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The effect of restrictive fluid management on outcomes among geriatric hip fractures: a retrospective cohort study at five level I trauma centers

Jordan Willis, MD[a], Stephanie Jarvis, MPH[b], Gina M. Berg, PhD[a], Chad Corrigan, MD[a], Robert Madayag, MD[c], Cassandra Reynolds, MD[d], Allen Tanner II, MD[e], Gary Marshall, MD[f], Carlos Palacio Lascano, MD[g], David Bar-Or, MD[b,*]

Objective: Restrictive fluid management (RFM) for hemodynamically unstable trauma patients has reduced mortality rates. The objective was to determine whether RFM benefits geriatric hip fracture patients, who are usually hemodynamically stable.

Design: Retrospective propensity-matched study.

Setting: Five Level I trauma centers (January 1, 2018–December 12, 2018).

Patients: Geriatric patients (65 years or older) with hip fractures were included in this study. Patients with multiple injuries, nonoperative management, and preoperative blood products were excluded.

Intervention: Patients were grouped by fluid volume (normal saline, lactated Ringer, dextrose, electrolytes, and medications) received preoperatively or ≤24 hours of arrival; patients with standard fluid management (SFM) received ≥150 mL and RFM <150 mL of fluids.

Main Outcome Measurements: The primary outcomes were length of stay (LOS), delayed ambulation (>2 days post-operatively), and mortality. Paired Student t-tests, Wilcoxon paired rank sum tests, and McNemar tests were used; an α value of < 0.05 was considered statistically significant.

Results: There were 523 patients (40% RFM, 60% SFM); after matching, there were 95 patients per arm. The matched patients were well-balanced, including no difference in time from arrival to surgery. RFM and SFM patients received a median of 80 mL and 1250 mL of preoperative fluids, respectively ($P < 0.001$). Postoperative fluid volumes were 1550 versus 2000 mL, respectively, ($P =$ 0.73), and LOSs were similar between the two groups (5 versus 5 days, $P = 0.83$). Mortality and complications, including acute kidney injuries, were similar. Delayed ambulation rates were similar overall. When stratified by preinjury ambulation status, SFM was associated with delayed ambulation for patients not walking independently before injury ($P = 0.01$), but RFM was not ($P = 0.09$).

Conclusions: RFM seems to be safe in terms of laboratory results, complications, and disposition. SFM may lead to delayed ambulation for patients who are not walking independently before injury.

Keywords: hip fracture, geriatric trauma, restrictive fluid management, resuscitation

1. Background

The Advanced Trauma Life Support (ATLS) guidelines for the care of injured patients recommend judicious administration of 1 L of crystalloid after hemorrhage control for patients in shock.[1] Previous publications reported that this standard fluid management (SFM) led to an increase in ventilator days, mortality,

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[a] Wesley Medical Center, Wichita, KS, [b] Injury Outcomes Network (ION) Research, Englewood, CO, [c] Saint Anthony's Hospital, Lakewood, CO, [d] Swedish Medical Center, Englewood, CO, [e] Penrose Hospital, Colorado Springs, CO, [f] Medical City Plano, Plano, TX, [g] South Texas Health System McAllen, McAllen, TX

** Corresponding author. Address: Injury Outcomes Network (ION) Research, Englewood, CO 80113. E-mail address: davidbme49@gmail.com (David Bar-Or).*

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pulmonary edema, cerebral edema, intracranial pressure, acute respiratory distress syndrome (ARDS), development of hyperchloremic metabolic acidosis, acute kidney injury (AKI) for susceptible patients, increased hemorrhage volume, and increased time to hemostasis.[2–11] Increased time to bleeding control and increased bleeding volume for those with SFM may be attributable to hemodilution of coagulation factors, decreasing blood viscosity, detachment of the initial clot, and thrombus shift.[2–10]

Because of these factors, there is a trend toward the use of restrictive fluid management (RFM) before hemorrhage control, as it was was previously found to be effective in reducing mortality rates for hemodynamically unstable patients or those who have penetrating injuries.[1,3,12,13] RFM is believed to maintain a lower systolic blood pressure (SBP), termed “permissive hypotension,” allowing for adequate vasoconstriction and prevention of undesired coagulopathy.[14] The risks of RFM are not well-established. One report points to a possibility of tissue hypoperfusion.[15] The Brain Trauma Foundation advises against RFM for traumatic brain injuries because of a link with mortality caused by reduced cerebral perfusion pressure.[14,16] Das et al[14] stated that blunt trauma patients may experience worsened mortality rates after RFM. Kudo et al[15] suggested that age, mechanism, injury severity, and presence of shock may be important factors for RFM selection.

Other than those hemodynamically unstable and those with penetrating injuries, it is unclear who may benefit from RFM.[11,15] Geriatric patients who suffer hip fractures typically do not have penetrating injuries, nor do they meet the definition of hemodynamically unstable, despite potentially being in a state of shock.[1,17,18] Thus, they do not have characteristics of patients currently identified to benefit from RFM.[1,3,12,13] Owing to the paucity of research investigating RFM for geriatric hip fracture patients, the purpose of this study was to determine the effects of RFM on this population of traumatic geriatric hip fractures.[19]

2. Methods

This retrospective observational propensity-matched study at 5 Level I trauma centers from January 1, 2018, to December 21, 2018, included geriatric patients (65 years and older) with hip fractures. Patients who had multiple injuries (defined as having an Abbreviated Injury Scale Score of ≥2 in any other anatomical region), those who were managed nonoperatively, and patients who received preoperative blood products were excluded from the analysis. Three institutional review boards (IRBs): (1) Medical City Plano IRB, (2) HCA-HealthONE IRB, and (3) CommonSpirit Health Research Institute IRB, which represented all 5 participating centers, approved of this study with a waiver of patient consent. This research was conducted in accordance with the Declaration of the World Medical Association. Patients were identified from the individual center’s trauma registries using the International Classification of Diseases, Tenth Revision (ICD-10) diagnoses codes indicating hip fracture (S72), with an ICD-10 procedure code indicating operative repair of the hip fracture.

Patients were dichotomized based on the fluid volume received preoperatively or within 24 hours of arrival, whichever came first. Patients with RFM received <150 mL of fluids were compared to those with SFM received ≥150 mL of fluids.[2] Fluids included normal saline (NS), lactated Ringer (LR), dextrose 5% in water (D5W), electrolytes, LR in D5W, potassium chloride (KCL) in NS, KCL in NS and D5W, and any medications given in fluids. Fluids were summarized by those received intraoperatively (administration time between the surgical start and stop time) and those received postoperatively (administration time after the surgical stop time). Medication volumes and total fluid volumes were summarized for each setting preoperatively, intraoperatively, and postoperatively; blood volumes were summarized for those administered intraoperatively and postoperatively.

Variables collected from the trauma registry and patients’ electronic medical records included sex (% female, n), age (years, continuous, also summarized as % above 99, n), transfer status (% yes, n), injury mechanism (categorized as fall from height >6 feet, ground-level fall, or other, %, n), lived at home before injury (%, n), preinjury ambulation (% walking independently, n), comorbidities (diabetes, hypertension, functional dependence, chronic renal failure, advanced directive, dementia, and anticoagulant use, %, n), time from arrival to surgery (minutes, continuous), fracture type (extracapsular, intracapsular, other, %, n), Injury Severity Scale (% below average, n, ≤9), SBP (% normal, n, defined as >90 millimeters mercury [mm Hg]), heart rate (HR, % normal, n, defined as ≤120 beats per minute [bpm]), oxygen saturation (O_2, % normal, n, defined as ≥95), preoperative and postoperative laboratory results (described below), complications (AKI, pressure ulcer, unplanned intensive care unit [ICU] admission, venous thromboembolism or deep vein thrombosis [DVT], % [n]), time to ambulation (hours, continuous), delayed ambulation (defined as >2 days after surgery), discharge disposition (categorized as home or home with health services, rehabilitation or long-term acute care, skilled nursing facility, or in-hospital mortality, % [n]), hospital length of stay (HLOS), ICU length of stay (ICU LOS), and ICU admittance. IRB approval was granted to collect vitals (SBP and HR) on admission; intraoperative vitals were not collected, thus the incidence of hypotension while under anesthesia was not evaluated.

Laboratory results were examined continuously and were presented as proportion (n) with a normal result. The laboratory results included and the ranges used to define a normal result were as follows: anion gap (AGAP, 3–10), blood urea nitrogen (≤24), carbon monoxide (23–29), creatinine clearance (CrCl, 0.74–1.35 for male patients, 0.59–1.04 for female patients), platelets (plt, 150,000–450000), potassium (K, 3.6–5.2), sodium (NA, 135–145), white blood cell count (4500–11000), hematocrit (38.3–48.6 for male patients, 35.5–44.9 for female patients), red blood cell count (4.35–5.65 for male patients, 3.92–5.13 for female patients), and hemoglobin (Hgb, 13.5–17.5 for male patients, 12.0–15.5 for female patients). The change in Hgb was evaluated as the preoperative result subtracted from the postoperative result.

Statistical analyses were performed using Statistical Analysis Software v9.4 (SAS, Cary, NC) and alpha <0.05. Continuous variables were summarized as mean (SD) and median (interquartile range) when appropriate based on the distribution of the data. Dichotomous and categorical data were summarized as proportion (count). Patients with RFM were matched 1:1 to patients with SFM using propensity scores. Propensity scores were created using a stepwise logistic regression model, having a caliper distance of 0.001, an entry criterion of 0.20, and an exit criterion of 0.05. Variables available to the model were significantly different in the univariate analysis between groups, which are presented in Table 1. Variables that stayed in the logistic model included chronic renal failure, lived at home before injury, ISS, walking independently before injury, ground-level fall, O_2, functional dependence, time from arrival to surgery (within 24 hours), medication count, preoperative AGAP, preoperative plt count, preoperative Hgb, and preoperative CrCl. The Hosmer-Lemeshow goodness-of-fit statistic was 0.70 indicating a good model with acceptable discrimination. Paired

TABLE 1

Baseline Demographic Characteristics

Characteristics	Restrictive <150 mL (n = 209)	Standard ≥150 mL (n = 314)	P
Sex, % female (n)	66.0 (138)	70.4 (221)	0.29
Age, median (IQR)*	79.0 (74.0, 85.0)	80.0 (74.0, 85.0)	0.76
Age ≥99 years, % (n)	23.0 (48)	22.6 (71)	0.92
Transfer, % yes (n)	15.3 (32)	16.2 (51)	0.78
Injury mechanism % (n)			**0.001**
Fall from height >6 ft	7.7 (16)	19.5 (61)	
Ground-level fall	90.0 (188)	72.3 (245)	
Other	2.4 (5)	2.2 (7)	
Independent ambulation before injury, % (n)	60.8 (127)	47.1 (148)	**0.01**
Lived at home before injury, % (n)	4.0 (8)	72.4 (173)	**0.01**
Comorbidities, % (n)			
Diabetes	18.7 (39)	18.5 (58)	0.96
Hypertension	57.9 (121)	63.1 (198)	0.24
Functional dependence	18.2 (38)	32.2 (101)	**0.0004**
Chronic renal failure	5.7 (12)	2.2 (7)	**0.04**
Advanced directive	28.7 (60)	27.4 (86)	0.74
Dementia	19.6 (41)	24.4 (76)	0.22
Anticoagulant use	14.4 (30)	15.9 (50)	0.63
Admitting facility			**<0.0001**
A	60.3 (126)	12.7 (40)	
B	16.8 (35)	39.2 (53)	
C	15.8 (33)	16.9 (53)	
E	6.2 (13)	27.7 (87)	
F	1.0 (2)	3.5 (11)	
ISS, ≤9 (average), % (n)	75.1 (157)	82.5 (259)	**0.04**
Fracture type, % (n)			
Extracapsular	44.5 (93)	48.1 (181)	0.67
Intracapsular	54.6 (114)	50.6 (159)	
Other/unspecified	1.0 (2)	1.3 (4)	
Medication count, median (IQR)	3.0 (2.0–4.0)	4.0 (3.0–5.0)	**<0.0001**
Normal SBP, % (n)	94.7 (198)	96.8 (304)	0.24
Normal HR, % (n)	98.1 (205)	98.4 (309)	>0.99
Normal O_2, % (n)	49.8 (104)	39.5 (124)	**<0.0001**
NPO admission to surgery	69.1 (143)	47.7 (144)	**<0.0001**
Time to surgery median (IQR), hours	37.2 (17.0–55.4)	48.8 (37.8–61.7)	**<0.0001**

Bold indicates statistically significant differences.
IQR = interquartile range.
* Median age calculated for patients younger than 99 years; actual age for patients older than 99 years was not collected because of IRB restrictions.

Student t-tests, Wilcoxon paired rank sum tests, and McNemar tests were used to compare the matched data.

3. Results

There were 523 patients, 40% (209) of whom had RFM and 60% (314) had SFM. Patients with RFM were similar in their age (P = 0.76) and sex (P = 0.29) when compared with those with SFM (Table 1). RFM patients were significantly more likely to suffer a ground-level fall (P = 0.001), to walk independently before injury (P = 0.01), and to have chronic renal failure (P = 0.04), but were less likely to live at home before injury (P = 0.01) and to have functional dependence (P = 0.0004). Other comorbidities and the type of fracture were similar between groups. There were significant differences in the admitting facility between groups (P < 0.0001). RFM patients were also less likely to have an ISS of ≤9 (P = 0.04) than those with SFM. While the proportion of patients with a normal SBP and HR was similar between groups, there were significantly more RFM patients with a normal O_2 (P < 0.0001) than SFM. Those treated with RFM were taking significantly less medications (3 versus 4; P < 0.0001). The RFM group was more likely to have nil per os (NPO) orders the entire time from admission to surgery than the SFM group (P < 0.0001). Patients with RFM had a shorter time from arrival to surgery than those with SFM (P < 0.0001). Most of the baseline preoperative laboratory results were similar between groups, except that those with RFM had a significantly higher AGAP (P < 0.0001), which was normal less often (P < 0.0001), as well as a significantly higher CrCl (P = 0.003) and higher HgB (P = 0.05); HgB was also normal more often (P = 0.01) than patients with SFM (Table 2).

3.1. Matched Population

After matching, there were 190 patients, 95 per arm, and the groups were well-balanced (Table 3). There were no longer any significant differences for any baseline demographics or characteristics, including the proportion of patients walking independently before injury (P = 0.23), ISS (P > 0.99), rate of NPO orders (P = 0.85), admitting facility (P = 0.44), and time from arrival to surgery (P = 0.12). Similarly, when examining the matched patient's preoperative laboratory results, there were no differences in any laboratory examination continuously or when examined as a proportion with a normal result (Supplemental Table 1, http://links.lww.com/OTAI/A74).

As expected, and based on the definitions for the 2 arms, patients with RFM received a significantly smaller volume of total preoperative fluids (80 versus 1250 mL; P < 0.0001) than patients with RFM (Fig. 1). There was also a difference (P = 0.02) in the volume of medications administered preoperatively, although the difference was small (90 mL). There was no difference in the proportion of patients who received an intraoperative blood transfusion (2% versus 3%; P > 0.99),

TABLE 2

Preoperative laboratory results

Laboratory Test	Restrictive <150 mL (n = 209)	Standard ≥150 mL (n = 314)	P
AGAP, median (IQR)	12.0 (10.0–4.0)	11.0 (9.0–12.0)	**<0.0001**
Normal, % (n)	27.9 (58)	45.7 (143)	**<0.0001**
BUN, median (IQR)	19.0 (15.0–25.0)	19.0 (14.0–25.0)	0.73
Normal, % (n)	72.7 (152)	73.3 (230)	0.90
CO_2, median (IQR)	25.0 (23.0–27.0)	25.0 (23.0–27.0)	0.73
Normal, % (n), 23-29	70.8 (148)	70.4 (221)	0.64
CrCl, median (IQR)	1.0 (0.8–1.3)	0.9 (0.7–1.2)	**0.003**
Normal, % (n)	57.2 (119)	64.9 (203)	0.08
Platelet count, median (IQR)	191.0 (153.5–244.0)	198.0 (167.0–236.0)	0.34
Normal, % (n)	74.2 (155)	82.8 (260)	**0.03**
K, median (IQR)	4.0 (3.7–4.2)	4.0 (3.7–4.3)	0.17
Normal, % (n)	82.2 (171)	82.2 (171)	0.09
Na, median (IQR)	140.0 (137.0–142.0)	140.0 (137.0–142.0)	0.49
Normal, % (n)	87.0 (181)	87.0 (181)	0.32
WBC, median (IQR)	9.3 (7.3–11.8)	9.3 (7.3–11.8)	0.45
Normal, % (n)	67.9 (142)	67.9 (142)	0.74
HCT, median (IQR)	39.6 (35.3–42.6)	39.6 (35.3–42.6)	0.05
Normal, % (n)	64.7 (134)	64.7 (134)	0.26
RBC, median (IQR)	4.2 (3.7–4.6)	4.2 (3.7–4.6)	0.32
Normal, % (n)	56.0 (116)	56.0 (116)	0.55
Hgb, median (IQR)	13.0 (11.4–14.2)	13.0 (11.4–14.2)	**0.05**
Normal, % (n)	59.4 (123)	59.4 (123)	**0.01**

Bold indicates statistically significant differences.
BUN = blood urea nitrogen; CrCl = creatinine clearance; K = potassium; NA = sodium; WBC = white blood count; HCT = hematocrit; RBC = red blood count.

TABLE 3

Matched population baseline demographics and characteristics

Characteristics	Restrictive <150 mL (n = 95)	Standard ≥150 mL (n = 95)	P
Age, median (IQR)*	79.0 (73.0–84.0)	80.0 (74.0–86.0)	0.21
Age ≥99 years, % (n)	25.6 (24)	21.1 (20)	0.62
Sex, % female (n)	64.2 (61)	73.7 (70)	0.26
Transfer, % yes (n)	14.7 (14)	12.6 (12)	0.84
Injury mechanism % (n)			>0.99
Fall from height >6 ft	4.3 (4)	5.3 (5)	
Ground-level fall	95.7 (90)	92.6 (87)	
Other	0 (0)	2.1 (2)	
Lived at home before injury, % (n)	79.0 (75)	74.7 (71)	0.85
Independent ambulation before injury, % (n)	54.7 (52)	55.8 (53)	0.23
Facility			0.44
A	37.9 (36)	42.1 (40)	
B	34.7 (33)	35.8 (34)	
C	27.4 (26)	22.1 (21)	
Comorbidities, % (n)			
Diabetes	23.2 (22)	15.8 (15)	0.26
Hypertension	63.2 (60)	62.1 (59)	>0.99
Functional dependence	25.3 (24)	23.2 (22)	0.87
Chronic renal failure	4.2 (4)	4.2 (4)	>0.99
Advanced directive	28.4 (27)	22.1 (21)	0.44
Dementia	24.2 (23)	14.3 (14)	0.16
Medication count, median (IQR)	3 (1–4)	3 (2–5)	0.24
Fracture type, % (n)			
Extracapsular	39.0 (37)	51.6 (49)	0.14
Intracapsular	60.0 (57)	47.4 (45)	
Other/unspecified	1.1 (1)	1.1 (1)	
ISS, ≤9 (average), % (n)	76.8 (73)	77.9 (74)	>0.99
SBP, % normal (n)	96.8 (92)	96.8 (92)	>0.99
HR, % normal (n)	99.0 (94)	100 (95)	>0.99
O_2, % normal (n)	57.9 (55)	57.9 (55)	0.70
NPO admission to surgery	66.3 (59)	64.0 (57)	0.85
Time to surgery, median (IQR)	18.8 (10.4–25.6)	18.4 (11.4–22.0)	0.12

IQR = interquartile range.
* Median age calculated for patients younger than 99 years; actual age for patients older than 99 years was not collected because of IRB restrictions.

nor in the intraoperative medication volume ($P = 0.17$). The proportion of patients who received an intraoperative pressor was similar between those with RFM and SFM (0% (0) versus 3.0% (2), respectively, $P = 0.47$). There was also no difference in the total intraoperative fluid volume ($P = 0.54$), in the proportion of patients who received a postoperative blood transfusion (21% versus 24%, $P = 0.71$), nor in their postoperative blood volume ($P = 0.99$). The postoperative medication volume ($P = 0.82$) and total postoperative fluid volumes ($P = 0.73$) were similar between groups.

All the matched patients' postoperative laboratory results were comparable between groups (Supplemental Table 2, http://links.lww.com/OTAI/A75) when examined both continuously and as the proportion of patients with a normal result. The median change in Hgb preoperatively to postoperatively was also not significantly different (−2.1 versus −2.2; $P = 0.99$).

Across the matched population, complications were very rare, but the complication rate was comparable between groups (Table 4). For those with RFM, 5% had an unplanned ICU admission compared with 2% for the SFM group ($P = 0.73$). There were no other complications for patients with RFM, whereas there were 2 SFM patients with an AKI and one with a DVT. There were no patients with pulmonary embolism. There was a lower proportion of patients with RFM who had delayed ambulation when compared with patients with SFM (11% versus 17%), but the difference was not significant ($P = 0.45$). The median time to ambulation was similar between groups ($P = 0.63$). The HLOS ($P = 0.45$), ICU LOS ($P = 0.48$), and rate of ICU admittance ($P = 0.42$) were similar between groups, and there were no differences in discharge disposition ($P = 0.44$), including in-hospital mortality.

In a stratified analysis including patients' preinjury ambulation status, it was observed that preinjury ambulation status did not significantly ($P = 0.09$) affect the rate of delayed ambulation among patients with RFM (Fig. 2). Among the RFM population, 5% of those who were walking independently before injury experienced delayed ambulation, 23% of those who were ambulatory with assistance before injury experienced delayed

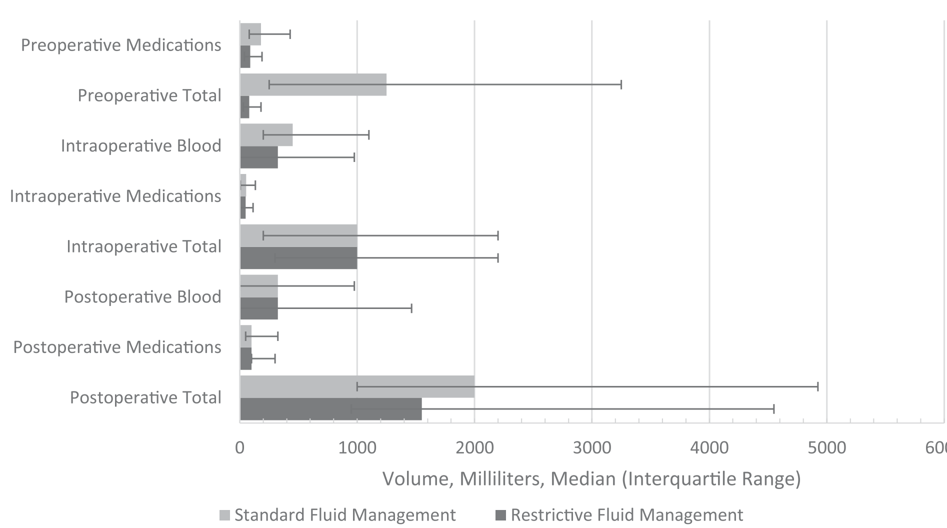

Figure 1. The volume in mL of fluids, blood products, and medications received in the preoperative, intraoperative, and postoperative settings for each group. Fluid volumes for SFM patients are colored light gray and for RFM patients are colored dark gray. Patients with RFM received <150 mL of fluids, and those with SFM received ≥150 mL of fluids.

TABLE 4

Matched outcomes

Outcomes	Restrictive <150 mL (n = 95)	Standard ≥150 mL (n = 95)	P
Complications, % (n)			
AKI	0 (0)	2.1 (2)	0.48
Unplanned ICU admission	5.3 (5)	3.2 (3)	0.73
VTE or DVT	0 (0)	1.1 (1)	>0.99
Delayed ambulation,* % (n)	10.8 (7)	16.9 (11)	0.45
Time to ambulation, hours, median (IQR)	38.4 (19.2)	39.8 (23.3)	0.63
HLOS, median (IQR)	5.0 (4.0–6.0)	5.0 (4.0–5.0)	0.45
ICU LOS, mean (SD)	3.0 (1.7)	3.2 (1.6)	0.48
Admitted to ICU, % (n)	17.9 (17)	12.6 (12)	0.42
Discharge disposition, % (n)			0.44
Home or home with health services	11.6 (11)	14.7 (14)	
Rehab/care	9.5 (9)	20.0 (19)	
Skilled nursing facility	75.8 (72)	60.0 (57)	
In-hospital mortality	3.2 (3)	5.3 (5)	

VTE = venous thromboembolism, DVT = deep vein thrombosis, PE = pulmonary embolism.
* Among those who did ambulate postoperatively.

ambulation, and 20% of those not ambulatory before injury had delayed ambulation ($P = 0.09$). Whereas in the SFM group, the preinjury ambulation status was significantly associated with the rate of delayed ambulation ($P = 0.01$). Among those with SFM, 6% of patients who were walking independently preinjury experienced delayed ambulation, compared with 36% of those who were ambulatory with assistance before injury experiencing delayed ambulation and 25% of patients who were not ambulatory before injury experiencing delayed ambulation ($P = 0.01$).

4. Discussion

This study was successful in examining the effect of RFM on outcomes among geriatric hip fractures when compared with SFM by mimicking a randomized controlled trial (RCT) through propensity score matching. Based on these data, RFM did not significantly affect the complication rate, HLOS, ICU LOS, or discharge dispositions, including mortality. While there were no significant differences in the proportion of RFM patients with delayed ambulation compared by their preinjury ambulation status, there were differences for SFM patients. Patients who were ambulatory with assistance or not ambulatory were more likely to experience delayed ambulation than those who were walking independently before injury when they were treated with SFM.

The ATLS guidelines for injured patients mention a movement toward the use of restrictive, yet balanced, blood product administration among pediatric patients, but do not discuss the use of RFM for adult or geriatric patients.[1] They do recommend the use of early permissive hypotension alongside balanced fluid and blood resuscitation for trauma patients with obvious shock and penetrating injuries.[1] However, geriatric patients who suffer hip fractures typically do not have penetrating injuries and rarely meet the definition of hemodynamic instability (HR >100 bpm, SBP <90 mm Hg).[1,17,18] It has also been suggested not to use RFM for geriatric patients with preinjury hypertension because of their cardiovascular risks.[13] Thus, it is unclear whether geriatric patients with hip fractures will benefit from RFM too. Despite that 60% of these geriatric patients had preinjury hypertension and more than 90% had a normal HR and SBP on admission, RFM seemed to be safe and did not negatively affect outcomes when compared with SFM.

One notable finding was that SFM did lead to an increase in delayed ambulation for patients who were not walking independently before injury. This could be caused by larger fluid volumes that lead to sodium and fluid retention, which can expand the intravascular and interstitial space.[8,11,16,20] Trauma can trigger endothelial permeability and trauma-induced capillary leak syndrome, allowing for further fluid absorption, which can be exacerbated with increased volumes of fluid administration.[16] This fluid expansion can cause decreased oxygen delivery to the tissues, abnormal aerobic metabolic pathways, decreased lactate production, and metabolic acidosis.[10,16] Capone et al[21] found that RFM was associated with improved metabolic parameters as measured by a lowered base deficit.[21] Jiang et al[7] also reported that RFM assists in clearing inflammatory factors. This reduction in inflammation may be why there was no difference in the proportion of RFM patients with delayed ambulation by their prehospital ambulation status. Selmer et al postulated that volume overload triggers skeletal myocytes edema leading to decreased ambulation.[22] Mitchell et al[23] found that fluid overload affects the ability to ambulate independently on

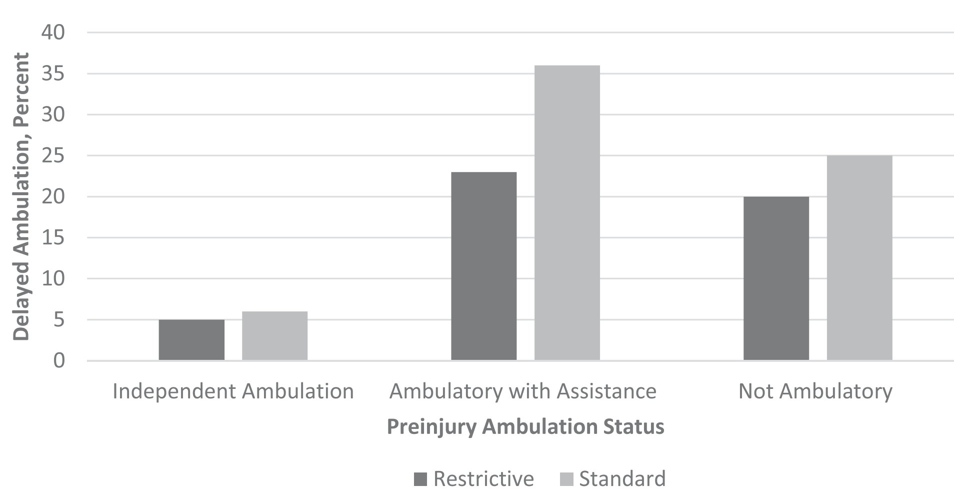

Figure 2. The proportion of patients with delayed ambulation within each group, stratified by their preinjury ambulation status. SFM patients are colored light gray, and RFM patients are in dark gray. Patients with RFM received <150 mL of fluids, and those with SFM received ≥150 mL of fluids.

hospital discharge for patients with severe septic shock. In their study, those with fluid overload received a higher volume of fluid administration both during shock and after shock, whereas in this study, the only significant difference in fluid volumes administered was preoperatively.[23]

There was no difference in the intraoperative or postoperative fluid volumes, nor in the rate of blood product use, providing evidence that RFM did not lead to a subsequent need for fluid or blood administration at a later point during hospitalization as was hypothesized. In another study of hemodynamically unstable trauma patients with penetrating torso injuries, there was no difference in the intraoperative fluid volumes, but the fluid administration rate was faster among those with SFM when compared with RFM.[24] Previous studies have found that those treated with preoperative SFM, and not RFM, required higher volumes of intraoperative fluid.[2,4] The differing results could be because of the underlying diagnoses and characteristics of trauma patients included. Matsuyama et al[4] observed that hemodynamically unstable trauma patients treated with SFM received significantly more fluids intraoperatively, but no difference in postoperative fluid volumes. Duke et al[2] studied trauma patients suffering hemodynamically unstable penetrating torso injuries and found that SFM patients received significantly more fluids intraoperatively; in addition, SFM patients experienced a significantly longer HLOS than those with RFM.

There was no difference in the HLOS or ICU LOS in this study. Matsuyama et al[4] also observed no difference in HLOS. Mitchell et al[23] observed longer HLOS after ICU discharge for patients with SFM. Kasotakis et al[25] observed a longer HLOS and ICU LOS with early aggressive crystalloid resuscitation. A plethora of the reports on RFM have used animal models and obviously do not include HLOS and ICU LOS as outcomes.[8,21,26–28] Another study found no difference in the HLOS for patients with RFM when compared with SFM, but used a higher cutoff volume of <1.75 L for RFM than that used in our study.[29] Zhao et al[5] observed that the RFM group had a significantly shorter ICU and total ventilator days.

The total ventilator days were not collected in this study, but the postoperative CO_2 levels were statistically similar between groups, which could indicate that the groups had a similar postoperative lung or kidney function. Other studies have reported improvements to lung function for RFM patients by reduced pulmonary complications or reduced total ventilator days.[4,6,7,23,25] Two studies found that early RFM was associated with a lower rate of ARDS.[7,25] Mitchell et al[23] reported that those with volume overload were more likely to be mechanically ventilated and to have an AKI in the ICU. While Bickell et al[24] observed a similar rate of ARDS and pneumonia between groups, they reported that RFM led to a significant decrease in renal failure. It was believed that RFM may increase the risk of AKI; in this study, there was only one AKI in the matched population, making it difficult to compare the rate between groups, although the CrCl was also similar between groups. Carrier et al[6] also found that RFM had no effect on AKI nor on mortality.

Similar to this study, other studies observed no difference in the mortality rate for RFM in trauma patients.[4–6] Malbrain et al[20] observed that RFM was associated with an improved mortality rate when compared with liberal fluid management in critically ill patients (25% versus 33%, $P < 0.0001$). Duke et al[2] reported that RFM had a protective effect on mortality for trauma patients. Other studies investigating animals found that permissive hypotension improved the mortality rate.[3,9,21,28] Large volumes of fluids have shown to contribute to mortality associated with the lethal triad: acidosis, coagulopathy, and hypothermia; the latter could be attributable to the low temperature of fluids administered.[16] This is the first study to our knowledge to examine the effect of RFM on mortality, specifically for geriatric hip fractures. Future RCT should be conducted to confirm these results.

5. Limitations

This was a retrospective cohort study with a relatively small sample size. The results may not be generalizable to patients who received preoperative blood transfusions as they were excluded because of the low frequency (n = 9) and potential for this fluid management technique to bias the results. Other confounders not accounted for may play a role in outcomes, such as preoperative base deficit or lactate. Currently, there is not a standard threshold to define SFM; the definition varies across research studies. In this study, we followed the fluid volume used by Duke et al[2] to define RFM (<150 mL), which was an early article examining the effect of RFM. In addition, fluids used for resuscitation (LRs, saline, dextrose, etc) varied by patient; there was not a uniform protocol followed across the participating centers. Similarly, the postoperative mobilization routine was not uniform across the participating centers. Future prospective studies are needed to confirm these results, specifically analyzing time to ambulation. Future studies should further evaluate the effect of RFM on ambulation among patients with hip fractures, including more information about the gait such as the initial distance walked, ambulatory with assistance or independently, the final distance walked, loss of balance, and timing how long it takes to stand up and walk. In addition, the incidence of hypotension under anesthesia is another important factor to consider for future studies because unexpected hypotension with vasodilation has been seen in geriatric populations; intraoperative HR and SBP were not variables included in this study.

6. Conclusions

In this study, it was observed that SFM was associated with delayed ambulation for patients who were not walking independently before injury. However, there was no significant difference in the time to ambulation between those treated with RFM and SFM. The data from this study showed that RFM may be safe in terms of postoperative laboratory results examined and in-hospital clinical outcomes, including the complication rate, ICU LOS, HLOS, mortality, and discharge disposition, for geriatric patients with hip fractures. Future prospective studies are needed to confirm these results before recommending treatment or guideline changes.

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