2000 to 33.9% in 2011. During the same period, the proportion of our geriatric
admissions attributed to falls increased from 66.1% to 80.4%. As falls are the most common mechanism of injury for the expanding elderly population, both at our trauma centre and nationwide [18], our trauma service is actively seeking to identify and address risk factors for geriatric falls. We sought to examine the relationship between hyponatremia and falls in our geriatric trauma population. We hypothesized that hyponatremia is a predictor of falls in our elderly trauma patients.

Methods

Following study review and approval by the Institutional Review Board of Lancaster General Health, the trauma registry of the Pennsylvania Trauma Systems Foundation (Digital Innovations, Forest Hill, MD) was interrogated for all admissions age ≥65 years at a Pennsylvania-verified Level II trauma centre from 2008 to 2011. Age, gender, injury severity score (ISS), pre-existing conditions (PECs), mechanism of injury (MOI), and mortality were queried. Additionally, serum sodium levels at admission were abstracted from the patient’s medical record in the Epic electronic medical record system (EpicSystems Corporation, Verona, WI). These serum sodium levels were obtained during the admission workup, as part of a basic metabolic panel, collected between Emergency Department (ED) arrival and hospital admission. ED length of stay (LOS) was used as a surrogate for time from ED arrival to serum sodium collection. Admissions were excluded from the study if they were missing any of the study variables. Patients were identified as hyponatremic (<135 mmol/L), or not hyponatremic (≥135 mmol/L), based on admitting serum sodium levels. Hyponatremia (≥145 mmol/L) was not analyzed in this study because of its infrequency in our patient population. Admissions were further split into two cohorts based on their MOI: falls admissions and non-falls admissions (all other MOIs).

Twelve categories of pre-existing conditions were analyzed, based on Pennsylvania System Trauma Foundation (PTSF) definitions: cardiac disease, diabetes, hematologic disorder, liver disease, musculoskeletal disorder, neurological disorder, obesity, psychiatric disorder, pulmonary disease, renal disease, and thyroid disease [Supplemental File 1]. These pre-existing conditions were coded retrospectively from patients’ medical records by certified trauma registrars. Our trauma registries have an accuracy rate of 98–99%, as determined by outside audits. PTSF pre-existing condition categories present in fewer than 50 patients were excluded from study analyses. Lastly, patient ages were split into three age categories for analysis: 65–74, 75–84, and ≥85.

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.injury.2014.06.013.

The Pearson Chi-Square test was used to compare categorical variables between groups. The Kruskal–Wallis test was used to compare continuous variables between groups. Unadjusted odds ratios of falls were calculated for gender, age, pre-existing condition categories, ISS, and serum sodium group. Variables significantly associated with falls in univariate analyses were subsequently incorporated into a multivariable binary logistic regression model to determine adjusted odds ratios of falls. To determine the discrimination of the multivariable model, the receiver operating characteristic (ROC) was calculated.

Results

Of the total 8169 trauma admissions between 2008 and 2011, 2461 (30.1%) admissions were attributed to patients aged 65 and older. Of these geriatric admissions, 91 (3.7%) were excluded from this study due to missing data (89 missing serum sodium at admission and 2 missing mechanism of injury), resulting in a study population of 2370 geriatric trauma admissions. There were 946 (39.9%) males and 1424 (60.1%) females in this population, with an age range of 65–102. The median age was 80 (IQR: 74–86). A majority of patients were admitted for falls (77.7%; 1841 patients), with motor vehicle accident as the second most common MOI (16.5%; 392 patients). The median ISS of this population was 9 (IQR: 5–16), ranging from 1 to 50. Mortality of this population was found to be 5.7% (136 patients). The median ED LOS was 3.3 hours (IQR: 2.3–4.7 hours). There was a normal distribution of serum sodium levels which ranged from 115 to 153 mmol/L with a median level of 138 mmol/L (IQR: 136–140). Within this trauma population, 293 (12.4%) patients were classified as hyponatremic (serum sodium <135 mmol/L), and 2077 (87.6%) patients were classified as not hyponatremic (serum sodium ≥135 mmol/L). There were 17 (0.8%) patients classified as hypernatremic (serum sodium >145 mmol/L) within the not hyponatremic group.

The study population was split into two cohorts: 1841 (77.7%) falls admissions and 529 (22.3%) non-falls admissions. These two cohorts were found to differ significantly with respect to several demographics: distribution of age groups, gender, admitting serum sodium group, and three of sixteen pre-existing condition categories (Table 1). Falls admissions had a smaller proportion of patients age 65–74 and 75–84 years and a larger proportion of patients >85 year, compared to non-falls admissions (p < 0.001). Additionally, falls admissions were more likely to be attributed to females (p < 0.001) as well as hyponatremic patients (p < 0.001). Further, haematological disorders (p < 0.001), neurological disorders (p < 0.001), and psychiatric disorders (p = 0.035) were found to be more common among patients admitted for falls. The cohorts were indistinguishable with respect to median ISS and mortality (Table 1).

When included in a univariate binary logistic regression model of falls admissions, age group, gender, neurological disorder, hematologic disorder, and serum sodium group were found to be significant predictors of falls (Table 2). When inserted into a multivariable logistic regression model, all factors remained significant falls predictors. Psychiatric disorder (OR: 1.33; 95% CI: 1.02–1.73; p = 0.035) was also found to be a significant predictor of falls in univariate analysis; however, when inserted into a multivariable analysis, it was no longer found to be statistically significant (AOR: 1.15; 95% CI: 0.87–1.52; p = 0.327). Consequently, psychiatric disorder was omitted from our final model of falls prediction (Table 2). In this model, hyponatremia was found to increase the odds of trauma admission by 81% (AOR: 1.81; 95% CI: 1.26–2.60; p = 0.001). Additionally, a neurological disorder was found to increase one’s odds of trauma admission by 68% (AOR: 1.68; 95% CI: 1.31–2.15; p < 0.001), and a hematologic disorder was found to increase one’s odds of trauma admission by 41% (AOR: 1.41; 95% CI: 1.13–1.74; p = 0.002). The most common neurological disorders in this population were chronic dementia (10.3%) history of a stroke (9.0%), Alzheimer’s (3.5%) and Parkinson’s disease (3.2%). The most common groups of patients with hematologic disorders were patients on Warfarin therapy (16.4%), patients with pre-existing anaemia (10.0%), and patients on anti-platelet agents (9.2%). Our multivariable model of falls was found to have adequate discrimination with an ROC of 0.70.

Discussion

In an age when the elderly compose the fastest growing segment of the population [22] and falls represent the leading cause of both fatal and nonfatal injuries in the elderly [23], identifying risk factors for geriatric falls has great potential clinical significance. As hyponatremia has been reported to have a prevalence of nearly 20% in elderly patients presenting to the emergency department [24], the relationship between hyponatremia and geriatric falls has received significant attention in the
last decade. A 2006 study by Renneboog et al. [13] found asymptomatic hyponatremia to significantly increase odds of falling in a population of emergency department admissions (AOR: 67.43; 95% CI: 7.48–607.42; \( p < 0.001 \)), when controlling for multiple covariates. This increased odds of falling is believed to be a result of the significant gait and attention impairments found to be correlated with hyponatremia. Tolouian et al. [17] found a similar relationship between hyponatremia and falls in a population of patients admitted to the hospital for hip fracture secondary to fall (AOR: 4.80; 95% CI: 1.06–21.67; \( p = 0.04 \)), when adjusting for age. Gunathilake et al. [25] demonstrated a significant correlation between hyponatremia and falls in a population of community-dwelling individuals (chi-square = 8.16; \( p = 0.01 \)), after adjusting for age, sex, and diuretic use in community-dwelling elderly. As the effect of serum sodium was found to be nonlinear on the log-odds scale, the study reported that the magnitude of the effect of a 5 mmol/L drop in serum sodium from 135 to 130 mmol/L was correlated with a 32% increased risk of falling (OR: 1.32; 95% CI: 1.04–1.64).

In our geriatric trauma population, we found a hyponatremia prevalence of 12.4%. When adjusting for age, gender, neurological disorder, and hematologic disorder, we found that this electrolyte disorder significantly increases odds of falling (AOR: 1.81; 95% CI: 1.26–2.60; \( p = 0.001 \)), supporting previous findings [13,24]. Although our multivariable model of odds of falling was only found to have adequate discrimination with an ROC value of 0.70, it is important to note that there are many extenuating factors that may contribute to an individual’s falls risk are difficult to reliably collect. These factors include current medications as well as whether or not an individual lives alone, is a care giver, and is exposed to environmental hazards, such as stairs. Consequently, we believe it is impressive that adequate discrimination for odds of falls admission can be achieved with a few easily accessible patient demographic variables, allowing clinicians to quickly assess falls risk.

Falls attributed to hyponatremic patients are of special concern because hyponatremia has been correlated with increased morbidity and mortality [12,26,27]. Several studies have shown that hyponatremia is associated with an increased risk of fracture among elderly patients. A case control study by Kengne et al. [11] found rates of hyponatremia to be 13.1% and 3.9% in bone fracture and non-bone fracture groups of falls patients, respectively \( (p < 0.001) \). Kinsella et al. [12] found similar results, with 8.7% of fracture patients being hyponatremic, compared to 3.2% in the non-fracture group \( (p < 0.001) \). Additionally, hyponatremia has been found to increase the odds of 30-day readmission (AOR: 3.49; 12.4%)

### Table 1

<table>
<thead>
<tr>
<th>Total</th>
<th>Falls admissions % (N)</th>
<th>Non-falls admissions % (N)</th>
<th>( p )-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>77.7 (1841)</td>
<td>22.3 (529)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65–74</td>
<td>23.1 (425)</td>
<td>43.1 (228)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>75–84</td>
<td>39.3 (723)</td>
<td>43.5 (230)</td>
<td></td>
</tr>
<tr>
<td>≥85</td>
<td>37.6 (693)</td>
<td>13.4 (71)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>36.5 (671)</td>
<td>51.9 (275)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Female</td>
<td>63.6 (1170)</td>
<td>48.0 (254)</td>
<td></td>
</tr>
<tr>
<td>Admitting serum sodium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥135 mmol/L</td>
<td>86.3 (1588)</td>
<td>92.4 (489)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>&lt;135 mmol/L</td>
<td>13.7 (253)</td>
<td>7.6 (40)</td>
<td></td>
</tr>
<tr>
<td>Pre-existing conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac disease</td>
<td>80.3 (1479)</td>
<td>78.3 (414)</td>
<td>0.323*</td>
</tr>
<tr>
<td>Diabetes</td>
<td>26.8 (494)</td>
<td>26.5 (140)</td>
<td>0.910*</td>
</tr>
<tr>
<td>Hematologic disorder</td>
<td>40.4 (744)</td>
<td>30.4 (161)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Liver disease</td>
<td>21.1 (388)</td>
<td>18.0 (95)</td>
<td>0.132*</td>
</tr>
<tr>
<td>Musculoskeletal disorder</td>
<td>2.1 (39)</td>
<td>2.3 (12)</td>
<td>0.834*</td>
</tr>
<tr>
<td>Neurological disorder</td>
<td>30.1 (554)</td>
<td>19.1 (101)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Obesity</td>
<td>4.5 (91)</td>
<td>6.3 (33)</td>
<td>0.285*</td>
</tr>
<tr>
<td>Psychiatric disorder</td>
<td>19.3 (356)</td>
<td>15.3 (81)</td>
<td>0.041*</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td>13.8 (254)</td>
<td>13.2 (70)</td>
<td>0.94*</td>
</tr>
<tr>
<td>Renal disease</td>
<td>2.4 (45)</td>
<td>2.5 (13)</td>
<td>0.887*</td>
</tr>
<tr>
<td>Thyroid disease</td>
<td>16.6 (305)</td>
<td>14.6 (77)</td>
<td>0.298*</td>
</tr>
<tr>
<td>Median ISS (IQR)</td>
<td>9 (5–16)</td>
<td>9 (4–17)</td>
<td>0.617</td>
</tr>
<tr>
<td>Mortality</td>
<td>5.7 (105)</td>
<td>5.9 (31)</td>
<td>0.976*</td>
</tr>
</tbody>
</table>

* Yates’ corrected \( p \)-values.

### Table 2

<table>
<thead>
<tr>
<th>Fall rate</th>
<th>Unadjusted Odds ratio (95%CI)</th>
<th>Adjusted Odds ratio (95%CI)</th>
<th>( p )-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65–74</td>
<td>65.1% Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>75–84</td>
<td>75.9% 1.69 (1.35–2.10)</td>
<td>1.56 (1.25–1.95)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>≥85</td>
<td>90.7% 5.24 (3.91–7.02)</td>
<td>4.46 (3.31–6.00)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>70.9% Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>82.2% 1.89 (1.55–2.29)</td>
<td>1.62 (1.32–1.99)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pre-existing condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neurological disorder</td>
<td>84.6% 1.82 (1.44–2.32)</td>
<td>1.68 (1.31–2.15)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hematologic disorder</td>
<td>82.2% 1.55 (1.26–1.91)</td>
<td>1.41 (1.13–1.74)</td>
<td>0.002</td>
</tr>
<tr>
<td>Serum sodium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥135 mmol/L</td>
<td>76.5% Reference</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>&lt;135 mmol/L</td>
<td>86.4% 1.95 (1.37–2.76)</td>
<td>1.81 (1.26–2.60)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

\( ROC=0.70. \)
A study of factors has shown that hyponatremia is not only a risk factor for falls; it is also a predictor of poor outcome. Further, treating this condition is challenging due to the risk for osmotic demyelination syndromes if corrected too rapidly [28].

Our findings that neurological disorders are a significant predictor of falls supports current literature [33]. History of a stroke is known to be correlated with an increased risk of falls [34–36], as is Parkinson’s disease [37–40] and Alzheimer’s disease [41,42]. Our finding that hematologic disorders are significantly correlated with trauma admission for geriatric falls is likely a result of many of these patients being on anticoagulation and antipilet agents, which are known to increase a patient’s tendency to bleed [43]. This predisposition for increased bleeding increases the likelihood of morbidity and mortality following head injury in this patient population [31,32,44,45], which makes this population more likely to be admitted to trauma for a fall. Further, anaemia has been found to be a powerful prognostic factor for the development of frailty, including muscle weakness, falls, and mortality [16]. Our finding that the female gender is a significant predictor of falls in the geriatric trauma population is likely impacted by the reality that women often live longer than men [29] and are more likely to live alone [40]. These factors may expose women to more opportunities to fall and may result in a study screening bias.

Although this study finds that hyponatremia is a significant fall predictor in a geriatric trauma population, it is important to note the inherent limitations of single-institution, retrospective research. Moreover, many underlying factors, such as the mechanism of the fall, current medications, and whether the patient was living alone, were not evaluated. Additionally, neither hyponatremia severity nor chronicity were designated nor analyzed in this study. A further topic not addressed in this study was the possibility that hyponatremic-induced deficits contributed to other mechanisms of injury (e.g. attention deficit causing a motor vehicle accident).

**Conclusions**

In conclusion, age, neurological disorder, hematologic disorders, and hyponatremia were found to be significant predictors of geriatric falls in trauma patients. As hyponatremia is correlated with increased morbidity and mortality, addressing hyponatremia should be a priority in geriatric falls risk assessments. If hyponatremia is identified, it should be corrected in hospital and closely followed thereafter by a primary care physician to possibly prevent recurrent falls and improve outcome. If polypharmacy, co-morbidities, or other restrictive factors prevent correction of hyponatremia, patients should be closely monitored and counselled to prevent the occurrence of hyponatremia-related falls.

**Conflicts of interest**

All authors have no conflicts of interest nor disclosures of funding to declare.

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**Author contributions:**

Katelyn Rittenhouse, BS: Design, Data Collection, Analysis, Interpretation, Manuscript Preparation, Revisions.

Tuc To, BS: Design, Data Collection, Analysis, Manuscript Preparation, Interpretation.

Amelia Rogers, BS: Design, Data Collection, Analysis, Interpretation.

Daniel Wu, DO: Data Analysis, Interpretation, Editorial Oversight.

Michael Horst, PhD: Design, Data Analysis, Interpretation, Editorial Oversight, Revisions.

Josie Edavettal, MD, PhD: Design, Editorial Oversight.

Jo Ann Miller, BSN: Design, Editorial Oversight.

Frederick Rogers, MD, MS: Design, Data Interpretation, Editorial Oversight, Revisions.

**References**


