

# Significant variations in preoperative fluid resuscitation volumes delivered to elderly hip fracture patients at six level 1 trauma centers: an observational descriptive study

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## Abstract

**Objective:** To describe the variations in administration of preoperative (preop) fluids and in the volumes of fluid administered among geriatric hip fracture patients requiring surgical repair.

**Design:** Observational descriptive.

**Setting:** Six Level 1 trauma centers.

**Patients:** A total of 595 patients aged  $\geq 65$  with ICD-10 codes indicating hip fracture and surgical repair were identified. Of these, 87.9% ( $n=525$ ) received preop fluid. The median volume of preop fluid delivered was 1500 mL (IQR: 1000–2250 mL).

**Intervention:** None.

**Main Outcome Measures:** Receipt of preop fluids; median volume of fluid received.

**Results:** Receipt of preop fluid was significantly different by inter-hospital transfer, facility, BMI, hospital length of stay, and postop fluid volume. Age, sex, time to surgery, time to ambulation, and hospital disposition were not associated with preop fluid. There were significant differences in median preop fluid volumes by facility and postop fluid volume.

**Conclusion:** This descriptive study of current practices among geriatric trauma patients with isolated hip fractures revealed significant differences in the use of preop fluid resuscitation and the resuscitation volumes administered. Treating facility may be the most substantial source of variation highlighting the need for a guideline on fluid resuscitation. These observed variations may be a result of patient characteristics or provider discretion and should be evaluated further.

**Keywords:** fluid, geriatric, hip fracture, preop, resuscitation

## 1. Introduction: background and purpose

The global incidence of hip fractures is expected to reach 6.3 million by the year 2050.<sup>[1,2]</sup> In the United States alone, there

were 310,000 hip fracture discharge diagnoses in 2014.<sup>[3]</sup> As the nation's population ages, this number is predicted to increase to over 500,000 hip fractures annually in 2040 and could cost over \$16 billion per year.<sup>[4]</sup> A hip fracture diagnosis is often considered to be a preterminal event, with an annual postinjury mortality of 20% to 30% in the country's population aged 65 and older.<sup>[5]</sup> Moreover, patients often suffer from post-repair complications—affecting around 20% of patients—as well as loss of functionality, and decreased quality of life.<sup>[5–7]</sup> As such, hip fractures are among the most common, expensive, and life-threatening health problems encountered by elderly adults in the United States.

Physicians and researchers have sought to develop practice guidelines that can improve outcomes associated with hip fractures in the  $\geq 65$  population. In 2014, the American Academy of Orthopaedic Surgeons (AAOS) adopted best practice guidelines including 25 evidence-based treatment recommendations for treating hip fractures designed to reduce mortality, morbidity, and increase cost effectiveness.<sup>[8]</sup> These recommendations make no mention of the utility of preoperative (preop) fluid resuscitation; yet, it has been shown as far back as 1995 that inadequate fluid resuscitation prior to surgery is strongly associated with poor outcomes among elderly patients with surgically managed hip fractures.<sup>[9]</sup> Furthermore, the Eastern Association for the Surgery of Trauma (EAST) recently published a guideline for the use of orthogeriatric services for elderly patients with isolated hip

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fracture, but the guideline does not make any reference to the use of preoperative fluid resuscitation in this patient population.<sup>[10]</sup>

Because there is no formally recognized guideline or algorithm used by trauma centers to direct preop fluid resuscitation in the elderly hip fracture population, this gap in treatment recommendations may contribute to significant differences among fluid volumes delivered. To our knowledge, these potential discrepancies in preop fluid resuscitation have yet to be defined. This study sought to describe the differences among geriatric hip fracture patients requiring surgical repair by receipt of preop fluid resuscitation (yes/no) as well as the variations in volume of fluid administered to the patients who did receive preop fluid resuscitation at 6 geographically distinct level 1 trauma centers.

## 2. Methods

### 2.1. Patient population

Four Institutional Review Boards (IRBs) representing all six participating centers approved of this study: 1) Medical City Plano IRB, 2) HCA-HealthONE IRB, 3) CommonSpirit Health Research Institute IRB and 4) Western IRB. After obtaining Institutional Review Board (IRB) approval for all participating sites with a waiver of patient consent, patients were identified for this retrospective, descriptive study using the trauma registries at 6 level 1 trauma hospitals across 4 states. Included patients were admitted between January 1 and December 31, 2018, were  $\geq 65$  years old, had an International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) diagnosis code indicating hip fracture, and had an ICD-10 Procedure Coding System (ICD-10-PCS) code indicating operative repair of the hip fracture. Patients were excluded if they had multiple injuries (i.e., Abbreviated Injury Scale  $> 1$  in any other body region) or if the hip fracture was managed nonoperatively. This study followed all the guidelines for experimental investigation with human subjects required by the IRBs with which all the authors and hospitals are affiliated.

### 2.2. Study variables

The primary dependent variable explored in this study was the receipt of preop fluid resuscitation, defined as receiving  $\geq 100$  milliliters (mL) of total fluids preoperatively. Preop fluids were delivered any time between hospital admission and the start of the hip fracture repair surgery. Preop fluids included: any blood products, normal saline, lactated ringers, albumin, dextrose, and medications diluted in fluid. Although resuscitative volumes in trauma tend to be larger, in the range of liters,<sup>[11]</sup> we wanted the ability to examine the full range of preop fluid volumes delivered to this study population. In addition, the “standard” volume of fluid resuscitation is individual to each patient—based on various patient characteristics such as comorbidities, injury severity, dehydration, body mass index, etc.—so setting a larger volume as the minimum barrier to entry might exclude patients whose data can add value to the study’s findings. Furthermore, restrictive fluid resuscitation has been proven beneficial in some trauma populations, and we took this into consideration when determining the minimum volume for resuscitation.<sup>[12]</sup> The secondary dependent variable was the median volume of preop fluids delivered, described in mL.

Multiple independent variables, both exposures (i.e., risk factors or covariates) and outcomes, were analyzed for their association with both dependent variables described previously. Exposure variables included facility (described at A-F for

anonymity), age category (65–74, 75–84, or  $\geq 85$  years old), sex, interhospital transfer status (transfer patient, direct admit), number of prehospital medications (1–5, 6–10, 11+), prehospital ambulation status (independently ambulatory, ambulatory with assistance, not ambulatory, unknown), injury mechanism (ground level fall, fall from height, other, and BMI category ( $< 18.5$ —underweight, 18.5–24.9—normal,  $\geq 25.0$ —overweight/obese). Comorbidities and admission laboratory results were also examined, data not presented in tables. Outcome variables included time to index operation (examined from arrival to operation start time, within 24 hours, after 24 hours), ED discharge disposition [operating room (OR), intensive care unit (ICU), floor, other], intraoperative (intraop) fluid volume (none, up to 2000 mL, more than 2000 mL), postoperative (postop) fluid volume (none, up to 2000 mL, more than 2000 mL), time to postop ambulation (early—within 24 hours; late—after 24 hours), any complication, discharge disposition [home, skilled nursing facility (SNF), other inpatient facility, other location], in-hospital mortality, hospital length of stay (HLOS, 1–5 days,  $\geq 6$  days), and intensive care unit length of stay (ICU LOS, 0 days,  $\geq 1$  day). Individual complications were also examined but not reported in the tables.

### 2.3. Statistical methods

The associations of all variables with the receipt of preop fluid resuscitation were measured using chi-square or Fisher exact tests, where appropriate. Due to the non-normal distribution of preop fluid volumes, the variations in median fluid volumes delivered across covariates and outcomes were assessed using nonparametric Wilcoxon rank-sum or Kruskal-Wallis tests, where appropriate. Results for categorical variables are presented as numbers and proportions (n, %), and results for continuous variables are presented as medians and interquartile ranges (IQRs). Figures displaying the histogram for proportion of patients with each preop fluid volume, incremented by 500 mL, among specific exposure and outcome variables including facility, inter-hospital transfer status, time to index operation, postop fluid volume, and HLOS were created to further describe preop fluid volumes. The alpha level for this study was 0.05, and all statistical analyses were generated using SAS software v14.3 (2016, SAS Institute Inc, Cary, North Carolina).

## 3. Results

Across all 6 hospitals, we identified 597 geriatric patients undergoing surgical repair for isolated hip fracture. Most patients (n=261, 44%) were 85 years old or older, 34% (n=204) were 75–84 years old, and 22% (n=132) were 65–74 years old. A majority of patients (n=387, 76%) were living at home prior to their hospital admission, and nearly all patients were injured in a ground level fall (n=501, 84%). The majority of patients were in surgery for their hip fracture repairs within 24 hours (n=379, 74%), and only 18 (3%) died in-hospital. The median HLOS was 5 days. Among the patients who survived to discharge, most patients left for a skilled nursing facility (SNF; n=402, 69%) or other inpatient care facility (n=91, 16%), such as rehabilitation or long-term acute care facility.

### 3.1. Use of preop fluid resuscitation

Overall, 88% (n=525) of patients received preop fluids (Table 1). The administration of preop fluids was significantly different by facility, fracture type, inter-hospital transfer status, BMI, HLOS,

**Table 1**  
**Associations of various exposure and outcome variables with the receipt of preop fluid resuscitation**

Exposure variable	Received preop fluid			P value	Outcome variable	Received preop fluid		P value
	Yes, n (%)	No, n (%)				Yes, n (%)	No, n (%)	
Overall (N=597)	525 (87.9)	72 (12.1)			Overall (N=597)	525 (87.9)	72 (12.1)	
Facility			<b>&lt;.001</b>		Time to index operation			.170
A	154 (91.1)	15 (8.9)			Within 24 h	325 (85.8)	54 (14.3)	
B	147 (91.3)	14 (8.1)			After 24 h	122 (90.4)	13 (9.6)	
C	93 (93.0)	7 (7.0)			ED discharge disposition			.111
D	59 (67.1)	29 (40.3)			OR	38 (77.6)	11 (22.5)	
E	58 (90.6)	6 (9.4)			ICU	16 (94.1)	1 (5.9)	
F	14 (93.3)	1 (6.7)			Floor	425 (88.5)	55 (11.5)	
Age category			.357		Other	46 (90.2)	5 (9.8)	
65–74	115 (87.1)	17 (12.9)			Intraoperative fluid volume			.870
75–84	175 (85.8)	29 (14.2)			None	64 (88.9)	8 (11.1)	
85+	235 (90.0)	26 (10.0)			Up to 2000 mL	441 (87.7)	62 (12.3)	
Sex			.368		> 2000 mL	20 (90.9)	2 (9.1)	
Male	162 (86.2)	26 (36.1)			Postop fluid volume			<b>&lt;.001</b>
Female	363 (88.8)	46 (11.3)			None	13 (48.2)	14 (51.9)	
Inter-hospital transfer status			<b>.040</b>		Up to 2000 mL	193 (85.4)	33 (14.6)	
Transfer patient	77 (82.8)	16 (17.2)			> 2000 mL	319 (92.7)	23 (7.3)	
Direct admit	448 (88.9)	56 (11.1)			Postop ambulation			.910
No. of prehospital medications			.991		Early, within 2 d	449 (87.0)	63 (12.3)	
1–5	366 (91.3)	35 (8.7)			Late, after 2 d	67 (88.2)	9 (12.5)	
6–10	53 (91.4)	5 (8.6)			Any in-hospital complication			.230
11+	12 (92.3)	1 (7.7)			No	482 (87.5)	69 (12.5)	
Fracture type			<b>.037</b>		Yes	43 (93.5)	3 (6.5)	
Intracapsular	261 (84.7)	47 (15.3)			Discharge disposition			.518
Extracapsular	258 (91.2)	25 (8.8)			Home	69 (83.3)	14 (16.9)	
Prehospital ambulation			.196		SNF	356 (88.6)	46 (11.4)	
Independently ambulatory	254 (87.3)	37 (12.7)			Other inpatient facility	79 (86.8)	12 (13.9)	
Ambulatory with assistance	129 (85.3)	24 (14.7)			Other location	3 (0.6)	0 (0)	
Not ambulatory	32 (97.0)	1 (3.0)			Hospital discharge status			.145
Unknown	16 (80.0)	4 (20.0)			Alive	507 (96.6)	72 (12.4)	
Injury mechanism			.544		Dead	18 (100)	0 (0)	
Ground level fall	438 (87.4)	63 (12.6)			Hospital LOS			<b>.021</b>
Fall from height	75 (91.5)	7 (8.5)			1–5 d	369 (86.1)	60 (14.0)	
Other	11 (84.6)	2 (15.4)			6+ d	156 (92.9)	12 (7.1)	
BMI category			<b>.001</b>		ICU LOS			.054
Underweight	49 (94.2)	3 (5.7)			0 d	444 (86.9)	67 (13.0)	
Normal weight	210 (91.7)	19 (8.3)			1 d or more	81 (94.1)	5 (5.8)	
Overweight/obese	182 (81.3)	42 (18.8)						

Bolded P values indicate statistical significance.

and ICU LOS. Significantly more patients with extracapsular hip fractures (91%) received preop fluid than patients with intracapsular fractures (85%,  $P = .037$ ). A greater proportion of direct admit patients (89%) received preop fluids than did transfer patients (83%,  $P = .040$ ). The percentage of overweight/obese patients (81%) who received preop fluids was lower than that of normal weight (92%) or underweight (94%) patients ( $P = .001$ ). Furthermore, the exposure variable most significantly associated with differing rates of preop fluid delivery was treating facility ( $P < .001$ ); across all 6 facilities, the proportions of patients who received preop fluids were as low as 67% and as high as 93%. Variables not associated with receipt of preop fluids included age, sex, number of prehospital medications, prehospital ambulation, and injury mechanism (Table 1). Further, preexisting conditions (e.g., history of cerebrovascular accident, status as a smoker, current renal disease, etc.) and preop lab measures (e.g., hemoglobin, sodium, creatinine, etc.) were not significantly associated with the receipt of preop fluids (data not shown).

The proportions of patients who received preop fluids also differed by study outcomes of hospital LOS (HLOS), and postop fluid delivery volume. The group of patients who were

administered > 2000 mL of fluid postop had the highest percentage of patients who had received preop fluid resuscitation (93%); this was significantly higher than the percentage of patients who received up to 2000 mL postop (88%) or no fluids postop (48%,  $P < .001$ ). A lower proportion of patients who had a HLOS of 1 to 5 days (86%) received preop fluid resuscitation than those with HLOS 6 or more days (93%,  $P = .021$ ). Preop fluid resuscitation was not associated with in-hospital mortality, ICU LOS, time to surgery, ED discharge disposition, intraop fluid resuscitation, time to postop ambulation, or developing an in-hospital complication (Table 1).

### 3.2. Volume of preop fluids delivered

The median volume of preop fluids delivered to the 525 patients who underwent fluid resuscitation was 1500 mL (IQR: 1000–2250, Table 2). The distribution of volumes of preop fluid delivered was significantly different across all 6 hospitals, as seen in Figure 1 ( $P < .001$ ). The median volume of preop fluids was not significantly different for any other exposure variable. Although receipt of preop fluid was significantly different by inter-hospital

**Table 2**  
Differences in median preop fluid volumes administered, across various exposure and outcome variables

Exposure variable	Preop fluid volume median (IQR), mL	<i>P</i> value	Outcome variable	Preop fluid volume median (IQR), mL	<i>P</i> value
Overall (N=525)	1500 (1000–2250)		Overall (N=525)	1500 (1000–2250)	
Facility		<b>&lt;.001</b>	Time to index operation		.236
A	2000 (1000–2500)		Within 24 h	1500 (1000–2100)	
B	1500 (1000–2350)		After 24 h	1405 (1000–3000)	
C	2000 (1000–3000)		ED discharge disposition		.313
D	1000 (1000–1500)		OR	2000 (1000–3000)	
E	1025 (1000–2050)		ICU	1875 (1000–4575)	
F	1000 (400–1150)		Floor	1500 (1000–2200)	
Age category		.186	Other	1088 (1000–2050)	
65–74	2000 (1000–3000)		Intraoperative fluid volume		.631
75–84	1500 (1000–2100)		None	1950 (1000–2180)	
85+	1500 (1000–2225)		Up to 2000 mL	1500 (1000–2250)	
Sex		.936	> 2,000 mL	1625 (1000–3075)	
Male	1515 (1000–2180)		Postop fluid volume		<b>.017</b>
Female	1450 (1000–2500)		None	1150 (1000–2050)	
Inter-hospital transfer status		.102	Up to 2000 mL	1200 (1000–2000)	
Transfer patient	1190 (1000–2000)		> 2000 mL	2000 (1000–2500)	
Direct admit	1513 (1000–2450)		Postop ambulation		.463
No. of prehospital medications		.345	Early, within 24 h	1515 (1000–2250)	
Up to 5	1500 (1000–2250)		Late, after 24 h	1050 (1000–2350)	
6–10	2000 (1000–2876)		Any in-hospital complication		.986
11+	1500 (1015–4175)		No	1500 (1000–2250)	
Fracture type		.435	Yes	1350 (1000–2500)	
Intracapsular	1450 (1000–2150)		Discharge disposition		.631
Extracapsular	1500 (1000–2350)		Home	1250 (1000–2050)	
Prehospital ambulation		.572	SNF	1513 (1000–2500)	
Independently ambulatory	1500 (1000–2300)		Other inpatient facility	1275 (1000–2100)	
Ambulatory with assistance	1250 (1000–2075)		Other location	1000 (1000–2000)	
Not ambulatory	2000 (1000–3000)		Hospital discharge status		.850
Unknown	1075 (1000–2500)		Alive	1500 (1000–2250)	
Injury mechanism		.790	Dead	1625 (1000–2650)	
Ground level fall	1500 (1000–2300)		Hospital LOS		.085
Fall from height	2000 (1000–2000)		1–5 d	1500 (1000–2100)	
Other	2000 (1000–3000)		6+ d	1880 (1000–2975)	
BMI category		.622	ICU LOS		.111
Underweight	1900 (1000–2100)		0 d	1500 (1000–2150)	
Normal weight	1500 (1000–2150)		1 d or more	2000 (1000–2876)	
Overweight/obese	1250 (1000–2400)				

Bolded *P* values indicate statistical significance.

transfer status, the median volume of preop fluids by inter-hospital transfer status was only trending toward statistically different,  $P=.102$ , with patients who were directly admitted receiving more preop fluids than those who were transferred in (1513 mL vs 1190 mL), Supplemental Figure 1, <http://links.lww.com/OTAI/A23>.

With regard to outcome variables, postop fluid volumes was the only variable significantly associated with preop fluid volume. Patients who received more than 2000 mL of postop fluid also received a significantly higher median preop fluid volume (2000 mL) than those patients who received no postop fluids (1150 mL) or those who received  $\leq 2000$  mL of postop fluid (1200 mL), as seen in Figure 2 ( $P=.017$ ). Time to index operation was not significantly associated with median preop fluid volume,  $P=.236$ ; patients who underwent surgery for hip fracture repair within 24 hours had nearly the same median preop fluid volume as those who underwent surgery after that 24-hour mark (1500 mL vs 1405 mL,  $P=.236$ ), Supplemental Figure 2, <http://links.lww.com/OTAI/A24>. Again, while receipt of preop fluids was significantly associated with HLOS, the median volume of preop fluids was not,  $P=.085$ ; patients who stayed in the hospital for 6 days or

more received a larger median preop fluid volume (1880 mL) than patients whose HLOS  $< 6$  days (1500 mL), as seen in Supplemental Figure 3, <http://links.lww.com/OTAI/A25>.

The results demonstrated no statistically significant difference in median volume of preop fluid delivery across exposure variables of age, sex, inter-hospital transfer status, number of prehospital medications, fracture type, preexisting conditions (data not shown), prehospital ambulation status, injury mechanism, BMI, or preop lab measures (data not shown) nor across outcome variables of time to index operation, ED discharge disposition, intraop fluid volume, time to postop ambulation, any in-hospital complications, discharge disposition, in-hospital mortality, HLOS, or ICULOS.

#### 4. Discussion

In this descriptive observational study of current practices, we identified statistically significant differences in the use of preop fluid resuscitation as well as the resuscitation volumes administered to geriatric trauma patients with isolated hip fractures.

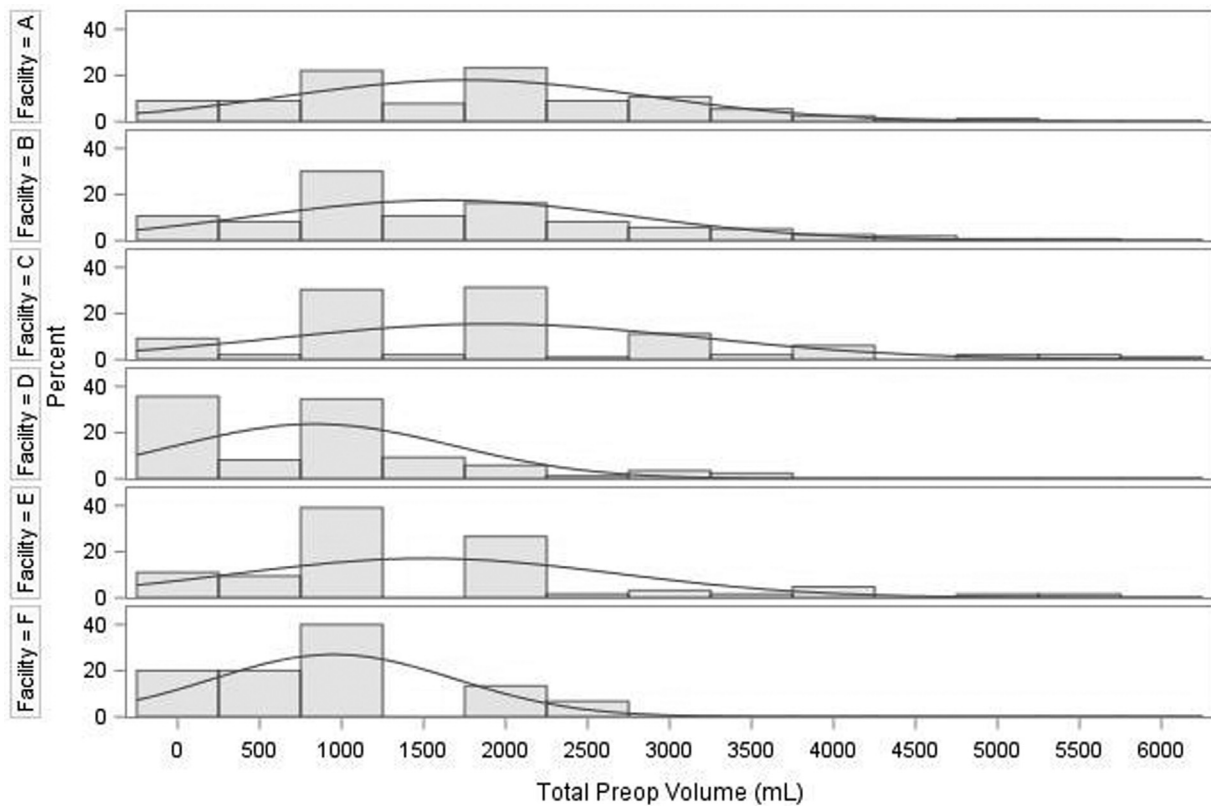


Figure 1. Distributions of varying preop fluid volumes delivered across all 6 facilities.

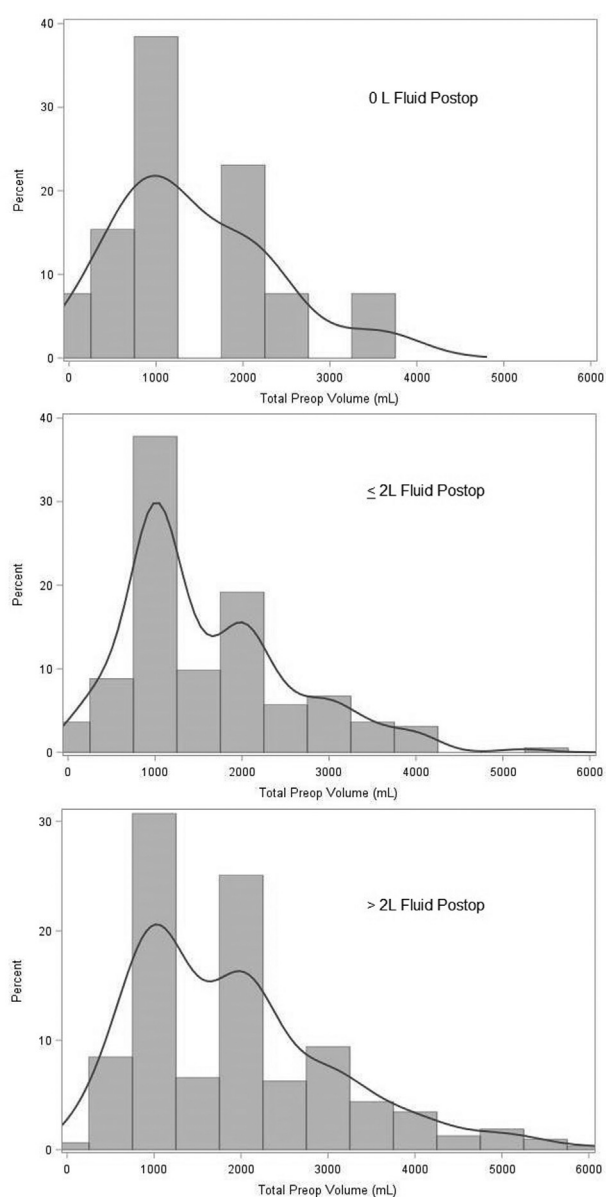
Among the variables examined, the facility at which a patient is treated appeared to be the most substantial source of variation not only in the administration of preop fluid resuscitation but also in the volumes delivered to the geriatric hip fracture patients in our study. The variation between centers highlights the need for a guideline directing the administration of fluids in this population. Researchers in Australia assessed fluid resuscitation for 1955 patients in 391 intensive care units across 25 countries and showed that the utilization of fluid resuscitation differed significantly across the facilities, even after adjusting for patient characteristics such as age, clinical signs such as sepsis, and prescriber role (e.g., ICU specialist vs ICU resident).<sup>[13]</sup>

Additionally, extracapsular fractures were more likely to have received any preop fluids when compared to intracapsular fractures. This may be due to the different levels of blood loss caused by the 2 fracture types. Patients with extracapsular fractures tend to suffer increased blood loss, which may explain the more frequent use of preop fluids among these fracture types in our study.<sup>[14,15]</sup> Fracture type could be a characteristic used to guide the administration of preop fluid. However, fracture type did not significantly impact preop fluid volume.

The association of lower rates of preop fluid administration with interhospital transfer status may be a result of the care provided before or during the transfer process. Established clinical guidelines regarding patient transport have demonstrated the benefits of fluid therapy in stabilizing a patient for and during transport,<sup>[16]</sup> so it is likely that these patients received fluids either at the transferring hospital or during the transfer process—either of which could result in less of a need for preop fluid resuscitation at the receiving hospital.

Interestingly, we also found that patients' time to index operation was not associated with the receipt of or volume of preop fluid. Although published guidelines recommend hip fracture repair within 24 hours, this population oftentimes requires considerable fluid resuscitation before they are stabilized sufficiently to undergo an operation.<sup>[17,18]</sup> Thus, it may be expected that delaying an operation past this 24-hour window, aside from a patient's medical needs, could result in additional administration of resuscitative fluids. In this dataset there was a higher proportion of patients who went to surgery after 24 hours and received preop fluids than among patients who went to surgery within 24 hours, but the difference observed was not significant ( $P = .170$ ). There was also no difference in the volumes administered by time to operation.

Significant differences in the use of preop fluid resuscitation and the median volumes of fluids delivered were also associated with vital outcome measures, such as HLOS. It is possible that the geriatric patients in our study who received a lower median fluid volume had arrived with a healthier baseline status that was not captured in the covariates examined resulting in a shorter HLOS and less of a need for fluid resuscitation. An alternative explanation can be found in a growing body of literature on the association of restrictive fluid resuscitation with improved outcomes, such as shorter HLOS. Two recent studies have demonstrated the benefit of restrictive fluid use with regard to long-term survival, reduced HLOS, and fewer ventilator days.<sup>[12,19]</sup> However, the population for 1 study included hemodynamically unstable patients with penetrating injuries,<sup>[12]</sup> while the other encompassed all types of surgical patients, including burn and cardiac patients.<sup>[19]</sup>



**Figure 2.** Distributions of preop fluid volumes delivered to patients who received 0 L,  $\leq 2$  L, and  $> 2$  L postop fluids.

In a 2018 study of more than 500,000 patients aged 50 years or older who underwent surgical repair of their hip fractures, the presence of a fluid or electrolyte disorder, typically seen as dehydration or hyponatremia, was one of the 8 essential predictors of in-hospital mortality.<sup>[20]</sup> The management of a patient's fluids and electrolyte levels before, during, and after surgery is crucial to avoid adverse outcomes. In general, preop hemodynamic preconditioning (i.e., optimizing hemodynamic stability and reversing dehydration with fluids) and achieving appropriate fluid resuscitation in elderly hip fracture patients is associated with reduction in short- and long-term mortality and complications.<sup>[21–25]</sup> However, the lack of a consensus guideline or algorithm defining the appropriate amount of preop fluid resuscitation in the surgically managed elderly hip fracture patient appears to result in significant variations in whether or not fluid is administered as well as the volumes delivered.

At present, there is a need for an evidence-based guideline to direct clinical practice regarding preoperative fluid resuscitation in

geriatric patients with hip fractures. With an ever-growing elderly population, it is vital to first identify any existing treatment discrepancies along with the patient factors and outcomes associated with these discrepancies. Using our findings, investigators may move toward treatment optimization through well-informed and widely accepted guidelines for the administration of preoperative fluid resuscitation to elderly hip fracture patients. Future endeavors within this patient population will be to determine whether these variations are predictive of adverse outcomes and whether or not there exists an optimal preop resuscitation volume for geriatric patients with isolated hip fracture.

Our study has limitations. Beyond those inherent to a retrospective study, the analyzable population was collected as a convenience sample. We did not assess the use of invasive techniques for monitoring hemodynamic status, such as esophageal Doppler or central venous pressure (CVP) monitoring, which may have offered explanations as to the use of fluid resuscitation as well as the volumes administered. We did not assess the anesthesia methodology for surgery (i.e., spinal vs general), which has also been shown to affect mean intravenous fluid administration.<sup>[26]</sup> With regard to fluid and electrolyte disorders, namely dehydration and hyponatremia, we did collect preop serum sodium values, but we did not collect the diagnosis of dehydration. Identifying the patients who suffered from dehydration could provide additional insight into the variations in use of preop fluids and the volumes delivered. We also did not assess postop fluid overload. Finally, we did not assess any differences associated with the delivery of prehospital fluids. We found that few patients had their prehospital fluid volumes documented, but prehospital data are often inconsistently recorded or missing,<sup>[27–29]</sup> and it is possible that there are missing or unrecorded fluid volumes that could have impacted the volume of fluid delivered preoperatively. The injury time was not collected and time from injury to arrival may play a role in fluid resuscitation as some geriatric patients are not found immediately after their injury.

## 5. Conclusion

The volumes of resuscitative fluids delivered preoperatively to geriatric hip fracture patients vary greatly. These observed variations may be a result of patient characteristics such as baseline health status, or they may be a result of provider discretion, as seen in the substantial variations in fluid use and volumes delivered at all 6 participating facilities. The discrepancies found within this study highlight the need to conduct additional studies that can be used to develop evidence-based guidelines that will support and guide the optimal treatment of elderly patients suffering from hip fractures. Clinical characteristics identified as significantly associated with preop fluid administration including the fracture type, patients BML, and transfer status could be used to guide fluid administration for geriatric patients with hip fractures. The differences in the use of preop fluid resuscitation as well as the volumes delivered should both be evaluated further, with an end goal of developing an algorithm or set of recommendations for precise preop fluid delivery that could improve care and help patients avoid adverse outcomes.

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