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Death by Decade: Establishing a Transfusion Ceiling for Futility in Massive Transfusion

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ABSTRACT

Background: Age and massive transfusion are predictors of mortality after trauma. We hypothesized that increasing age and high-volume transfusion would result in progressively elevated mortality rates and that a transfusion "ceiling" would define futility.

Methods: The Trauma Quality Improvement Program (TQIP) database was queried for 2013-2016 records and our level I trauma registry was reviewed from 2013 to 2018. Demographic, mortality, and blood transfusion data were collected. Patients were grouped by decade of life and by packed red blood cell (pRBC) transfusion requirement (zero units, 1-3 units, or ≥4 units) within 4 h of admission.

Results: TQIP analysis demonstrated an in-hospital mortality risk that increased linearly with age, to an odds ratio of 10.1 in ≥80 y old ($P < 0.01$). Mortality rates were significantly higher in older adults ($P < 0.01$) and those with more pRBCs transfused. In massively transfused patients, the transfusion "ceiling" was dependent on age. Owing to the lack granularity in the TQIP database, 230 patients from our institution who received ≥4 units of pRBCs within 4 h of admission were reviewed. On arrival, younger patients had significantly higher heart rates and more severe derangements in lactate levels, base deficits, and pH compared with older patients. There were no differences among age groups in injury severity score, systolic blood pressure, or mortality.

Conclusions: In massively transfused patients, mortality increased with age. However, a significant proportion of older adults were successfully resuscitated. Therefore, age alone should not be considered a contraindication to high-volume transfusion. Traditional physiologic and laboratory criteria indicative of hemorrhagic shock may have reduced reliability with increasing age, and thus providers must have a heightened suspicion for hemorrhage in the elderly. Early transfusion requirements can be combined with age to establish prognosis to define futility to help counsel families regarding mortality after traumatic injury.

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Introduction

According to the United States Census Bureau, the proportion of people over the age of 65 y is expected to increase from 15.2% in 2016 to 23.5% by 2060. This equates to an increase from 49.2 billion to 94.7 billion individuals.[1] The aging of the population will likely be associated with an increase in the amount of traumatic injuries seen in older individuals.[2] Keller *et al.* demonstrated that older trauma patients were up to 3 times more likely to die than their younger counterparts. Older patients also have more severe injuries, longer hospitalizations, and greater resource utilization at discharge.[3] Multiple factors contribute to increasingly complex care for elderly trauma patients, including polypharmacy, comorbidities associated with age, differing injury patterns, and unique physiologic differences.

Traumatic hemorrhage is the leading cause of potentially preventable death after trauma.[4,5] The mortality after hemorrhage requiring massive transfusion was greater than 50% until the early 2000s when damage control resuscitation was adopted.[6] Damage control resuscitation, which consists of permissive hypotension, limited crystalloid use, and balanced blood product resuscitation, has been shown to improve 24 h and 30-d survival.[7] The Pragmatic Randomized Optimal Platelet and Plasma Ratios study demonstrated that the mortality after massive transfusion continues to decline. A mortality rate of 26% and 22% in patients who received plasma:platelet:packed red blood cell (pRBC) ratios of 1:1:2 and 1:1:1, respectively, was demonstrated.[8] The use of such predefined ratios and early initiation of massive transfusion protocols has been associated with improved survival.[9]

Massive transfusion and increased age have been shown to be risk factors for mortality after trauma. A limited number of studies have evaluated the effect of massive transfusion in the older population. A retrospective study evaluating the use of pRBC, age, and mortality showed that no patient aged >75 y requiring >12 units of pRBC survived and concluded that age and pRBC transfusion act synergistically. Two other studies suggested that age is not a predictor of mortality after MTP activation.[10,11] Some investigators have concluded that restrictive resuscitation or blood transfusion should not be based on age alone.[12] However, the literature is limited and demonstrates conflicting results, as there is no consensus on age groups studied or definition of “elderly”. Furthermore, multiple definitions of massive transfusion, including 10 units of pRBC in 24 h, 5 units of pRBC in the first 4 h, 10 units of pRBC in the first 6 h, 3 or more units of pRBC in the first hour, and total product administration in the first 30 min, have been used in the literature.[13-15] Therefore, we first hypothesized that increasing age and high-volume transfusion are associated with progressively elevated mortality rates. Second, we aimed to determine if there was a “ceiling,” or an amount of transfusion, that would be futile in these elderly patients. The third aim was to determine if the definition of “massive transfusion” should be applied uniformly to populations of any age.

Methods

After Institutional Review Board approval (Study #2018-0134) at the University of Cincinnati, the Trauma Quality Improvement Program (TQIP) database (2013-2016) was queried for all trauma patients aged ≥18 y to evaluate mortality rates based on age and blood transfusion. Because TQIP lacks admission laboratory data, the University of Cincinnati Medical Center trauma registry was reviewed from January 2013 to December 2018 to identify patients who were admitted to the hospital, aged ≥18 y and received ≥4 units of pRBC in the first 4 h of admission to increase data granularity. Patients were grouped by decade of life and by pRBC transfusion within 4 h of admission: zero units, 1-3 units as minimal transfusion, or ≥4 units as massive transfusion. The traditional definition of massive transfusion is 10 units of pRBC in 24 h. However, we wanted to use an earlier time point and 4 h is captured in the TQIP database. Transfusion of 4 or more units of pRBCs in the first 4 h of admission was chosen as our definition of massive transfusion because multiple definitions have been previously used, but there is not a standard or consensus definition utilizing an earlier time point.[13-15] All institutional data utilized were therefore considered to fall in the massive transfusion category.

Patient demographics, including age, gender, race, medical comorbidities, vital signs on admission, Glasgow Coma Scale (GCS), injury severity score (ISS), blood component transfusions, hospital length of stay (LOS), discharge to skilled nursing facility, 24 h and in-hospital mortality were obtained from TQIP. From the University of Cincinnati Medical Center registry, demographic data, admission vital signs and laboratory values, blood product transfusion, LOS, and in-hospital mortality were evaluated.

Statistical analyses were performed using SAS 9.4 (SAS institute, Cary, NC). Continuous variables are described as median and interquartile range and categorical variables by the number of individuals and percentages. Univariate analysis was performed using Student’s t-test, Mann–Whitney, or Chi-square test with Fisher’s exact test when appropriate. The variables found to be significantly different on univariate analysis were utilized in a multivariate logistic regression model to predict mortality. Data are presented as odds ratios and 95% confidence intervals. Statistical analysis was considered significant at a level of $P < 0.05$.

Results

After query of the national TQIP database, 508,463 patients were identified. Of those patients identified, 474,042 (93.2%) did not require a transfusion, 18,026 (3.5%) patients required minimal transfusion, and 16,395 (3.2%) patients required massive transfusion. Patients who were massively transfused were younger, more likely to be male and less likely to be of white race. On admission, the massively transfused cohort demonstrated a lower GCS, lower systolic blood pressure, higher heart rate (HR), lower temperature, and higher ISS than

Table 1 – Demographic and injury-related information for patients from the TQIP database.

	No transfusion (n = 474,042)	1-3 units pRBC (n = 18,026)	≥4 units pRBC (n = 16,395)	P value
Age (y)	56 (35-73)	43 (28-60)	39 (26-56)	<0.01
Male gender	63.2%	71.2%	76.3%	<0.01
Race				<0.01
White	76.3%	67.1%	62.2%	
Black	11.6%	18.4%	21.8%	
Other	12.1%	14.6%	16.0%	
GCS at admission	15 (15-15)	14 (3-15)	12 (3-15)	<0.01
SBP at admission	138 (123-155)	115 (94-137)	104 (82-130)	<0.01
HR at admission	85 (74-98)	99 (81-118)	110 (89-130)	<0.01
Temperature at admission	36.7 (36.4-36.9)	36.4 (36-36.8)	36.3 (35.7-36.7)	<0.01
Injury severity score	10 (9-17)	22 (14-29)	27 (17-38)	<0.01
Transfusion plasma (4 h)	0 (0-0)	0 (0-1)	4 (2-7)	<0.01
Transfusion platelets (4 h)	0 (0-0)	0 (0-0)	1 (0-2)	<0.01
Transfusion cryoprecipitate (4 h)	0 (0-0)	0 (0-0)	0 (0-0)	<0.01
Hospital LOS (d)	5 (3-8)	10 (5-18)	11 (3-23)	0.02
In-hospital mortality	3.5%	14.7%	29.7%	<0.01

Data presented as median (interquartile range) or percentage.
GCS = Glasgow Coma Scale; SBP = systolic blood pressure; HR = heart rate; LOS = length of stay.

those patients who required no transfusion and those who were minimally transfused. With respect to blood product administration, the massive transfusion group received more units of plasma, cryoprecipitate, and platelets. Overall, the massively transfused patients had a longer hospital LOS and higher in-hospital mortality (Table 1).

When the three transfusion groups were analyzed by decade of life, the in-hospital mortality was significantly elevated in the massively transfused cohort as compared with patients who required minimal or no transfusions in each decade of life cohort. Older patients also demonstrated a higher mortality as compared with younger patients when comparing within transfusion groups (Fig. 1). Massively transfused patients of ages 18-29, 30-39, 40-49, and 50-59 had initial shock indices of 1.09, 1.08, 1.03, and 1.00, respectively. By contrast, the shock index was below the standard 1.0 cutoff used to define hemodynamic instability in the 60-69, 70-79, and ≥80 y old groups. Massively transfused patients were found to have a different pRBC-to-plasma ratio dependent on age ($P < 0.01$). Patients of 18-29, 30-39, 40-49, 50-59, 60-69, 70-79, and ≥80 y old groups were found to have median ratios of 1.55 (1.13-2.00), 1.56 (1.13-2.16), 1.60 (1.17-2.08), 1.66 (1.18-2.12), 1.67 (1.20-2.40), 1.67 (1.18-2.25), and 1.75 (1.20-2.25), respectively. However, these differences are unlikely to be clinically significant and speak more to the large sample size in the study. On multivariate analysis, patients aged 60-69, 70-79, and ≥80 y and underwent massive transfusion were at increased risk for 24-h mortality compared with 18-29 y olds. Comparatively, an incremental increase in risk of in-hospital mortality was observed for each additional decade of life starting at 40 y of age compared with ages 18-29 y. Each increased point on the GCS and each unit of platelets transfused in the first 4 h was associated with lower 24-h and in-hospital mortality. Each unit of plasma transfused in the first 4 h was associated with lower 24-h but not overall in-hospital mortality. By contrast, increasing amounts of pRBCs transfused and each one point increase in ISS were associated with an increased risk of death for both 24-h and in-hospital mortality (Table 2).

In review of our institutional data, a total of 230 trauma patients were identified who received 4 or more units of pRBC in the first 4 h of their hospitalization. The median age was 33 (24-49) y and most patients were white males. Average ISS was 29 (19-41) and the vital signs on admission included GCS 14 (3-

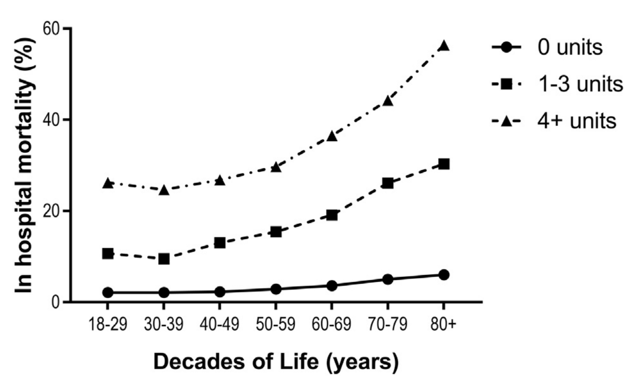

Fig. 1 – In-hospital mortality for each decade of life in patients who received no transfusion, minimal transfusion (1-3 units packed red blood cells [pRBC]), and massive transfusion (≥4 units pRBC) in the first 4 h of admission. Mortality is increased between groups at all decades of life ($P < 0.05$) and is increased in the older decades of life for each group ($P < 0.05$).

Table 2 – Multivariate analysis of patients undergoing massive transfusion.

Variable	24 h mortality		In-hospital mortality	
	Odds ratio	P value	Odds ratio	P value
Age range				
18-29 (reference)	1.00		1.00	
30-39	0.96 (0.83-1.10)	0.56	1.04 (0.92-1.18)	0.50
40-49	0.94 (0.81-1.09)	0.41	1.16 (1.01-1.32)*	0.03
50-59	0.97 (0.84-1.13)	0.72	1.50 (1.31-1.70)*	<0.01
60-69	1.20 (1.01-1.41)*	0.04	2.50 (2.16-2.89)*	<0.01
70-79	1.92 (1.58-2.32)*	<0.01	4.15 (3.47-4.96)*	<0.01
80 and older	2.61 (2.07-3.27)*	<0.01	10.1 (8.16-12.6)*	<0.01
SBP (10 mmHg increment)	1.00 (0.99-1.02)	0.61	1.02 (1.01-1.03)*	<0.01
HR (10 beat increment)	0.99 (0.97-1.01)	0.21	0.98 (0.97-0.99)*	<0.01
GCS total	0.88 (0.87-0.89)*	<0.01	0.85 (0.85-0.86)*	<0.01
pRBCs—1st 4 h	1.09 (1.08-1.10)*	<0.01	1.08 (1.07-1.09)*	<0.01
ISS	1.02 (1.02-1.03)*	<0.01	1.04 (1.03-1.04)*	<0.01
Platelets—1st 4 h	0.98 (0.97-0.99)*	<0.01	0.99 (0.97-1.00)*	0.03
Plasma—1st 4 h	0.99 (0.98-1.00)*	0.02	1.00 (0.99-1.01)	0.75

Data presented as odds ratio (95% confidence interval).
GCS = Glasgow Coma Scale; HR = heart rate; ISS = injury severity score; pRBC = packed red blood cells; SBP = systolic blood pressure.
*$P < 0.05$.

15) systolic blood pressure 107 (80-136) mmHg, HR 109 (86-131) beats per minute, and temperature 36.5 (36.1-36.8) °C. Non-pRBC blood products received in the first 4 h consisted of a median of 6 (4-10) units of plasma, 1 (0-2) unit of platelets, and 0 (0-0.5) units of cryoprecipitate to match a median of 6 (4-11) units pRBCs. The hospital LOS was 10 (3-21) d and in hospital mortality was 30.7%. Our institutional data appeared to be on par with national data; however, we were unable to statistically compare our institutional data to TQIP demographic data because of our data being a part of TQIP as well.

For our institutional cohorts based on age, no differences were observed in regards to in-hospital mortality. However, the HR was lower in the older decades compared with the younger decades. Evaluation of laboratory data on admission showed that the older patients had lactate levels, base deficits, and pH that were closer to physiologic normal compared with younger patients (Table 3).

Subsequently, utilizing the TQIP data, mortality was evaluated by number of units of pRBC received in the first 4 h regardless of age. Mortality was evaluated for each unit from 0 to 10 units and then in groups by 10 from 11 to 90 units. Mortality increased as the amount transfused increased and 100% mortality was reached at 81-90 units of pRBCs within 4 h of admission across all age groups (Fig. 2). Further analysis of the mortality rates and the number of pRBCs transfused was examined in each decade of life to determine if a "ceiling" of transfusion utility exists in each age group. Table 4 is color-coded based on mortality: white is 0-24.9% mortality, green is 25-49.9% mortality, yellow is 50-74.9% mortality, red is 75-100% mortality, and black did not contain any patients. The

Table 3 – Physiologic and laboratory parameters of patients from the University of Cincinnati trauma registry.

Decade of life (y)	Patients (*n*)	In-hospital mortality (%)	ISS	HR (beats per minute)	SBP (mmHg)	Lactate (mg/dL)	pH	Base deficit
18-29	180	28.3%	29 (19-41)	116 (93-139)	108 (78-136)	6.8 (4.4-10.4)	7.18 (7.01-7.27)	−7.9 (−14.5 to −3.8)
30s	99	29.3%	26 (19-41)	110 (82-132)	109 (85-138)	6.7 (3.9-10.4)	7.22 (7.03-7.29)	−8.9 (−14.9 to −2.8)
40s	54	27.8%	32 (19-41)	110 (88-126)	102 (70-133)	5.8 (3.9-8.4)	7.16 (7.13-7.26)	−7.0 (−11.0 to −2.7)
50s	53	34.0%	29 (22-38)	101 (86-120)	98 (81-124)	4.9 (3.6-7.6)	7.25 (7.14-7.31)	−4.8 (−10.1 to −2.2)
60s	33	33.3%	25 (19-34)	100 (81-111)	114 (74-143)	3.5 (2.4-5.7)	7.27 (7.22-7.31)	−3.8 (−6.2 to −1.9)
70s	12	41.7%	26 (18-33)	90 (69-117)	106 (91-144)	2.2 (1.7-2.9)	7.29 (7.21-7.35)	−1.6 (−8.3 to 1.1)
≥80	9	66.7%	30 (26-38)	96 (76-101)	105 (89-150)	3.5 (3.3-4.7)	7.25 (7.23-7.27)	−1.2 (−6.9 to −0.2)
P value		0.29	0.85	0.01	0.84	<0.01	<0.01	<0.01

Data presented as median (interquartile range or percentage); heart rate (HR); injury severity score (ISS); systolic blood pressure (SBP).

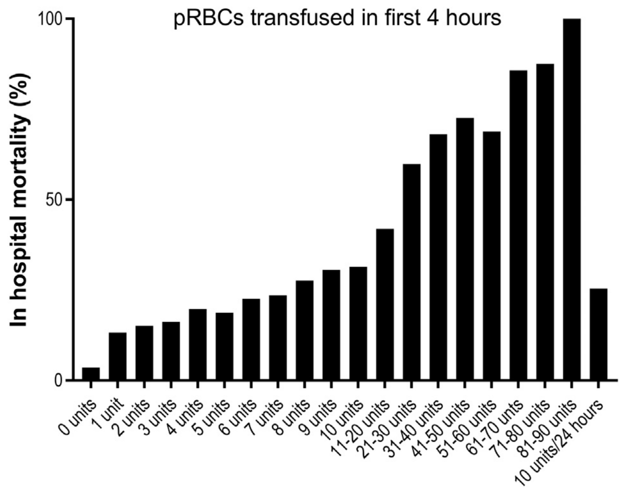

Fig. 2 – In-hospital mortality by unit of packed red blood cells (pRBC) received in the first 4 h on admission. The traditional definition of massive transfusion (≥10 units of pRBC in 24 h) is shown for comparison.

mortality of patients who received the more classic definition of massive transfusion of 10 units of pRBCs in the first 24 h is also shown for each decade of life. Analysis of mortality rates on this table revealed that the number of pRBC units required to reach a certain mortality rate depends on the age of the patient. Therefore, if the definition of massive transfusion were to be considered based on the associated risk of mortality, the definition would vary based on patient age.

Discussion

In this study utilizing the TQIP and a single institutional database, we evaluated the effect of massive transfusion on mortality with a novel design utilizing the decades of life rather than an arbitrary age cutoff. Overall, massively transfused patients were more likely to be younger men and were less likely to be of white race as compared with black or other. They were more likely to receive non-pRBC blood products, have a greater derangement in their admission vital signs, and more likely to die during their hospitalization than trauma patients who were not transfused within 4 h of admission. Evaluating mortality by decade of life in a multivariate model, we further demonstrate an incremental increase of in-hospital mortality for each later decade of life. Our model also demonstrated an increased risk of death in the first 24 h or during sentinel hospitalization as ISS and pRBC transfusion number increased. Our own institutional data demonstrated that massively transfused older patients were also more likely to have an HR, base deficit, pH, and lactic acid closer to

Table 4 – Mortality and relation to the number of packed red blood cells transfused in the first 4 h of admission evaluated by each decade of life (y).

	18-29	30-39	40-49	50-59	60-69	70-79	≥80
0 units	2.1%	2.1%	2.3%	2.9%	3.6%	5.0%	6.0%
1 unit	7.8%	7.1%	12.6%	12.3%	17.0%	22.5%	21.5%
2 units	11.3%	10.6%	13.4%	15.5%	19.9%	27.4%	28.0%
3 units	13.3%	9.5%	10.9%	18.8%	20.3%	28.7%	41.0%
4 units	14.5%	17.9%	18.1%	18.7%	24.0%	31.9%	46.2%
5 units	15.6%	12.7%	16.5%	19.3%	23.4%	28.6%	42.5%
6 units	18.9%	16.7%	19.3%	23.3%	28.4%	35.8%	50.0%
7 units	21.1%	18.2%	17.8%	22.9%	33.3%	38.0%	57.1%
8 units	24.6%	18.3%	18.8%	29.0%	35.6%	52.6%	68.3%
9 units	27.6%	23.3%	26.2%	25.6%	43.4%	54.3%	55.0%
10 units	26.3%	24.2%	30.9%	25.9%	44.1%	58.3%	79.2%
11-20 units	36.9%	35.3%	39.5%	44.4%	50.0%	64.6%	80%
21-30 units	54.6%	51.3%	55.7%	64.6%	77.2%	88.6%	88.2%
31-40 units	65.8%	63.9%	62.2%	71.2%	88.9%	50.0%	83.3%
41-50 units	62.6%	79.2%	70.6%	73.7%	88.2%	100%	
51-60 units	40.0%	70.6%	80.0%	88.9%	60.0%	100%	100%
61-70 units	80.0%	66.7%	100%	83.3%		100%	
71-80 units	100%		80.0%	80.0%			
81-90 units				100%			
10 units in 24 hours	26.0%	24.8%	27.2%	22.9%	29.7%	42.6%	59.4%

physiologic normal on admission compared with their younger counterparts. In the second aim of our study, we showed that transfusion of more than 80 units of pRBCs in the first 4 h of admission was uniformly fatal. However, on further subgroup analysis, older patients are likely to reach the transfusion “ceiling” earlier and octogenarians have an in-hospital mortality of 28% after receiving just 2 units of pRBC.

Damage control resuscitation has improved mortality after hemorrhage after traumatic injury.[16] In the last decade, two large multicenter trials were performed that further evaluated massive transfusion. The Prospective, Observational, Multicenter, Major Trauma Transfusion study enrolled patients who received 3 or more blood product units and showed an overall in-hospital mortality of 21%.[17] The Pragmatic Randomized Optimal Platelet and Plasma Ratios study determined that 30-d mortality for 1:1:1 and 1:1:2 plasma:platelet:pRBC resuscitation were 22% and 26%, respectively.[8] However, the median patient ages in each of these studies were in the 30s and may not be applicable to all patient populations. Specifically, multiple studies have demonstrated a higher mortality rate in the elderly after trauma.[18-21] A study from Carolinas Medical Center used an arbitrary age cutoff to show that patients older than 55 y of age had a significantly higher mortality when receiving a blood transfusion in the first 24 h[10] Previous studies have traditionally utilized arbitrary cutoffs for age to compare two groups when evaluating at mortality in the “elderly”. By comparison, our study stratifies patients by decade of life and demonstrated that there is an incremental increase in mortality for each additional decade of life. Octogenarians demonstrated almost a 10-fold increase in hospital mortality compared with 18-29-y-old patients who were massively transfused. Although two previous studies have evaluated massive transfusion in the elderly, neither study found a change in mortality for the older group compared with the younger cohort. However, both studies used arbitrary and discrete age cutoffs and were limited by the small number of massively transfused elderly patients.[11,12] The use of the TQIP database allowed us to evaluate a larger number of patients in each age group compared with these single-center studies.

Although older patients are more likely to die after injury, our study further supports current literature showing that elderly patients do not all present with severe derangements in admission vital signs and laboratory values.[22-27] Two studies utilizing the National Trauma Data Bank to evaluate blunt injury in the elderly found that traditional vital signs such as HR and systolic blood pressure were reliable in predicting mortality.[25,26] Pandit *et al.* demonstrated a superior ability to predict mortality using the shock index rather than blood pressure or HR alone. However, Zarzaur *et al.* found age x shock index to be a better predictor of mortality than traditional vital signs or shock index.[26] A subsequent study using national data further supported shock index as being the strongest predictor for mortality.[27] In our study, HR was significantly lower in the older patients, but systolic blood pressure was similar. These differences in initial vital signs create an inability to use the shock index as an accurate predictor of hemorrhagic shock. While adding a modifying calculation may help correct the age-related inaccuracy of the shock index, additional calculation nullifies the simplicity of the shock index, reducing its utility at the bedside of an acutely ill trauma patient. However, our study again highlights that there is an important incremental decrease in shock index with age measured by decade rather than arbitrarily dichotomized. We further demonstrated with institutional data that certain admission laboratory values might not be as reliable in the elderly. Although there is limited literature on admission laboratory values for the elderly patient in hemorrhagic shock, Salottolo *et al.* showed that venous lactate levels might be a better predictor of mortality than traditional vital signs.[23] However, this is contrary to our findings that lactate levels having significant less derangement in the older patients. Although there is some conflicting data, the current data highlight the importance of increased vigilance when evaluating an elderly patient in the trauma bay because they may not display the classic vital signs or physiologic derangements of hemorrhagic shock.

Futility of care is an elusive, complex, and real issue that trauma surgeons face. While no consensus definition of futility exists, a $\geq$90% mortality rate has been previously used as a point of excessive mortality.[28] A survey of American Association for the Surgery of Trauma members found that approximately one-quarter of respondents admitted to aborting a trauma operation one to five times in the past year due to perceived futility. Uncontrollable hemorrhage was noted to be among the leading reasons for cases to be aborted.[29] Multiple studies have investigated the futility of massive transfusion and have concluded that massive transfusion is still justified in all patient populations. Among these studies, the mean pRBC transfusion was 20 to 40 units of pRBCs and the highest mortality rate approached 70%.[30-34] Our study differs in that we utilized a national database, which allowed the point where mortality reached 100% to be determined and allowed for a more detailed analysis to identify mortality by each decade of life. To our knowledge, this is the first study that demonstrates that further transfusion may approach futility and 100% mortality after 80 units of pRBC in the first 4 h. However, as age increases, the number of units needed to approach futility decreases, and there is futility of transfusion past 51-60 units of pRBC within the first 4 h of admission in the octogenarian population. While the whole clinical picture needs to be considered for each patient, these data and simplified mortality figure can be a useful tool for a surgeon struggling to gain control of hemorrhage in the operating room with ongoing transfusion requirements or in counseling a patient’s family after an acute resuscitation. This figure also integrates age with pRBCs administered within the first 4 h to provide an all-cause mortality estimate that can be used when counseling family members and establishing expectations of care and outcomes.

The traditional definition of massive transfusion being 10 units of pRBC in 24 h has been used in the literature for the past 2 decades. However, there is still no consensus on the definition of “massive transfusion,” leading many authors to generate alternative definitions. These definitions have included, but are not limited to 5 units of pRBC in the first 4 h, 10 units of pRBC in the first 6 h, 3 or more units of pRBC in the first hour, and total product administration in the first 30 min.[13-15] These definitions have all been created in the search for a way to address survival bias and changes in resuscitation practice because implementation of damage control resuscitation.[16,30,35] These newer definitions have identified more patients who undergo early resource-intense resuscitations that never reach 10 units of pRBC in 24 h and also capture the patients who die within 24 h of presentation. Despite many definitions of massive transfusion that exist, none of them have accounted for age. Age as a risk factor for mortality in trauma has been previously discussed. If the ultimate outcome of interest after massive transfusion is death, our data demonstrate that the traditional definition of massive transfusion is associated with roughly 30% mortality in all patients regardless of age. However, an octogenarian is already at 30% mortality after 2-3 units of pRBC in 4 h, and by comparison, a 20-y-old does not reach 30% mortality until after receiving 10 units of pRBC. Therefore, we believe that a consensus on the definition of massive transfusion would be helpful to increase our ability to compare and study this patient population. Furthermore, we suggest the age should be considered when defining massive transfusion.

The main limitations are inherent to the retrospective nature of the study. The utilization of a national database is limited by heterogeneity in coding and incomplete data for individual patients. In fact, TQIP is missing enough data on mechanism of injury that this variable was not able to be utilized for the current analysis. The TQIP database is also limited on the physiologic data that can be obtained, but we supplemented our analysis with our own institutional data so that we would be able to evaluate more granular data. However, the relatively small number of acutely transfused elderly trauma patients also limits the conclusions that can be drawn from our own institutional data.

In conclusion, although 30-d mortality increases with age in massively transfused patients, a significant proportion of older adults are successfully resuscitated. In addition, physiologic and laboratory value criteria of hemorrhagic shock may have reduced reliability with increasing age. Although age alone should not be considered a contraindication to initiation of high-volume transfusion, the resuscitation "ceiling" at which mortality approaches 100% should be kept in mind. However, these data demonstrating increased risk of post-traumatic death by decade can be utilized to help counsel patients and families regarding mortality risk after trauma and to establish a ceiling of successful resuscitation for appropriate blood product resource management.

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Disclosure

Dr Goodman serves as an Associate Editor for the Journal of Surgical Research; as such, he was excluded from the entire peer-review and editorial process for this manuscript.

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