Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

Association for Academic Surgery

The Magic Number 63 — Redefining the Geriatric Age for Massive Transfusion in Trauma

Joseph C. L'Huillier, MD, MS-HPEd,[a,b,c] *Heather J. Logghe, MD,*[a,c]
Shuangcheng Hua, MS,[d] *Ajay A. Myneni, MBBS, PhD, MPH,*[a]
Katia Noyes, PhD, MPH,[a,b] *Jihnhee Yu, PhD,*[d]
and Weidun Alan Guo, MD, PhD, FACS[a,c,*]

[a] *Department of Surgery, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, New York*
[b] *Division of Health Services Policy and Practice, Department of Epidemiology and Environmental Health, School of Public Health and Health Professions, University at Buffalo, Buffalo, New York*
[c] *Division of Trauma, Critical Care, and Acute Care Surgery, Department of Surgery, Erie County Medical Center, Buffalo, New York*
[d] *Department of Biostatistics, School of Public Health and Health Professions, University at Buffalo, Buffalo, New York*

ARTICLE INFO

Article history:
Received 5 February 2024
Received in revised form 20 April 2024
Accepted 29 April 2024
Available online 2 July 2024

Keywords:
Age
Blood transfusion
Geriatric
Transfusion threshold
Trauma
TQIP

ABSTRACT

Introduction: The arbitrary geriatric age cutoff of 65 may not accurately define older adults at higher risk of mortality following massive transfusion (MT). We sought to redefine a new geriatric age threshold for MT and understand its association with outcomes.
Material and methods: The 2013-2018 Trauma Quality Improvement Program database was queried for all adults who received ≥10 units of packed red blood cells (pRBCs) within 24 h of admission. A bootstrap analysis using multiple logistic regression established transfusion futility thresholds (TTs), where additional pRBCs no longer improved mortality for various age cutoffs. The age cutoff at which the TT for those relatively older and relatively younger was statistically significant was used to define the new "geriatric" age for MT. Outcomes were then compared between the newly defined geriatric and nongeriatric patients.
Results: The difference in TT first became significant when the age cutoff was 63 y. The TT for patients aged ≥63 y (new geriatric, $n = 2870$) *versus* <63 y (nongeriatric, $n = 17{,}302$) was 34 and 40 units of pRBCs, respectively ($P = 0.04$). Although geriatric patients had a higher Glasgow coma scale score (9 *versus* 6, $P < 0.01$) and lower abbreviated injury score-abdomen (3 *versus* 4, $P < 0.01$) than the nongeriatric, they suffered higher overall mortality (62% *versus* 45%, $P < 0.01$). A lower percentage of geriatric patients were discharged to home (7% *versus* 35%, $P < 0.01$).
Conclusions: The new geriatric age for MT is 63 y, with a TT of 34 units. Despite suffering less severe injuries, physiologically "geriatric" patients have worse outcomes following MT.

* *Corresponding author*. Erie County Medical Center, 462 Grider Street, Buffalo, NY 14215.
E-mail address: waguo@buffalo.edu (W.A. Guo).

https://doi.org/10.1016/j.jss.2024.04.089

Introduction

From 2012 to 2050, the US population aged 65 and older will double to an estimated 84 million.[1] This significant shift in the demographic landscape brings forth new changes in the realm of trauma care, particularly as the incidence of geriatric trauma rises, leading to an increased utilization of massive transfusion (MT) in this subgroup of patients.[2] However, the consequences of this practice, including potential complications and its association with mortality, warrant closer examination.

In the broader context of transfusion practice, the administration of MT can cause significant complications and may not always improve mortality.[3] The concept of transfusion futility thresholds (TTs) — the amount of transfused blood product after which the odds of mortality do not improve with additional transfusion — has been defined in the adult population, encompassing both younger and geriatric adults. Specifically, this threshold is set at 39 units of total blood product within 4 h of admission or 53 units of total blood product within 24 h of admission.[4] However, only a few studies to date have explored MT in geriatric trauma patients in isolation. For example, Morris *et al.* showed that all patients aged ≥80 y who received ≥51 units of packed red blood cells (pRBCs) within 4 h of admission died.[5] Schneider *et al.* found that the number of units of pRBCs transfused at which point 50% of patients died was 18 units for patients aged 65-79 y and 6 units for patients aged ≥80 y.[6] Our prior work has demonstrated that the TT for geriatric patients (aged ≥65) is 34 units of pRBCs within 24 h, irrespective of frailty, compared with 39 units of pRBCs for adults <65 y old.[7] Nevertheless, the existing literature may not fully capture the nuances of geriatric trauma patients.

Perhaps most importantly, in this context, the arbitrary categorization of a geriatric patient as 65 y and older raised questions about the precision of age as a defining variable. The traditional geriatric age cutoff (aged ≥65) is based on the historical definition of retirement age rather than on biological function.[8] Some studies have suggested different age cutoffs based on the analysis of mortality by age, leaving uncertainty about whether the age cut off of 65 holds true in terms of MT and TT.[9] In general, the geriatric age cutoff is suggested to be 45 in the case of rib fractures,[10] 55 by the American College of Surgeons (ACS),[11] 65 by the American Association for the Surgery of Trauma,[12] and as old as 77, by one US trauma program.[13] This heterogeneity should continue to be addressed, especially in the context of geriatric MT.

In this study, we sought to address these gaps by pursuing three key objectives: 1) redefine a new geriatric age cutoff at which point the response to MT changes compared to younger adults; 2) define true TTs for newly defined geriatric *versus* nongeriatric patients; and 3) compare outcomes following MT between the newly defined geriatric *versus* nongeriatric groups. We hypothesized that the geriatric age for MT would be different from the arbitrary 65 y old and that the physiological responses and clinical outcomes would be different between the new geriatric and relatively young patients.

Material and Methods

Study design and patient population

The 2013-2018 ACS Trauma Quality Improvement Program (TQIP) database was queried for adult patients (age ≥18 y old) who received at least 10 units of pRBCs within 24 h of admission. Patients who had an advanced directive limiting care were excluded. The TQIP database is one of the largest databases of trauma patients worldwide, with over 900 participating US trauma centers.[14] We chose to focus this study on the 24-h transfusion data rather than the 4-h transfusion data because one recent study demonstrated that among patients receiving MTP, only half of the total product that they received was transfused within 3 h of admission.[15] The 24-h transfusion data was discontinued with the 2019 dataset; therefore, although additional years of TQIP data are available, the final year containing this variable is 2018. Because this was a retrospective review of a deidentified national database, neither institutional review board approval nor informed consent was required for this work.

Data extraction

Patients meeting the inclusion criteria were extracted from the database by the research team. Variables collected for each patient included admission year, demographics (age, sex, and race), comorbidities (bleeding disorder, congestive heart failure, chronic renal failure, cirrhosis, chronic obstructive pulmonary disease [COPD], diabetes, and prior myocardial infarction [MI]), and mechanism of injury (blunt, penetrating, and other). Injury-related data collected included emergency department (ED) admission vital signs (systolic blood pressure [SBP], respiratory rate [RR], and heart rate [HR]) and injury parameters (Glasgow coma scale [GCS], injury severity score [ISS], brain abbreviated injury score [AIS-brain], thoracic abbreviated injury score [AIS-thorax], abdominal abbreviated injury score [AIS-abd], upper extremity abbreviated injury score [AIS-upper extremity], and lower extremity abbreviated injury score [AIS-lower extremity]). Hospital variables collected included trauma center level verification (I-III), number of adult beds (0-200, 201-400, 401-600, and ≥600), and teaching status (community, nonteaching, or university). Transfusion variables collected were the number of units of pRBCs, fresh frozen plasma (FFP), platelets, and cryoprecipitate transfused within 24 h of admission as well as the pRBCs: FFP ratio. We utilized similar data cleaning procedures for pRBCs and FFP as we described in our previously published work.[7] These transfusion variables are entered into TQIP as a quantity (#) in either “units” or “cc’s”. Any pRBC or FFP transfusion that was coded in “cc’s” of product with a quantity <100 was recoded as “units.” Transfusing a quantity of <100 “cc’s” of product does not make clinical sense and was likely intended to be recorded as “units.” Any patient with pRBC or FFP transfusion who was coded in “units” of product with a quantity >100 was excluded from the study. These values were either extreme outliers or errors in data entry.[4] The outcomes included 24-h and in-hospital mortality, hospital and intensive care unit (ICU) length of stay (LOS), and days requiring mechanical ventilation. The complications collected included acute kidney injury, acute respiratory distress syndrome, cardiac arrest with cardiopulmonary resuscitation, catheter associated urinary tract infection, catheter associated blood stream infection, deep surgical site infection (SSI), deep vein thrombosis, MI, osteomyelitis, pulmonary embolism, pressure ulcer, severe sepsis, stroke/cerebrovascular accident, superficial SSI, unplanned ICU admission, unplanned return to operating room, and ventilator associated pneumonia . Discharge dispositions included home or self care, home health, short or intermediate care, long-term care, inpatient rehab, skilled nursing facility, and hospice.

Data analysis

Similar to the definition by Quintana *et al.*, the TT estimate was defined as the number of blood product (units) at which the odds of mortality between the group receiving 10 fewer units of blood product (reference) and the group receiving up to 10 more units of blood product than the number of blood product itself was equal to 1.[4,7] Similar to our previous work, a multiple logistic regression was built to determine TTs, which included all patients who received any pRBCs within 24 h of admission.[7] To estimate an odds radio beginning at 10 units of pRBCs transfused, data were needed for patients receiving 10 fewer units than this point (i.e. 1-9 units of pRBCs) as the reference group. Patients receiving nine or fewer units of pRBCs were utilized for this multiple logistic regression model to determine TTs only and were not used in the remainder of the analyses.

We expanded our previously published multiple logistic regression model to determine TT, which originally included only pRBCs, age ≥65 y, degree of frailty, and ISS.[7] In this study, we included the following variables: pRBCs, FFP, age, gender, race, comorbidities, ED admission vitals, injury mechanism, GCS, AIS-brain, AIS-thorax, AIS-abd, AIS-upper extremity, and AIS-lower extremity. A bootstrap methodology accounting for these variables was used to examine the change in odds of survival as pRBC transfusion increased. This statistical method involves repeated random sampling from the original data to estimate the TT directly in a robust manner without using the confidence interval of the odds ratio that is dependent on sample size.[16] This approach permits *t*-testing on the difference in TTs by categorical group. Various age cutoffs ranging from 50 to 70 y were used to bisect the total population into a younger and older adult group for a total of 21 head-to-head comparisons. The difference in TT between groups was evaluated using the bootstrap method at each of the 21 age cutoffs. For each age cutoff, respective standard errors of TT for the younger and older groups were obtained based on TT estimates using 100 bootstrap samples, and the difference in TT was tested using the normal distribution-based two-group test. The threshold for statistical significance was set at $P < 0.05$ using one-tailed tests given our a priori hypotheses that increased age will decrease the TT. When moving the cutoff from younger (50) to older (70), the first age cutoff at which point the TT between the younger and older groups became statistically different was used to redefine the geriatric age for MT.

Bivariate analyses were conducted to examine differences in characteristics and outcomes between younger adults and older adults using the new, redefined geriatric age cutoff for MT. Characteristics included demographics, comorbidities, mechanism of injury, admission to ED vital signs, injury parameters, hospital parameters, and transfusion variables. The outcomes included 24-h and in-hospital mortality, hospital and ICU LOS, days requiring mechanical ventilation, complications, and discharge disposition. Analyses included the chi-square test for categorical data and the *t*-test for continuous data. Of note, the Shapiro–Wilk test was used to test continuous variables for normality. For instance, the number of pRBCs transfused showed a significant deviation from normality ($P < 0.05$), with a skewness of 2.87 and kurtosis of 23.98. However, with very large sample sizes ($n = 114{,}972$), normal distribution assumption of continuous data is not critical in statistical inference. The *t*-test is known to be robust to departure from normality since the central limit theorem ensures that the sampling distribution of the sample mean approaches a normal distribution, regardless of the underlying distribution of the data.[17] Therefore, even if the data are not normally distributed, the *t*-test still provides valid inference. Furthermore, bootstrap methods are a robust alternative for statistical inference as they can be applied to various distributions, including skewed, heavy-tailed, or multimodal data without requiring adherence to a specific distribution.[18] This makes bootstrap methods particularly useful when the normality assumption is violated. Ultimately, these principles justify the use of *t*-testing for continuous data regardless of normality. The threshold for statistical significance was set at $P < 0.05$. The categorical data were reported as raw numbers and percentages of the total sample. The continuous data were reported as medians and interquartile ranges. If there was a statistically significant difference between groups but the median and interquartile range were the same for both groups, the means and standard deviations were provided as footnotes to the tables. All analyses were conducting using R version 4.2.2.

Results

A total of 114,972 patients from the 2013-2018 TQIP database received at least 1 unit of pRBCs within 24 h of admission, of which 20,172 (17.5%) patients received MT.

Redefining the geriatric age for MT

The various TTs between the relatively younger and relatively older groups by age cutoff are shown in Figure 1. Consistently, the TT for the relatively younger group exceeded that of the relatively older group across all age cutoffs. As age cutoff increased, the TT for both groups generally decreased. For example, at a cutoff of age 50, the relatively younger group has a TT of 43 compared with the relatively older group, which has a TT of 35. At a cutoff of age 70, the relatively younger group has a TT of 40 compared with the relatively older group, which has a TT of 33. The difference in TT for the relatively younger and relatively older groups first became statistically significant using an age cutoff of 63 y and remained significant at all

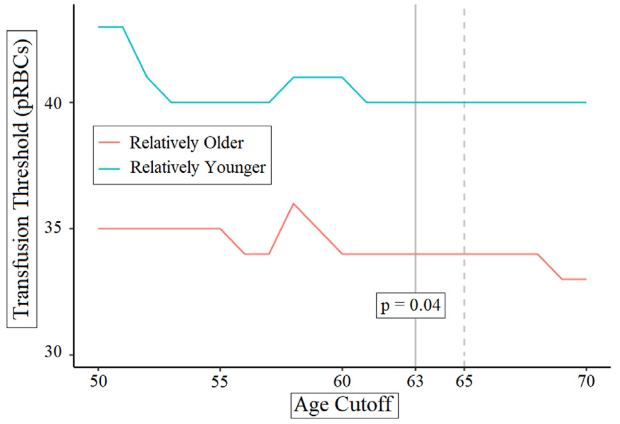

Fig. 1 – Transfusion futility thresholds (TTs)—the point at which additional pRBCs) do not improve mortality— by various age cutoffs between the relatively younger (blue) and relatively older (red) groups of adult patients in the 2013-2018 TQIP database.

age cutoffs >63. Consequently, the TT for the newly defined nongeriatric adults (aged <63) is 40 units (95% CI = 37-45) of pRBCs and the TT for the newly defined geriatric adults (aged ≥63 y) is 34 units (95% CI = 30-37) of pRBCs (P = 0.04). The underlying multiple logistic regression model that was used to derive the TTs for each age cutoff is shown in Figure 2 for an age cutoff of 63, specifically.

Comparing nongeriatric versus *geriatric adults*

Characteristics

The detailed characteristics are shown in Table 1. Notably, a lower percentage of geriatric adults were male (68.2% *versus* 90.4%, $P < 0.0001$) and a higher percentage were White (79.8% *versus* 53.8%, $P < 0.0001$) compared with the nongeriatric patients. Additionally, all comorbidities were more common among the geriatric adults than the nongeriatric patients ($P < 0.0001$). A higher percentage of geriatric adults suffered a blunt mechanism (89.6% *versus* 58.0%, $P < 0.0001$). Furthermore, geriatric patients demonstrated a higher admission SBP (95 *versus* 90, $P < 0.0001$) and lower admission HR (91 *versus* 106, $P < 0.0001$) than their nongeriatric counterparts. Geriatric patients had a higher GCS (9 *versus* 6, $P < 0.0001$) and a lower ISS (29 *versus* 29, $P = 0.0026$), AIS-brain (3 *versus* 3, $P < 0.0001$), AIS-thorax (3 *versus* 3, $P = 0.0049$), AIS-abd (3 *versus* 4, $P < 0.0001$), and AIS-upper extremity (2 *versus* 2, $P = 0.0002$). A lower percentage of geriatric adults were treated at university hospitals (59.7% *versus* 62.5%, $P = 0.0086$). Geriatric patients received fewer pRBCs (14 *versus* 16, $P < 0.0001$) and fewer FFP (10 *versus* 11, $P < 0.0001$) than nongeriatric patients. There was no difference in the ratio of pRBCs: FFP between groups (1.95 *versus* 1.89, $P = 0.0801$).

Outcomes

The detailed outcomes are shown in Table 2. Both 24-h (28.8% *versus* 26.0%, $P = 0.0024$) and in-hospital mortality (61.7% *versus* 45.4%, $P < 0.0001$) were higher for geriatric patients. Despite a shorter hospital LOS (5 *versus* 10, $Pp < 0.0001$), geriatric patients experienced more ventilator days (3 *versus* 3, $P = 0.0130$) than their nongeriatric counterparts. The following complications were more common among the geriatric than in the nongeriatric group: acute kidney injury (14.3% *versus* 12.3%, $P = 0.0082$), cardiac arrest (29.4% *versus* 26.8%, $P = 0.0135$), MI (3.0% *versus* 0.6%, $P < 0.0001$), and pressure ulcer (6.1% *versus* 4.9%, $P = 0.0167$). On the other hand, the following complications were more common among the nongeriatric than in the geriatric group: deep SSI (2.9% *versus* 6.7%, $P < 0.0001$), deep vein thrombosis (7.3% *versus* 10.0%, $P < 0.0001$), pulmonary embolism (2.6% *versus* 3.7%, $P = 0.0106$), and superficial SSI (1.2% *versus* 2.3%, $P = 0.0017$). Additionally, a lower percentage of geriatric patients were discharged to home or self care (7.3% *versus* 35.4%, $P = 0.0091$) and inpatient rehab (20.9% *versus* 21.6%, $P < 0.0001$). Meanwhile, a higher percentage of geriatric patients were discharged to long-term care (23.3% *versus* 14.4%, $P < 0.0001$),

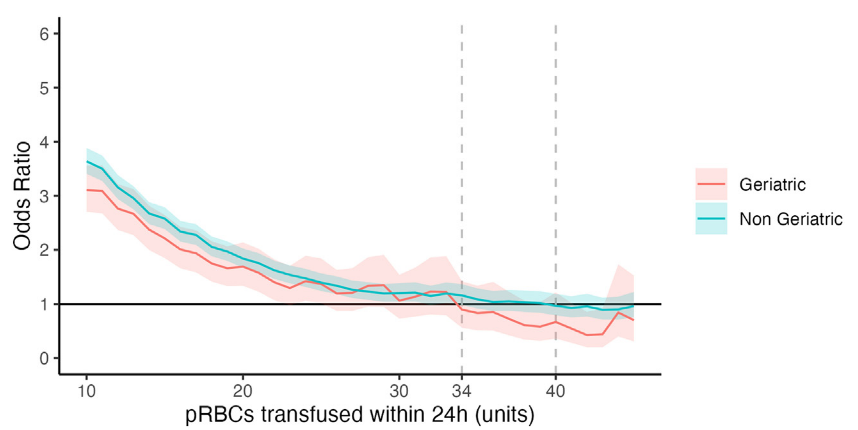

Fig. 2 – Underlying multiple logistic regression model that was used to derive the transfusion futility thresholds (TTs)—the point at which additional pRBCs do not improve mortality— of adult patients in the 2013-2018 TQIP database. An age cutoff of 63 was used. Odds of survival with increased transfusion by units of pRBCs transfused within 24 h of admission.

Table 1 – Characteristics between geriatric (≥63 y old) and nongeriatric (< 63 y old) adults receiving MT in the 2013-2018 TQIP database.

Characteristics	Geriatric, ≥63 y ($n = 2870$)	Nongeriatric, <63 y ($n = 17,302$)	OR (95% CI)	P-value
Age, median (IQR)	71 (66-77)	33 (25-47)	N/a	<0.0001
Male, *n* (%)	1956 (68.2)	13,912 (80.4)	0.52 (0.48-0.57)	<0.0001
Race, *n* (%)				
White	2207 (79.8)	8932 (53.8)	2.87 (1.50-5.48)	0.0009
Black	268 (9.7)	5506 (33.2)	0.56 (0.29-1.09)	0.0842
American Indian	10 (0.4)	116 (0.7)	Ref	
Asian	109 (3.9)	314 (1.9)	4.03 (2.04-7.96)	<0.0001
Pacific Islander	4 (0.1)	54 (0.3)	0.86 (0.26-2.86)	0.8048
Other	167 (6.0)	1683 (10.1)	1.15 (0.59-2.24)	0.6783
Comorbidities, *n* (%)				
Bleeding disorder	241 (11.0)	210 (1.9)	6.32 (5.22-7.66)	<0.0001
CHF	109 (5.0)	58 (0.5)	9.84 (7.13-13.6)	<0.0001
Chronic renal failure	47 (2.2)	54 (0.5)	4.43 (2.99-6.56)	<0.0001
Cirrhosis	118 (5.4)	393 (3.6)	1.53 (1.24-1.89)	0.0001
COPD	184 (8.4)	322 (2.9)	3.03 (2.51-3.65)	<0.0001
Diabetes	439 (20.1)	585 (5.3)	4.44 (3.89-5.08)	<0.0001
Prior MI	41 (1.9)	41 (0.4)	3.82 (2.39-6.11)	<0.0001
Mechanism of injury				
Blunt	2162 (89.6)	8350 (58.0)	Ref	
Penetrating	235 (9.7)	5944 (41.3)	0.15 (0.13-0.18)	<0.0001
Other	15 (0.6)	105 (0.7)	0.55 (0.32-0.95)	0.0294
Vitals, median (IQR)				
SBP (mmHg)	95 (71-120)	90 (64-117)	N/a	<0.0001
RR (×/min)	18 (13-23)	18 (12-23)	N/a	0.2812
HR (×/min)	91 (69-111)	106 (74-128)	N/a	<0.0001
Injury parameters, median (IQR)				
GCS	9 (3-15)	6 (3-14)	N/a	<0.0001
ISS[*]	29 (21-41)	29 (21-41)	N/a	0.0026
AIS-brain	3 (2-4)	3 (2-5)	N/a	<0.0001
AIS-thorax[†]	3 (3-4)	3 (3-4)	N/a	0.0049
AIS-abd	3 (2-4)	4 (3-4)	N/a	<0.0001
AIS-upper extremity[‡]	2 (1-2)	2 (1-2)	N/a	0.0002
AIS-lower extremity	3 (2-3)	3 (2-4)	N/a	0.3134
Center verification level, *n* (%)				
I	1506 (73.1)	9198 (75.1)	Ref	
II	545 (26.5)	2999 (24.5)	1.11 (1.00-1.23)	0.0544
III	8 (0.4)	44 (0.4)	1.11 (0.52-2.36)	0.7856
Number of beds, *n* (%)				
0-200	118 (4.1)	763 (4.4)	Ref	
200-400	639 (22.3)	3683 (21.3)	1.12 (0.91-1.39)	0.2859
400-600	792 (27.6)	4632 (26.8)	1.11 (0.90-1.36)	0.3461
>600	1321 (46.0)	8222 (47.5)	1.04 (0.85-1.27)	0.7118
Teaching status, *n* (%)				
Community	913 (31.9)	5133 (29.7)	Ref	
Nonteaching	241 (8.4)	1342 (7.8)	1.01 (0.87-1.18)	0.9029
University	1711 (59.7)	10,808 (62.5)	0.89 (0.82-0.97)	0.0086
Transfusion data				

(*continued*)

Table 1 – (*continued*)

Characteristics	Geriatric, ≥63 y (n = 2870)	Nongeriatric, <63 y (n = 17,302)	OR (95% CI)	P-value
pRBCs, median (IQR)	14 (11-21)	16 (12-24)	N/a	<0.0001
FFP, median (IQR)	10 (6-15)	11 (7-18)	N/a	<0.0001
pRBCs:FFP ratio, mean ± SD	1.95 ± 1.72	1.89 ± 1.67	N/a	0.0801
Platelets, median (IQR)	2 (1-4)	2 (1-4)	N/a	0.2083
Cryoprecipitate, median (IQR)	0 (0-2)	0 (0-2)	N/a	0.4717

OR = odds ratio; IQR = interquartile range; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; MI = myocardial infarction; SBP = systolic blood pressure; RR = respiratory rate; HR = heart rate; GCS = glasgow coma scale; ISS = injury severity score; AIS = abbreviated injury score; Abd = abdomen; pRBCs = packed red blood cells; FFP = fresh frozen plasma.
* Geriatric mean ± SD = 31.2, Non geriatric mean ± SD = 32.1.
† Geriatric mean ± SD = 3.36, Non geriatric mean ± SD = 3.45.
‡ Geriatric mean ± SD = 1.81, Non geriatric mean ± SD = 1.90.

skilled nursing facility (28.6% *versus* 9.9%, $P < 0.0001$), and hospice (4.8% *versus* 0.7%, $P < 0.0001$).

Risk of mortality

The multiple logistic regression model for hazard ratio of mortality is shown in Table 3. The risk of mortality increases with increasing pRBC transfusion amount, newly defined geriatric age, White, Black, Asian, and other race, bleeding disorder, cirrhosis, increased admission respiratory rate, penetrating mechanism, and increased AIS-brain, AIS-thorax, and AIS-abd. The risk of mortality decreases with increasing FFP transfusion amount, COPD, diabetes, increased admission SBP, and increased GCS, AIS-upper extremity, and AIS-lower extremity.

Discussion

Prior studies have demonstrated that mortality increases with increased age and increased transfusion requirements, yet none have established a physiologically based geriatric age cutoff.[5-7] Through analysis of TQIP data, our study addresses a gap in the literature, departing from the conventional geriatric age cutoff of 65 y for MT. Our study demonstrated that the geriatric age at which response to MT changes is 63 y. This nuanced distinction holds clinical relevance as the newly defined geriatric patients exhibit a lower TT (34 units of pRBCs within 24 h) compared to their nongeriatric counterparts of 40 units. Despite sustaining less severe injuries, our newly defined geriatric patients suffered worse outcomes. These findings could help to optimize outcomes for geriatric trauma patients, a rapidly expanding population.

Defining the geriatric trauma patient is elusive. According to the Eastern Association for the Surgery of Trauma geriatric practice management guidelines update, there is a lack of consensus on how to define geriatric trauma patients.[19] Despite suggesting that patients aged 65 y and older should be deemed geriatric, a subsequent survey of the American Association for the Surgery of Trauma members found that only 40% of respondents agreed with this definition.[12] The Advanced Trauma Life Support manual from the ACS suggests that patients aged 55 and older are geriatric trauma patients.[11] One group posited an even earlier threshold— age 45— as a marker for increased risk of adverse outcomes following multiple rib fractures.[10] Others have defined older age thresholds for defining geriatric trauma patients. Recent single-center studies out of Switzerland[20] and Sweden[21] demonstrated a significant increase in mortality and decline in the outcomes after age 60 among their trauma patient populations. One multicenter retrospective review from South Korean EDs found that mortality increased the most after age 65.[22] A 4-y retrospective review of data from the Ohio Trauma Registry included patients who either died or were admitted for >48 h[23] They found that when accounting for ISS, patients aged 70 and older had worse mortality than younger groups. A 5-y retrospective study of Pennsylvania hospitals identified age 70 as an appropriate cutoff for mandatory triage to a trauma center to improve outcomes.[24] Similarly, a retrospective review of data from one hospital in Thailand showed a higher mortality for patients aged 70 and older compared to younger patients.[25] One meta-analysis and systematic review suggested that patients suffered a higher risk of death at 75 y and was unchanged at subsequent older ages.[26] Finally, one group in Indiana began escalating the trauma activations to the highest level for all patients older than age 70. However, they discovered that this only improved mortality for patients aged 77 y and older.[13] In this study, we defined geriatric trauma patients receiving MT at age 63 y and older, which is similar to — albeit slightly younger than most — prior estimations. It is possible that the definition of what makes a patient "geriatric" is not uniform. The point at which outcomes vary by age likely vary by specific patient population. Future studies should continue to investigate the association between aging and outcomes following specific traumatic injuries or scenarios.

Identifying high-risk geriatric trauma patients is essential. A 2023 systematic review highlighted the need for accurate identification of high-risk older adults to improve the care of geriatric trauma patients.[27] Early identification, evaluation, and close monitoring of these patients improve survival.[28] Physiologically, geriatric patients do not respond to traumatic injuries the same as younger adults, which may complicate appropriate triage—normotension and normal

Table 2 – Outcomes between geriatric (≥63 y old) *versus* nongeriatric (< 63 y old) adults receiving MT in the 2013-2018 TQIP database.

Outcomes	Geriatric, ≥63 y (*n* = 2870)	Nongeriatric, <63 y (*n* = 17,302)	OR (95% CI)	P-value
24-h mortality, *n* (%)	777 (28.8)	4285 (26.0)	1.15 (1.05-1.26)	0.0024
In-hospital mortality, *n* (%)	1731 (61.7)	7724 (45.4)	1.94 (1.79-2.11)	<0.0001
Hospital LOS, median (IQR)	5 (1-20)	10 (1-25)	N/a	<0.0001
ICU LOS, median (IQR)	6 (2-16)	6 (2-16)	N/a	0.2157
Vent days, median (IQR)	3 (1-11)	3 (1-10)	N/a	0.0130
Complications, *n* (%)				
AKI	306 (14.3)	1525 (12.3)	1.20 (1.05-1.36)	0.0082
ARDS	142 (6.7)	878 (7.1)	0.94 (0.78-1.13)	0.4840
Cardiac arrest	628 (29.4)	3333 (26.8)	1.14 (1.03-1.26)	0.0135
CAUTI	93 (4.4)	460 (3.7)	1.19 (0.95-1.50)	0.1289
CLABSI	19 (0.9)	135 (1.1)	0.82 (0.51-1.33)	0.4262
Deep SSI	62 (2.9)	837 (6.7)	0.41 (0.32-0.54)	<0.0001
DVT	156 (7.3)	1244 (10.0)	0.71 (0.60-0.84)	<0.0001
MI	63 (3.0)	78 (0.6)	4.81 (3.44-6.73)	<0.0001
Osteomyelitis	5 (0.2)	57 (0.5)	0.51 (0.20-1.27)	0.1407
PE	55 (2.6)	457 (3.7)	0.69 (0.52-0.92)	0.0106
Pressure ulcer	131 (6.1)	609 (4.9)	1.27 (1.04-1.54)	0.0167
Severe sepsis	127 (5.6)	737 (5.9)	1.00 (0.83-1.22)	0.9797
Stroke/CVA	56 (2.6)	281 (2.3)	1.16 (0.87-1.56)	0.3065
Superficial SSI	26 (1.2)	283 (2.3)	0.53 (0.35-0.79)	0.0017
Unplanned ICU admission	83 (3.9)	567 (4.6)	0.85 (0.67-1.07)	0.1613
Unplanned visit to OR	217 (10.2)	1423 (11.5)	0.87 (0.75-1.02)	0.0807
VAP	240 (11.2)	1329 (10.7)	1.07 (0.92-1.23)	0.3960
Discharge disposition				
Home/self care	69 (7.3)	2959 (35.4)	0.59 (0.40-0.88)	0.0091
Home health	39 (4.1)	989 (11.8)	Ref	
Short/intermediate term care	104 (11.0)	521 (6.2)	5.06 (3.45-7.42)	<0.0001
Long-term care	220 (23.3)	1201 (14.4)	4.65 (3.27-6.60)	<0.0001
Inpatient rehab	197 (20.9)	1804 (21.6)	2.77 (1.95-3.94)	<0.0001
SNF	270 (28.6)	827 (9.9)	8.28 (5.84-11.73)	<0.0001
Hospice	45 (4.8)	59 (0.7)	19.34 (11.70-31.98)	<0.0001

OR = odds ratio; IQR = interquartile range; LOS = length of stay; AKI = acute kidney injury; ARDS = acute respiratory distress syndrome; CAUTI = catheter-associated urinary tract infection; CLABSI = central line-associated blood stream infection; SSI = surgical site infection; DVT = deep vein thrombosis; MI = myocardial infarction; PE = pulmonary embolism; CVA = cerebrovascular accident; ICU = intensive care unit; VAP = ventilator-associated pneumonia; SNF = skilled nursing facility.

HRs do not rule out serious underlying insult.[29,30] One clinical trial at a level 1 trauma center in Switzerland found that implementing standardized ED protocols for patients aged ≥65 y with an ISS ≥9 decreased mortality.[31] Subsequently, in the hospital course, specialized geriatric consultation services have been shown to increase the quality of life,[32] decrease in-hospital delirium,[33] and improve advanced planning (e.g. DNR status).[34] Caring for geriatric trauma patients is specialized and complex; trauma centers that manage a higher proportion of patients aged ≥65 y have improved outcomes for this population.[35] Furthermore, the ACS has acknowledged the importance of geriatric-specific standards and has instituted the Geriatric Surgery Verification Program, designed to optimize outcomes for older adults.[36] Our results suggest that any patient aged 63 y or older who receives MT should be physiologically treated as geriatric. In this study, 433 patients were aged 63 or 64 y old and received MT who traditionally would not be eligible for geriatric services. However, using our revised cutoff, they would now qualify. Future studies should utilize this as a trigger for geriatric services in an attempt to explore causation between this threshold and downstream impacts in a prospective manner.

The TT of 34 units and 40 units of pRBCs in 24 h for geriatric trauma patients and nongeriatric trauma patients, respectively, are similar to our prior estimates. While other studies have supported the conclusion that the geriatric TT is lower than the TT for younger adults, no other researchers have defined geriatric-specific TTs.[5,6,37] Our previous work

Table 3 – Logistic regression model (mortality in 24 h) for adult patients receiving massive transfusion (MT) in the 2013-2018 Trauma Quality Improvement Program (TQIP) database.

Characteristics	HR (95% CI)	P-value
Blood product		
pRBCs (1-unit ↑)	1.09 (1.08-1.09)	<0.0001
FFP (1-unit ↑)	0.96 (0.96-0.97)	<0.0001
Age ≥63 y	2.18 (1.98-2.39)	<0.0001
Male gender	0.98 (0.90-1.07)	0.6521
Race, *n* (%)		
White	1.77 (1.13-2.93)	0.0179
Black	2.04 (1.30-3.38)	0.0034
Asian	2.03 (1.22-3.54)	0.0087
Pacific Islander	1.44 (0.59-3.29)	0.3948
Other	1.74 (1.09-2.91)	0.0268
Comorbidities		
Bleeding disorder	1.26 (1.05-1.49)	0.0096
CHF	1.01 (0.78-1.28)	0.9569
Chronic renal failure	1.15 (0.81-1.60)	0.4031
Cirrhosis	2.47 (2.05-2.97)	<0.0001
COPD	0.82 (0.68-0.98)	0.0337
Diabetes	0.77 (0.67-0.88)	0.0001
Prior MI	1.08 (0.72-1.57)	0.6930
Vitals		
HR (5 bpm ↑)	1.00 (0.99-1.00)	0.1494
SBP (10 mmHg ↑)	0.97 (0.96-0.98)	<0.0001
RR (5/min ↑)	1.04 (1.02-1.07)	0.0005
Mechanism of injury		
Penetrating	1.35 (1.23-1.49)	<0.0001
Nonpenetrating, nonblunt	0.80 (0.52-1.19)	0.3001
Injury parameters (1-point ↑)		
GCS	0.86 (0.85-0.87)	<0.0001
AIS-brain	1.09 (1.07-1.11)	<0.0001
AIS-thorax	1.13 (1.11-1.16)	<0.0001
AIS-abd	1.08 (1.06-1.10)	<0.0001
AIS-upper extremity	0.80 (0.76-0.83)	<0.0001
AIS-lower extremity	0.88 (0.86-0.91)	<0.0001

HR = hazard ratio; pRBCs = packed red blood cells; FFP = fresh frozen plasma; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; MI = myocardial infarction; HR = heart rate; SBP = systolic blood pressure; RR = respiratory rate; GCS = glasgow coma scale; AIS = abbreviated injury score; Abd = abdomen.

examined the TT for geriatric patients defined arbitrarily as 65 y and older and found it to also be 34 units of pRBCs.[7] The stability of this finding was in spite of changes to our previously published multiple logistic regression model for determining TTs. The original model included only age, frailty as measured by the modified five-factor frailty index (mFI-5),[38-40] and ISS, whereas the model presented here was much more comprehensive (e.g. included race, ED admission vitals, AIS values, etc.) yet yielded similar results. This would suggest that only components in both models have a significant association with TTs: age, injury parameters (ISS *versus* AIS values), and certain overlapping comorbidities that were included in the mFI-5 (congestive heart failure, COPD, and diabetes). Nevertheless, when a patient reaches their TT, we recommend a transfusion "timeout" as described by Quintana *et al.*[4] Rather than blindly terminating transfusion, clinicians should take a brief pause to gauge the clinical status of the individual patient and the likelihood of salvage. One study from the Netherlands found that over half of trauma patients aged ≥70 who were admitted to the ICU from the ED or after urgent surgery survived to discharge.[41] Similarly, mortality rates for patients receiving 10 units of pRBCs or more within 24 h of admission were 29.7%, 42.6%, and 59.4% for patients aged 60-69 y, 70-79 y, and ≥80 y, respectively.[5] Reaching a TT does not suggest death is imminent; it suggests that continuing transfusion alone will not improve a patient's chance for survival.

Geriatric patients who require MT have worse outcomes than nongeriatric adults, despite less severe injuries. Similarly, another large database study comparing geriatric (≥65 y old) and nongeriatric trauma patients found that although median ISS score declines with age (14 for nongeriatric patients *versus* 13 for patients aged 66-85), geriatric patients had longer hospital and ICU LOS, more complications, and increased mortality – 8% *versus* 1.9%.[42] Specific to patients receiving MT, age ≥65 y old confers a 2-5x increased risk of mortality.[7,43] The variable that independently conferred the highest risk of mortality in our analysis was cirrhosis, a high-risk disease state, which is associated with higher mortality, longer hospital and ICU LOS, and more complications than noncirrhotic patients.[44] Race was also independently associated with mortality in our study. Unfortunately, racial disparities in outcomes following trauma persist in the United States today.[45]

The limitations to this study are inherent to a retrospective review of a large database. First, physiologic variables, such as lactate or thromboelastography values, may convey the clinical status of a patient and hold implications for resuscitation but are notably absent from the TQIP database.[46] Second, the use of low-titer group O whole blood over component therapy improves survival in civilians in hemorrhagic shock.[47] TQIP first added a whole blood variable in 2020, which is outside of our study period (2013-2018).[48] Therefore, we are unable to evaluate the role of whole blood in MT for geriatric trauma patients in this work. Future studies could investigate this association once additional years of data that include the whole blood variable are available in TQIP. Third, there is inevitable heterogeneity in data entry. In the case of whole blood administration, while 1/5 of ACS-verified trauma centers were administering it to patients in years 2013-2018, there was no formal guidance on how centers should report these data in TQIP (e.g. entering 1 unit of whole blood as 1 unit of pRBCs plus 1 unit of FFP or simply one unit of pRBCs).[49] Finally, although frailty is an age-independent predictor of mortality,[50] our prior work showed no association between frailty and TT; therefore, it was not included in this analysis.[7] However, frailty may still be associated with other outcomes such as functional recovery and quality of life, which are important for geriatric trauma patients. Future studies should incorporate frailty assessment tools and patient-reported outcomes to better understand their association with degree of frailty among geriatric trauma patients.

Conclusions

The new geriatric age threshold for MT is 63 y instead of the conventional 65 y. Geriatric patients have a lower TT than nongeriatric patients (34 *versus* 40 units of pRBCs within 24 h of admission). Despite less severe injuries, geriatric patients had worse outcomes than younger patients. Our findings underscore the importance of recognizing any patient aged 63 y or older who receives MT as physiologically geriatric. This shift in perspective has significant implications for improving outcomes for this growing population of trauma victims. As the geriatric trauma patient population expands, this study provides valuable insights for the identification and management of geriatric trauma patients who require MT. Furthermore, it paves the way for future research to optimize the care of this vulnerable population.

Disclosure

W.A.G. is an Associate Editor for the *Journal of Surgical Research* and was excluded from the entire peer-review and editorial process for this manuscript.

Funding

J.C.L. is funded by the Empire Clinical Research Investigator Program grant awarded to K.N. in 2021.

Meeting Presentation

Full Oral Presentation, 19th Annual Academic Surgical Congress in Washington, D.C. in February 2024.

CRediT authorship contribution statement

Joseph C. L'Huillier: Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Heather J. Logghe:** Writing – original draft, Methodology, Conceptualization. **Shuangcheng Hua:** Writing – original draft, Software, Formal analysis, Conceptualization. **Ajay A. Myneni:** Writing – review & editing, Project administration, Conceptualization. **Katia Noyes:** Writing – review & editing, Resources, Funding acquisition, Conceptualization. **Jihnhee Yu:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Weidun Alan Guo:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization.

REFERENCES

1. Ortman J, Velkoff V, Hogan H. *An Aging Nation: the Older Population in the United States*. Washington DC: U.S. Census Bureau; 2014.
2. Jiang L, Zheng Z, Zhang M. The incidence of geriatric trauma is increasing and comparison of different scoring tools for the prediction of in-hospital mortality in geriatric trauma patients. *World J Emerg Surg*. 2020;15:59.
3. Sihler KC, Napolitano LM. Complications of massive transfusion. *Chest*. 2010;137:209–220.
4. Quintana MT, Zebley JA, Vincent A, et al. Cresting mortality: defining a plateau in ongoing massive transfusion. *J Trauma Acute Care Surg*. 2022;93:43–51.
5. Morris MC, Niziolek GM, Baker JE, et al. Death by decade: establishing a transfusion ceiling for futility in massive transfusion. *J Surg Res*. 2020;252:139–146.
6. Schneider AB, Adams U, Gallaher J, et al. Blood utilization and thresholds for mortality following major trauma. *J Surg Res*. 2023;281:82–88.
7. L'Huillier JC, Hua S, Logghe HJ, et al. Transfusion futility thresholds and mortality in geriatric trauma: does frailty matter? *Am J Surg*. 2023;228:113–121.
8. United States Social Security. Social security history: Life expectancy for social security. Available at: https://www.ssa.gov/history/lifeexpect.html. Accessed December 4, 2023.
9. Eichinger M, Robb HDP, Scurr C, et al. Challenges in the PREHOSPITAL emergency management of geriatric trauma patients - a scoping review. *Scand J Trauma Resusc Emerg Med*. 2021;29:100.
10. Holcomb JB, McMullin NR, Kozar RA, et al. Morbidity from rib fractures increases after age 45. *J Am Coll Surg*. 2003;196:549–555.
11. American College of Surgeons Committee on Trauma. *ATLS, Advanced Trauma Life Support for Doctors*. Chicago, IL: American College of Surgeons; 2004.
12. Kozar RA, Arbabi S, Stein DM, et al. Injury in the aged: geriatric trauma care at the crossroads. *J Trauma Acute Care Surg*. 2015;78:1197–1209.
13. Carr BW, Hammer PM, Timsina L, et al. Increased trauma activation is not equally beneficial for all elderly trauma patients. *J Trauma Acute Care Surg*. 2018;85:598–602.
14. American College of Surgeons. Trauma quality improvement Program. Available at: https://www.facs.org/quality-programs/trauma/quality/trauma-quality-improvement-program/. Accessed December 4, 2023.
15. Boye M, Py N, Libert N, et al. Step by step transfusion timeline and its challenges in trauma: a retrospective study in a level one trauma center. *Transfusion*. 2022;62:S30–S42.
16. Calmettes G, Drummond GB, Vowler SL. Making do with what we have: use your bootstraps. *J Physiol*. 2012;590:3403–3406.
17. Billingsley P. *Probability and measure*. 3rd ed. Hoboken, NJ: John Wiley & Sons; 1995.
18. Efron B, Tibshirani RJ. *An Introduction to Bootstrap*. 1st ed. Boca Raton, FL: Chapman and Hall/CRC; 1994.
19. Eastern Association for the Surgery of Trauma Workgroup. Geriatric trauma (Update) 2010. Available at: https://www.east.org/education-resources/practice-management-guidelines/archived/geriatric-trauma-update. Accessed November 20, 2023.
20. Fiumedinisi FA, Amsler F, Gross T. Short-term outcome following significant trauma: increasing age per se has only a relatively low impact. *Eur J Trauma Emerg Surg*. 2021;47:1979–1992.
21. Ruge T, Malmer G, Wachtler C, et al. Age is associated with increased mortality in the RETTS-A triage scale. *BMC Geriatr*. 2019;19:139.
22. Lee JH, Kim MJ, Hong JY, et al. The elderly age criterion for increased in-hospital mortality in trauma patients: a retrospective cohort study. *Scand J Trauma Resusc Emerg Med*. 2021;29:133.
23. Caterino JM, Valasek T, Werman HA. Identification of an age cutoff for increased mortality in patients with elderly trauma. *Am J Emerg Med*. 2010;28:151–158.

24. Goodmanson NW, Rosengart MR, Barnato AE, et al. Defining geriatric trauma: when does age make a difference? *Surgery*. 2012;152:668–674.
25. Wongweerakit O, Akaraborworn O, Sangthong B, Thongkhao K. Age as the impact on mortality rate in trauma patients. *Crit Care Res Pract*. 2022;2022:2860888.
26. Hashmi A, Ibrahim-Zada I, Rhee P, et al. Predictors of mortality in geriatric trauma patients: a systematic review and meta-analysis. *J Trauma Acute Care Surg*. 2014;76:894–901.
27. Halter M, Jarman H, Moss P, et al. Configurations and outcomes of acute hospital care for frail and older patients with moderate to major trauma: a systematic review. *BMJ Open*. 2023;13:e066329.
28. Demetriades D, Karaiskakis M, Velmahos G, et al. Effect on outcome of early intensive management of geriatric trauma patients. *Br J Surg*. 2002;89:1319–1322.
29. Heffernan DS, Thakkar RK, Monaghan SF, et al. Normal presenting vital signs are unreliable in geriatric blunt trauma victims. *J Trauma*. 2010;69:813–820.
30. St John AE, Rowhani-Rahbar A, Arbabi S, Bulger EM. Role of trauma team activation in poor outcomes of elderly patients. *J Surg Res*. 2016;203:95–102.
31. Peterer L, Ossendorf C, Jensen KO, et al. Implementation of new standard operating procedures for geriatric trauma patients with multiple injuries: a single level I trauma centre study. *BMC Geriatr*. 2019;19:359.
32. Min L, Cryer H, Chan CL, et al. Quality of care delivered before *versus* after a quality-improvement intervention for acute geriatric trauma. *J Am Coll Surg*. 2015;220:820–830.
33. Lenartowicz M, Parkovnick M, McFarlan A, et al. An evaluation of a proactive geriatric trauma consultation service. *Ann Surg*. 2012;256:1098–1101.
34. Olufajo OA, Tulebaev S, Javedan H, et al. Integrating geriatric consults into routine care of older trauma patients: one-year experience of a level I trauma center. *J Am Coll Surg*. 2016;222:1029–1035.
35. Zafar SN, Obirieze A, Schneider EB, et al. Outcomes of trauma care at centers treating a higher proportion of older patients: the case for geriatric trauma centers. *J Trauma Acute Care Surg*. 2015;78:852–859.
36. American College of Surgeons. Geriatric surgery verification. 2023. Available at: https://www.facs.org/quality-programs/accreditation-and-verification/geriatric-surgery-verification/. Accessed December 6, 2023.
37. Wu SC, Rau CS, Kuo PJ, et al. Significance of blood transfusion units in determining the probability of mortality among elderly trauma patients based on the geriatric trauma outcome scoring system: a cross-sectional analysis based on trauma registered data. *Int J Environ Res Public Health*. 2018;15:2285.
38. Tracy BM, Adams MA, Schenker ML, Gelbard RB. The 5 and 11 factor Modified Frailty Indices are equally effective at outcome prediction using TQIP. *J Surg Res*. 2020;255:456–462.
39. Tracy BM, Wilson JM, Smith RN, et al. The 5-Item Modified Frailty Index predicts adverse outcomes in trauma. *J Surg Res*. 2020;253:167–172.
40. Subramaniam S, Aalberg JJ, Soriano RP, Divino CM. New 5-factor modified frailty index using American College of Surgeons NSQIP data. *J Am Coll Surg*. 2018;226:173–181.e8.
41. van Wessem KJP, Leenen LPH. Geriatric polytrauma patients should not be excluded from aggressive injury treatment based on age alone. *Eur J Trauma Emerg Surg*. 2022;48:357–365.
42. Fu CY, Bajani F, Bokhari M, et al. Age itself or age-associated comorbidities? A nationwide analysis of outcomes of geriatric trauma. *Eur J Trauma Emerg Surg*. 2022;48:2873–2880.
43. Lo BD, Merkel KR, Dougherty JL, et al. Assessing predictors of futility in patients receiving massive transfusions. *Transfusion*. 2021;61:2082–2089.
44. Serrano E, Liu P, Nwabuo AI, et al. The effect of cirrhosis on trauma outcomes: a systematic review and meta-analysis. *J Trauma Acute Care Surg*. 2020;88:536–545.
45. Kishawi SK, Tseng ES, Adomshick VJ, et al. Race and trauma mortality: the effect of hospital-level black-white patient race distribution. *J Trauma Acute Care Surg*. 2022;92:958–966.
46. Van Gent JM, Clements TW, Lubkin DT, et al. Predicting futility in severely injured patients: using arrival lab values and physiology to support evidence-based resource stewardship. *J Am Coll Surg*. 2023;236:874–880.
47. Morgan KM, Abou Khalil E, Feeney EV, et al. The efficacy of low-titer group O whole blood compared with component therapy in civilian trauma patients: a meta-analysis. *Crit Care Med*. 2024;52:e390–e404.
48. American College of Surgeons. NTDS data dictionary. Available at: https://www.facs.org/quality-programs/trauma/quality/national-trauma-data-bank/national-trauma-data-standard/data-dictionary/. Accessed March 20, 2024.
49. Hashmi ZG, Chehab M, Nathens AB, et al. Whole truths but half the blood: addressing the gap between the evidence and practice of pre-hospital and in-hospital blood product use for trauma resuscitation. *Transfusion*. 2021;61:S348–S353.
50. Makary MA, Segev DL, Pronovost PJ, et al. Frailty as a predictor of surgical outcomes in older patients. *J Am Coll Surg*. 2010;210:901–908.