Improved outcomes in elderly trauma patients with the implementation of two innovative geriatric-specific protocols—Final report

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BACKGROUND: Elderly trauma care is challenging owing to the unique physiology and comorbidities prevalent in this population. To improve the care of these patients, two practice management guidelines (PMGs) were implemented: high-risk geriatric protocol (HRGP), which triages patients based on injury patterns and comorbid conditions for occult hypotension, and the anticoagulation and trauma (ACT) alert, which is designed to streamline the care of geriatric trauma patients on anticoagulants. We hypothesized that both HRGP and ACT would decrease mortality and complications in geriatric trauma patients.

METHODS: Geriatric blunt trauma patients (aged ≥65) presenting to our Level II center from January 2000 to July 2016 were extracted from the trauma registry. Do-not-resuscitate patients were excluded. The study period was divided into three phases: Phase 1, no PMGs in place (2000 to January 2006); Phase 2, HRGP only (February 2006 to February 2012); and Phase 3, HRGP + ACT (March 2012 to July 2016). Multivariate logistic regression models assessed adjusted mortality and complications during these phases to quantify the impact of these protocols. Statistical significance was set at $p < 0.05$.

RESULTS: A total of 8,471 geriatric trauma patients met inclusion criteria. Overall mortality rate was 5.6% (Phase 1, 7.2%; Phase 2, 6.1%; Phase 3, 4.0%). No significant change in mortality was observed during Phase 2 with the HRGP only (adjusted odds ratio (OR), 0.98; 95% confidence interval, 0.73–1.34; $p = 0.957$); however, a significantly reduced OR of mortality was found during Phase 3 with the combination of both the HRGP and ACT (adjusted OR, 0.67; 95% confidence interval, 0.47–0.94; $p = 0.021$). No significant changes in incidence of complications was observed over the study duration.

CONCLUSIONS: Geriatric trauma patients are not simply older adults. Improved outcomes can be realized with specific PMGs tailored to the geriatric trauma patients' needs. (*J Trauma Acute Care Surg.* 2018;84: 301–307. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Geriatric; trauma; mortality; complications.

The geriatric sector (ages ≥ 65 years) is the most rapidly expanding segment of the United States population and is projected to be 83.7 million in 2050, nearly double the 43.1 million estimate in 2012.[1] They currently constitute 15% of the total population and represent a unique demographic with specific issues.[2] The challenges inherent in providing health care for this aging cohort are not insignificant and requires a multidisciplinary approach that encompasses appropriate consideration of the changes in physiologic, psychosocial, and functional status. It is widely acknowledged that trauma in the elderly is associated with poor outcomes relative to trauma in the younger population with increasing age and incidence of complications more predictive of morbidity and mortality than severity of injury.[3–5] Given the comorbidities that accompany advancing age, polypharmacy is a significant concern in the management of these patients owing to the increased potential for adverse drug events and drug-drug interactions often secondary to the physiologic changes and decreased drug clearance observed in this population.[6] Of particular interest is the subset of population on chronic anticoagulation (AC), who, in the setting of trauma, are at significant risk for bleeding. Brain hemorrhage is a notable concern given the most common mechanisms of injury in the elderly are falls and motor vehicle collisions, which are associated with particularly increased risks for head injury and fractures.[7–9] Previous studies have generally demonstrated poor outcomes in geriatric head trauma patients on AC therapy at the time of injury[10–13] but have also shown the positive impact of early AC reversal in decreasing injury progression and mortality in documented intracerebral hemorrhage.[14,15]

As a result of the expansion in the geriatric population as well as the existence of gaps in knowledge regarding best practices for management of geriatric trauma, development of management protocols must be prioritized to optimize outcomes in these individuals. Over the past decade, our Level II community trauma center has sought to streamline the care of at-risk geriatric trauma patients through the implementation of two geriatric-specific practice management guidelines (PMGs): the high-risk geriatric protocol (HRGP) in 2006 and the anticoagulation and trauma (ACT) Alert in 2012.

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TABLE 1. High-Risk Geriatric Protocol (HRGP) Activation

A. Eligibility Criteria

High-Risk Injuries	Medical History Indicators	Assessment Indicators
Traumatic brain injury	Anticoagulation: Coumadin/Plavix	Admission GCS score ≤14
≥2 rib fractures	Cardiac history: CHF/HTN/arrhythmias	Need for blood products
Pulmonary contusion	Chronic liver failure: cirrhosis	PRBC/FFP
Pneumothorax	Chronic renal failure: Cr ≥ 1.8 and/or GFR ≤ 60	Surgical Intervention
Hemothorax	Pulmonary disease: chronic obstructive pulmonary disease	Base deficit > 6 mmol/L
Blunt cardiac injury		Systolic blood pressure <90 mm Hg
Hemoperitoneum		Lactic acid ≥2.4 mmol/L
Pelvic fracture		
Long bone fracture		
Open fracture		

B. HRGP

High-Risk Geriatric Protocol
STAT ABG
If base deficit ≥ 6 ABG every 4 h until base deficit ≤ 2 mmol/L
STAT EKG
Basic metabolic profile, magnesium, and phosphorus in AM
PT/PTT INR in AM
ICU admission and neuro checks every hour for 24 hours
For unexplained hemodynamic instability, obtain a STAT echocardiogram
Consult geriatrics

CHF, congestive heart failure; HTN, hypertension; Cr, creatinine; GFR, glomerular filtration rate; GCS, Glasgow Coma Scale; PRBC, packed red blood cells; FFP, fresh frozen plasma; ABG, arterial blood gas; EKG, electrocardiogram; PT, prothrombin time; PTT, partial thromboplastin time; INR, international normalized ratio; ICU, intensive care unit.

Although both of these PMGs have been investigated individually in preliminary analyses,[16,17] the long-term and combined impact of these initiatives has yet to be determined. The purpose of this investigation is to analyze trends in geriatric outcomes at our trauma center from 2000 to 2016 with consideration of the impact of the HRGP and the ACT Alert protocols. We hypothesized that notable reductions in in-hospital mortality and complications would be observed following introduction of two geriatric-specific PMGs when compared to control phase preceding these protocols.

METHODS

Following review and approval by the Institutional Review Board of Lancaster General Health/Penn Medicine, a longitudinal cohort study of our trauma registry was performed. While the registry was queried retrospectively, it is maintained in a prospective manner by trained registrars and contains Pennsylvania Trauma Systems Foundation–required data fields. Inclusion criteria were simple: all geriatric (age ≥ 65) blunt injury admissions from January 2000 to July 2016. Do-not-resuscitate patients unable to receive life-saving measures and penetrating/burn injury patients were excluded from analysis. Variables of interest included demographics (age, admission year), injury severity statistics (Injury Severity Score [ISS], Glasgow Coma Scale score, Abbreviated Injury Scale scores, Revised Trauma Score), length of stay, and outcome measures (mortality, complications).

To examine the progressive efficacy of our institution's two geriatric-specific PMGs, the study period was separated into three phases. Phase 1, which spanned January 2000 to January 2006, was used as a baseline control period, as no geriatric-specific PMGs were in place during this timeframe. Phase 2, which marked the implementation of the HRGP, tracked the impact of this single PMG from February 2006 to February 2012. Phase 3, which covered March 2012 to July 2016, encompassed both the implementation of ACT Alert and the continuation of the HRGP to examine the combined impact of these two PMGs. The HRGP, initiated in February 2006 with full implementation in early 2007, was a multidisciplinary collaborative effort between

TABLE 2. Anti-coagulation and Trauma (ACT) Alert Protocol

A. Triage Parameters

ACT Alert Triage Parameters
1. Age ≥65
2. Anticoagulation agents
3. GCS score ≥13
4. Head trauma within past 24 hours

B. Response protocol

ACT Alert Response Protocol
1. ED response team of ED doctor, nurse, and phlebotomist to see patient within 15 minutes of ACT
2. Point of care (Coagucheck) INR test completed within 20 minutes of ACT
3. STAT priority head CT completed within 30 minutes of ACT

GCS, Glasgow Coma Scale; ED, emergency department; INR, international normalized ratio; CT, computed tomography.

the trauma department and the geriatric program that sought to identify geriatric trauma patients at increased risk for developing worse outcomes. Geriatric patients meeting eligibility criteria for high-risk injury, accompanying medical history and assessment indicator(s) (Table 1A) were entered into the HRGP (Table 1B), which also included an automatic consult with the geriatrics service. Similarly, the ACT Alert, introduced in March 2012, was designed to triage geriatric patients on AC presenting with minor head trauma. Patients meeting ACT criteria (Table 2A) underwent the ACT Alert response protocol (Table 2B). The timeline of the study period is presented in Figure 1.

Outcome measures under investigation include mortality and complications, which were the primary and secondary outcomes, respectively. Within our trauma registry, a number of complications (varying from 45 to 48) were collected as defined by the Pennsylvania Trauma Systems Foundation, and the incidence of specific complications was determined. Complications are listed as multiple variables in collectable fields within the trauma registry, which can be used to generate reports on individual or groups of occurrences. Definitions of complications were revised over the years, with some entries added and deleted. Individual complications were chosen based on relevance to the geriatric population. The complications outcome was defined as a binary variable, with patients undergoing one or more specific complications during their hospital stay meeting inclusion criteria. Univariate analysis in the form of one-way analysis of variance tests were implemented to determine unadjusted differences in mortality rate and complication rate across the three phases. Multivariate logistic regression models adjusted for age, ISS, Glasgow Coma Scale, and Revised Trauma Score upon admission were used to assess the impact of the PMGs on mortality and specific complications across the three phases of the study. To gain an understanding of the combined effects of the PMGs throughout the study period, the phase variable was stratified within the models using the control Phase 1 as the reference interval. Model performance for the mortality and total complication models was determined through the area under the receiver operating characteristic curve. All data manipulation and statistical analyses were performed using Stata/MP version 15 (Stata Corp, College Station, TX). Statistical significance was set at $p < 0.05$.

RESULTS

Over the 17-year study period, 8,764 geriatric trauma patients presented to our Level II trauma center (Fig. 1). Within this population, 63 patients (0.72%) presented with penetrating trauma, and 30 patients (0.34%) sustained burn injuries, causing them to be excluded from analysis. In addition, 200 patients were also excluded secondary to do-not-resuscitate status, resulting in a final study population of 8,471 geriatric blunt trauma patients. A complete breakdown of study population demographics,

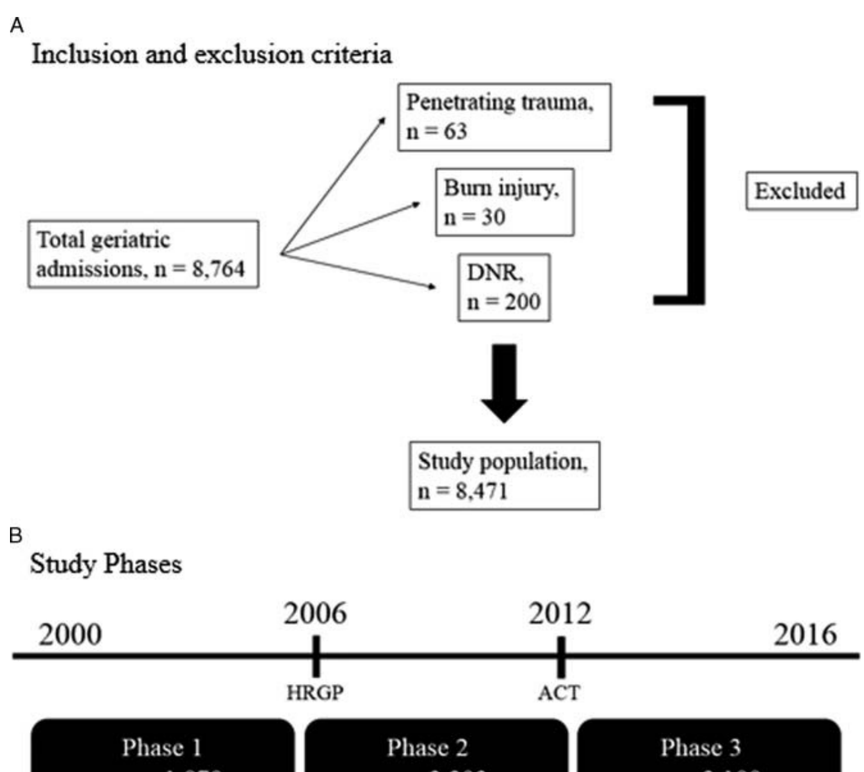

Figure 1. Timeline of PGMs throughout study period.

TABLE 3. Study Population Demographics and Injury Severity Statistics

Variable	Study Population (N = 8,471)	Phase 1 (n = 1,879)	Phase 2 (n = 3,393)	Phase 3 (n = 3,199)
Age, mean ± SD, years	79.6 ± 8.28	78.8 ± 7.95	79.8 ± 8.16	79.9 ± 8.57
ISS, mean ± SD	10.7 ± 8.21	12.0 ± 9.15	11.1 ± 8.29	9.4 ± 7.32
Median (IQR)	9.0 (4.0–14.0)	9.0 (5.0–16.0)	9.0 (5.0–16.0)	9.0 (4.0–13.0)
ISS ≥ 9, %	59.9	69.0	62.1	52.1
GCS score, mean ± SD	14.4 ± 1.97	14.3 ± 2.19	14.4 ± 2.01	14.42 ± 1.79
RTS, mean ± SD	7.71 ± 0.69	7.6 ± 0.92	7.7 ± 0.63	7.7 ± 0.61
AIS scores, mean ± SD				
Head/Neck	3.05 ± 1.23	3.2 ± 1.17	3.2 ± 1.15	2.8 ± 1.28
Face	1.60 ± 0.61	1.6 ± 0.67	1.7 ± 0.65	1.5 ± 0.51
Chest	2.60 ± 0.87	2.8 ± 1.00	2.6 ± 0.90	2.5 ± 0.76
Abdomen/Pelvis	2.30 ± 0.73	2.5 ± 0.91	2.4 ± 0.79	2.2 ± 0.56
Extremities	2.40 ± 0.58	2.6 ± 0.55	2.4 ± 0.59	2.2 ± 0.51
External	1.01 ± 0.12	1.0 ± 0.15	1.0 ± 0.08	1.0 ± 0.13
ICU LOS, mean ± SD, days	1.36 ± 2.94	1.8 ± 3.41	1.4 ± 3.08	1.1 ± 2.42
Hospital LOS, mean ± SD, days	4.95 ± 5.06	6.3 ± 5.84	5.2 ± 5.48	3.9 ± 3.70
Complications, n (%)	126 (1.53)	23 (1.28)	52 (1.57)	51 (1.64)
ARDS	1 (0.01)	0 (0.0)	1 (0.03)	0 (0.0)
Acute respiratory failure	22 (0.27)	8 (0.45)	13 (0.39)	1 (0.03)
PNA (including VAP)	13 (0.15)	4 (0.22)	6 (0.18)	2 (0.06)
Pulmonary embolus	11 (0.13)	4 (0.22)	6 (0.18)	1 (0.03)
Myocardial infarction	31 (0.38)	4 (0.22)	12 (0.36)	15 (0.48)
Acute renal failure	6 (0.07)	2 (0.11)	1 (0.03)	3 (0.10)
Progression of neurologic insult	8 (0.10)	1 (0.06)	7 (0.21)	–
CVA/stroke	33 (0.40)	–	5 (0.15)	28 (0.90)
Sepsis	1 (0.01)	0 (0.0)	1 (0.03)	0 (0.0)
Mortality, n (%)	472 (5.57)	136 (7.24)	208 (6.13)	128 (4.0)

AIS, Abbreviated injury scale; ARDS, acute respiratory distress syndrome; CVA, cerebrovascular accident; ICU, intensive care unit; IQR, interquartile range; ISS, injury severity score; LOS, length of stay; PNA, pneumonia; RTS, revised trauma score; SD, standard deviation; VAP, ventilator-associated pneumonia.

injury severity, and outcome measures is presented in Table 3. Complications most relevant to the geriatric population were included in the tabulation, and the tabulation is not an exhaustive list of the complications collected in our trauma registry. Of note, entry field "Progression of neurologic insult" was discontinued in 2012 with the simultaneous introduction of the "CVA/stroke" field, which did not exist previously.

Across the three phases, analysis of variance found significant reductions in unadjusted mortality rates (Fig. 2A). Mortality rate decreased by 3.2% over the study period (Phase 1, 7.2%; Phase 2, 6.1%; Phase 3, 4.0%; $p < 0.001$), while complication rate increased (Fig. 2B), albeit nonsignificantly, by 0.36% (Phase 1, 1.3%; Phase 2, 1.6%; Phase 3, 1.6%; $p = 0.607$). In adjusted analysis (Table 4), significant reductions in mortality were observed only during Phase 3 with combination of HRGP and ACT Alert (adjusted odds ratio (AOR), 0.67; 95% confidence interval, 0.47–0.94; $p = 0.021$) when compared to the reference control period (Phase 1). No significant adjusted changes in mortality was observed during Phase 2. Identical trends in mortality were found when adjusted for ISS of 9 or greater (indication of greater injury severity) in addition across the three phases (Phase 2 AOR, 1.01; $p = 0.945$; Phase 3 AOR, 0.67; $p = 0.020$). No significant changes in rates of complications were found over the study duration. Overall, these models were found to have good discrimination with an area under the receiver operating characteristic curve of 0.87 and 0.67 for the mortality and complications models.

DISCUSSION

The results of this investigation suggest that PMGs tailored to the geriatric population, such as the HRGP and the ACT Alert, can significantly improve outcomes in geriatric trauma patients. Although no significant adjusted reductions in mortality were observed until Phase 3, it suggests the combination of the two geriatric-specific PMGs may have had a synergistic impact on improving outcomes in this population. In addition, it should be noted that the combination of both protocols was also effective in reducing mortality when adjusted for ISS of 9 or greater, suggesting that these protocols also affect mortality in severely injured patients. Incidence of complications was not determined to be statistically different over the study duration, although unadjusted analysis revealed an increasing trend over the course of the study. While this was alarming at first, several points need to be mentioned. Discontinuation of the "Progression of neurologic insult" and addition of "CVA/stroke" made a noticeable impact in the reported complications. Since the specific "CVA/stroke" field did not exist before 2012, these events were never documented and thus could serve to artificially lower the reported incidence of complications from 2000 to 2012.

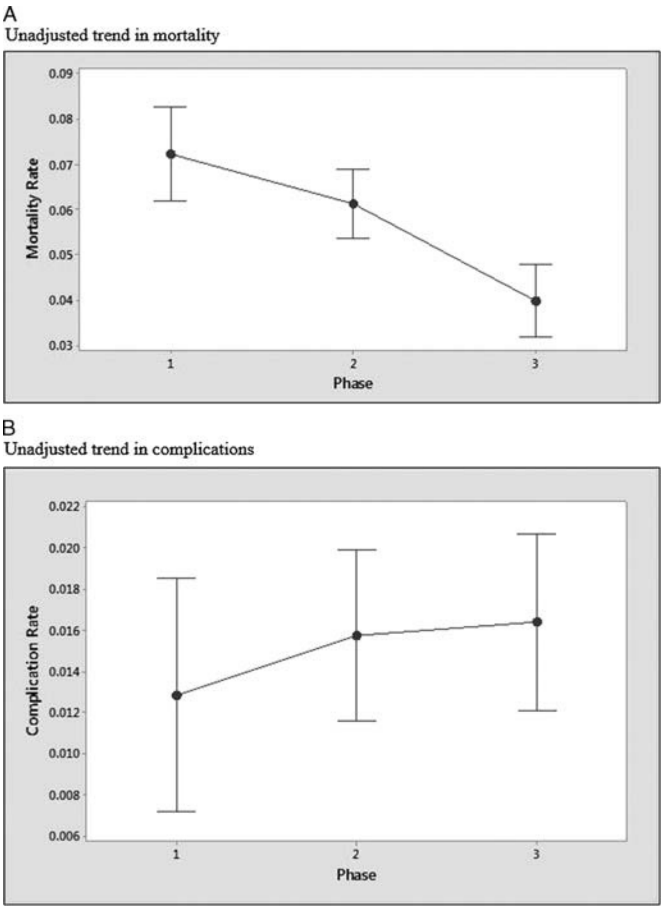

Figure 2. Unadjusted trends in mortality and complications over Phase 1 to Phase 3.

While an argument could be made for the capture of some of the "CVA/stroke" population in the "Progression of neurologic insult" field, it is the authors' opinion that the pronounced increase seen in "CVA/stroke" in Phase 3 is predominantly secondary to previous under capture of this subgroup of complications. In addition, it is also plausible that the increase in complications observed was secondary to the lower mortality rate in this population, which allowed for the development of complications in patients.

It should be noted that adherence to both of these protocols was not 100% with ACT Alert and HRGP averaging adherence rates of 91.2% and 93%, respectively, over 2012–2016. Viewing the results of this investigation in composite, our hypothesis suggesting decreased in-hospital mortality and complications with implementation of HRGP and ACT Alert is partially supported. The authors acknowledge that these protocols were not the sole measures introduced in the management of the geriatric trauma patients over the study period. With growing realization of the geriatric patient as a unique entity, more efforts, both on macro and institutional levels, have been directed to address this problem. At our institution, other protocols, albeit not specifically targeted to geriatric population, were also instituted during the study period, which could also have contributed to the observed decrease in mortality. Of note, implementation of other PMGs [severe traumatic brain injury algorithm (2001), venous thromboembolism prophylaxis and surveillance (2004) along with blunt cerebrovascular injury (2011)] could have affected mortality and incidence of certain complications.

Despite a rapidly expanding geriatric population, limited research exists detailing innovative interventional approaches for these patients. Most of the present literature on geriatric trauma details trends in outcomes only—with limited consideration for strategies to improve such measures. Several studies have reported poorer outcomes in geriatric trauma populations, suggesting these trends are the result of preexisting comorbidities and complications.[4,5,18] Meta-analysis of major predictors of mortality identified age and increasing injury severity (higher ISS values) as major predictors with low systolic blood pressure upon admission also potentially having a role.[19] Similarly, a host of research has detailed undertriage[20,21] and even age bias[22] as complex issues plaguing geriatric trauma patients. When developing the HRGP and the ACT Alert, we took these findings into consideration to combat the major issues plaguing the geriatric trauma population at our Level II community center. The demonstrated positive impact of these protocols on mortality while statistically significant may not initially seem clinically significant. However, these interventions can offer a wealth of information pertaining to the underlying reasons for their success, which can be instrumental in future development of interventions targeted to combat other geriatric-centric issues.

We postulate that one of the contributing factors to the success of the ACT Alert was the proviso regarding rapid radiographic imaging. It has been demonstrated numerous times that the elderly have worse outcomes compared to their younger cohort across the scale of injury severity.[3–5] A potentially contributing factor is the existence of any baseline cognitive impairment in this population that could limit the relevance of some of the variables typically used in assessing injury severity.[23] In this setting, radiographic imaging to assess for injuries becomes paramount to initiate early treatment with early aggressive treatment shown to increase likelihood of geriatric trauma patients returning to independent living status.[20] This is particularly relevant for trauma patients on chronic anticoagulants who have increased risk for brain hemorrhage and other neurological sequelae. In addition, due to the decreased physiologic reserve that occurs with advancing age, combined with comorbidities

TABLE 4. Multivariate Binary Logistic Regression Models for Mortality and Complications

N = 8,471	Mortality Model		Complications Model	
Variable	Adjusted Odds Ratio (95% CI)	p	Adjusted Odds Ratio (95% CI)	p
Phase				
1	Reference	-	Reference	-
2 (HRGP)	1.01 (0.74–1.38)	0.942	1.37 (0.80–2.32)	0.248
3 (HRGP + ACT Alert)	0.67 (0.47–0.94)	0.021	1.53 (0.89–2.61)	0.120
Age	1.07 (1.05–1.08)	<0.001	0.99 (0.97–1.01)	0.241
ISS	1.10 (1.10–1.12)	<0.001	1.06 (1.04–1.08)	<0.001
GCS	0.82 (0.75–0.91)	<0.001	0.98 (0.76–1.26)	0.888
RTS	0.61 (0.47–0.79)	<0.001	1.44 (0.70–2.97)	0.323
	AUROC: 0.87		AUROC: 0.67	

AUROC, area under the receiver operating characteristic curve.

and polypharmacy, geriatric trauma patients are exceedingly sensitive to changes in vital signs and occult hypoperfusion.[23] Serum lactate levels and base deficit have been demonstrated to be markers for hypoperfusion and predictive of outcomes in geriatric trauma patients,[24] which have both been incorporated into the HRGP either as existing indicators and/or laboratory tests to be obtained urgently. Despite differing approaches, both of these geriatric-specific protocols aim to identify issues promptly to initiate early aggressive treatment to improve outcomes. While advocates exist for early withdrawal of care in geriatric trauma patients with greater injury severity due to increased mortality and complications,[25,26] the authors of this paper believe geriatric trauma management is far from futile, although more investigation and trials of protocols are warranted to identify optimal approaches. Future studies could attempt to further assess the mortality reductions observed by identifying the impact of these interventions on underlying causes of death.

This study is not without its limitations. In addition to the previously acknowledged limitations on the inclusion of complications as an outcome measure, the retrospective nature of this investigation raises some concerns regarding validity. This is somewhat mitigated by the fact that the data were collected in a prospective manner by trained trauma registrars, which addresses much of the bias threatening the validity of the retrospective investigation. Another weakness of this work pertains to our necessity to compare our recent geriatric trauma populations to historical controls with no prospective randomization of geriatric patients to the PMGs. As a result, we are unable to definitively conclude that the improvements in mortality and specific complications observed in this study were directly due to our geriatric-specific PMGs, as they could also have occurred secondary to other advances in geriatric trauma care management over time. In addition, since this study only includes geriatric trauma patients with blunt injuries, the findings cannot be generalized to all geriatric trauma patients.

Another limitation pertaining to the two protocols themselves was the routine review and revisions when necessary to the protocols. The authors could not control for this, and indeed, it would have been highly unethical to not revise the protocols to reflect advancements in care. In addition, there was some variability in geriatric care providers for the HRGP protocol. During its initial introduction, there were two geriatric physicians on the service, with four more added within the first 2 years of the protocol. The authors feel this is not a tremendous amount of variation but acknowledge that it may have a role in the care provided. It should also be acknowledged that the ACT Alert did not control for changes in AC use or introduction of new oral ACs over the study period. However, the authors note the existence of an AC reversal protocol (July 2001) that has been routinely updated to reflect changing patterns of anticoagulant use and availability in the population. A final limitation of our study is that although it attempts to analyze trends in outcomes in the geriatric population by examining in-hospital complications and mortality, it fails to provide a comprehensive view of the impact of our initiatives. Assessment of mortality and functionality 30 days and 6 months after discharge would likely be a more useful indicator of the efficacy of these protocols. Unfortunately, data on these measures are not available at our institution.

CONCLUSION

Geriatric patients are not simply older adults, they are a rapidly expanding subset of population with complex and unique needs. Implementing multidisciplinary geriatric-specific standardized protocols tailored to the needs of this patient population has proven indispensable, as the increased surveillance associated with these protocols resulted in improved outcomes. Future efforts should continue to explore specific beneficial management approaches and intervention strategies to improve care and outcomes in this high-risk population.

AUTHORSHIP

E.B. and FR contributed to study design, data collection, data analysis, manuscript preparation, and editorial oversight. B.G. contributed to study design, data collection, data analysis, and manuscript preparation. S.J. contributed to data collection, data analysis, and manuscript preparation. W.A. and J.A.M. contributed to study design, data analysis, and manuscript preparation.

DISCLOSURE

The authors declare no conflicts of interest.

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