ORIGINAL ARTICLE

ONLINE FIRST

Assessing the Feasibility of the American College of Surgeons' Benchmarks for the Triage of Trauma Patients

Deepika Mohan, MD, MPH; Matthew R. Rosengart, MD, MPH; Coreen Farris, PhD; Elan Cohen, MS; Derek C. Angus, MD, MPH, FRCP; Amber E. Barnato, MD, MPH, MS

Objective: To test the feasibility of accomplishing the American College of Surgeons Committee on Trauma benchmarks of less than 5% undertriage (treatment of patients with moderate to severe injuries at nontrauma centers [NTCs]) and less than 50% overtriage (transfer of patients with minor injuries to trauma centers [TCs]) given current practice patterns by describing transfer patterns for patients taken initially to NTCs and estimating volume shifts and potential lives saved if full implementation were to occur.

Design, Setting, and Patients: Retrospective cohort study of adult trauma patients initially evaluated at NTCs in Pennsylvania (between April 1, 2001, and March 31, 2005). We used published estimates of mortality risk reduction associated with treatment at TCs.

Main Outcome Measures: Undertriage and overtriage rates, estimated patient volume shifts, and number of lives saved.

Results: A total of 93 880 adult trauma patients were initially evaluated at NTCs in Pennsylvania between 2001 and 2005. Undertriage was 69%; overtriage was 53%. Achieving less than 5% undertriage would require the transfer of 18 945 patients per year, a 5-fold increase from current practice (3650 transfers per year). Given an absolute mortality risk reduction of 1.9% for patients with moderate to severe injuries treated at TCs, this change in practice would save 99 potential lives per year or would require 191 transfers per year to save 1 potential life.

Conclusions: Given current practice patterns, American College of Surgeons Committee on Trauma recommendations for the regionalization of trauma patients may not be feasible. To achieve 5% undertriage, TCs must increase their capacity 5-fold, physicians at NTCs must increase their capacity to discriminate between moderate to severe and other injuries, or the guidelines must be modified.

Arch Surg. 2011;146(7):786-792. Published online March 21, 2011. doi:10.1001/archsurg.2011.43

Author Affiliations: Departments of Surgery (Drs Mohan and Rosengart) and Medicine (Drs Farris and Barnato and Mr Cohen) and Clinical Research, Investigation, and Systems Modeling of Acute Illness (CRISMA) Laboratory, Department of Critical Care Medicine (Drs Mohan, Rosengart, Angus, and Barnato), University of Pittsburgh, Pittsburgh, Pennsylvania.

REGIONALIZATION IN TRAUMA has become the standard of care.[1] Evidence suggests that inclusive trauma systems improve outcomes by matching patient needs with institutional resources.[2-7] Ideally, therefore, patients with moderate to severe injuries should receive care at trauma centers (TCs), while those with minor injuries should receive care at nontrauma centers (NTCs).[8]

See Invited Critique at end of article

Regionalization depends on the ability of health care providers to discriminate between patients with minor injuries and those with moderate to severe injuries so that they can correctly identify patients who would benefit from transfer to a TC. However, the clinical uncertainty associated with triage decisions makes discrimination necessarily imperfect. Balancing pragmatism with expert opinion regarding best practices, the American College of Surgeons Committee on Trauma (ACS-COT) has recommended that mature trauma systems strive to achieve rates of less than 5% undertriage (treatment of patients with moderate to severe injuries at NTCs) and less than 50% overtriage (treatment of patients with minor injuries at TCs).[8] Nonetheless, the feasibility of accomplishing these benchmarks remains unclear.

The purpose of this study was to explore the feasibility of implementing ACS-COT recommendations given current practice patterns. We used administrative data to describe the current patterns of region-

©2011 American Medical Association. All rights reserved.
Downloaded From: http://archsurg.jamanetwork.com/ on 10/30/2014

alization in Pennsylvania and then used our empirical observations to estimate the shifts in patient volume and number of lives saved if the ACS-COT undertriage target of less than 5% were achieved. Specifically, we focused on triage for patients taken initially to an NTC (secondary triage) because these decisions should theoretically have reflected only physicians' judgments about the need for transfer.

METHODS

DATA SOURCES

We conducted a retrospective cohort analysis of all trauma patients initially evaluated at an NTC in Pennsylvania who were then admitted to the NTC or transferred to a TC between April 1, 2001, and March 31, 2005. Pennsylvania accounts for 4.2% of the US population and contains both rural and urban centers, which should result in a representative mix of trauma injury severity and mechanism.[9] Additionally, it maintains both a statewide trauma registry and an administrative database of all hospitalizations. The Pennsylvania Trauma Systems Foundation (PTSF) collects data from TCs on all transfers from outlying hospitals, all admissions to the intensive care unit, all deaths, and all admissions from the field with a stay longer than 48 hours. It does not receive any information from NTCs. The Pennsylvania Health Care Cost Containment Council (PHC4) coordinates an administrative database of all hospital admissions. However, it does not contain any information on transfers that occur prior to admission (ie, from the emergency department [ED] of an NTC to a TC). Integrating information from both sources allowed us to construct a comprehensive picture of triage for patients who initially presented to the ED of an NTC.

HOSPITALS

We matched facilities in the PTSF and PHC4 databases using facility names. We identified TCs using a list published annually by the PTSF of accredited facilities.[10-14] All other hospitals were classified as NTCs. We excluded NTCs from the sample if they were from hospital referral regions with a central city outside the state, were specialty hospitals (eg, eye and ear infirmaries), or federal hospitals. We further characterized hospitals by annual trauma admission volume, bed size, teaching status (major, minor, no teaching), participation in a health system that included a TC, and a previously validated measure of hospital treatment intensity (an empirically weighted index of treatment intensity among patients with a high probability of dying, calculated as a factor score of 6 underlying standardized ratios including intensive care unit admission, intensive care unit length of stay, intubation or mechanical ventilation, tracheostomy, hemodialysis, and feeding tube insertion).[15]

PATIENTS

Within the PTSF, we identified patients older than 17 years who were transferred to a regional TC after evaluation in an NTC. We excluded patients with burns and patients admitted to the NTC prior to transfer (defined as having a stay longer than 24 hours). Within the PHC4, we identified patients older than 17 years who were admitted to an NTC for a primary diagnosis of trauma (*International Classification of Diseases, Ninth Revision, Clinical Modification* [*ICD-9-CM*] codes 800-959). We excluded patients with an admission related to the late effect of injuries, foreign bodies, burns, and isolated hip fractures.

We categorized injury severity as either minor (not requiring admission to a TC) or moderate to severe (requiring admission to a TC). We defined moderate to severe injuries as those in patients with an Injury Severity Score (ISS) higher than 15 or an injury defined by the ACS-COT as life threatening or critical. If ACS-COT definitions required treatment information,[8] we excluded the injury because the PHC4 did not include the necessary data (**Table 1**).

For each patient, we categorized the adherence to ACS-COT triage guidelines: true-positive (patient with moderate to severe injury transferred to a TC), false-positive (patient with minor injury transferred to a TC), false-negative (patient with moderate to severe injury admitted to an NTC), and true-negative (patient with minor injury admitted to an NTC). To assess the validity of using 2 separate data sets to describe Pennsylvania triage patterns, we confirmed that the cohort of people expected to appear in both data sets contained the same number of observations in each data set over the same period (PTSF, n = 57 591; PHC4, n = 57 451).

We abstracted data on patient age, sex, and insurance status (Medicare only, Medicare and Medicaid, Medicare and commercial, Medicaid only, commercial only, uninsured). We categorized the time of the day of the transfer as peak (8 AM to 6 PM) or off peak (before 8 AM or after 6 PM). We characterized comorbidities using the methods of Elixhauser et al[16] and the magnitude of injury using ISSs. In the PTSF, trauma registrars had calculated ISSs for patients based on information abstracted from the record. For the PHC4, we used a validated computer program (ICDMAP90; The Johns Hopkins University and Tri-Analytics Inc, Baltimore, Maryland) to translate *ICD-9-CM* diagnostic codes into ISSs.[17] However, in a sensitivity analysis, we observed that ICDMAP90 systematically underestimated injury severity compared with registrar-calculated ISSs for patients in the PTSF. To address this bias, we developed a modified *ICD-9-CM* diagnostic code to ISS conversion program that resulted in a better approximation of the distribution of ISSs in the PTSF (eAppendix, eReferences, eFigure 1, and eFigure 2, http://www.archsurg.com). Specifically, we calculated ISS by assigning an Abbreviated Injury Score (AIS) to each *ICD-9-CM* diagnostic code using assumptions to translate diagnostic codes into descriptions of injury severity. We used this tool to calculate ISSs for patients in the PHC4.

STATISTICAL ANALYSIS

We calculated rates of secondary triage of trauma patients (ie, triage after initial evaluation at an NTC) using the 2×2 table we constructed to categorize adherence to ACS-COT guidelines. We calculated secondary undertriage (1 – sensitivity) as the number of patients with moderate to severe injuries admitted to an NTC divided by the total number of patients with moderate to severe injuries initially evaluated at an NTC. We calculated secondary overtriage (1 – positive predictive value) as the number of patients with minor injuries transferred divided by the total number of patients transferred from an NTC to a TC. We compared patient- and hospital-level covariables among patients admitted to NTCs and patients transferred to TCs with moderate to severe injuries using *t* test, Pearson χ^2 test, or Spearman correlation test as appropriate. We performed multilevel hierarchical modeling to adjust for the association between patient- and hospital-level variables.

SIMULATION

To estimate the shifts in patient volume and number of lives saved if the ACS-COT–recommended undertriage rate of less than 5% were achieved in the context of these patterns, we simu-

©2011 American Medical Association. All rights reserved.
Downloaded From: http://archsurg.jamanetwork.com/ on 10/30/2014

Table 1. Diagnostic Codes Used to Identify Patients With Moderate to Severe Injuries

ACS-COT Description of Life-Threatening or Critical Injury	Assumption	*ICD-9-CM* Diagnostic Codes
Injury to aorta, carotid, and vertebral vessels		900, 901
Injury to heart		861.0, 861.1
>2 Rib fractures or bilateral pulmonary contusions	>2 Rib fractures, flail chest, or pulmonary contusions	807.03-807.09, 807.4, 861.20-861.22, 861.30-861.32
Injury to abdominal vasculature		902
Open fracture with loss of distal pulses	Complete or partial amputation of upper or lower extremity	887, 897
Open skull fracture		800.5-800.9, 801.5-801.9, 804.5-804.9
GCS score <14	Cerebral laceration with moderate to severe loss of consciousness	851.03-851.05, 851.13-851.15, 851.23-851.25, 851.33-851.35, 851.43-851.45, 851.53-851.55, 851.63-851.65, 851.73-851.75, 851.83-851.85, 851.93-851.95
	Subarachnoid, subdural, or epidural hemorrhage with moderate to severe loss of consciousness	852.03-852.05, 852.13-852.15, 852.23-852.25, 852.33-852.35, 852.43-852.45, 852.53-852.55
	Other intracranial hemorrhage with moderate to severe loss of consciousness	853.03-853.05, 853.13-853.15
	Intracranial injury of other and unspecified nature with moderate to severe loss of consciousness	854.03-854.05, 854.13-854.15
Any vertebral column fracture	Fracture of vertebral column	805, 806
Open fracture of long bone	Open fracture of humerus, radius or ulna, femur, tibia, fibula	812.1, 812.3, 812.5, 813.1, 813.3, 813.5, 813.8, 820.1, 820.3, 820.9, 821.1, 821.3, 823.1, 823.3, 823.9
Severe torso injury with comorbid disease	Injury to thoracic organs, GI tract, liver, spleen, kidney, pelvic organs, other intra-abdominal organs, unspecified intra-abdominal organs	862-869 with comorbid disease as defined by Elixhauser et al[16]
Grade IV liver laceration with >6 U of PRBCs transfused	Did not include	
Pelvic fracture with >6 U of PRBCs transfused	Did not include	

Abbreviations: ACS-COT, American College of Surgeons Committee on Trauma; GCS, Glasgow Coma Scale; GI, gastrointestinal; *ICD-9-CM*, *International Classification of Diseases, Ninth Revision, Clinical Modification*; PRBCs, packed red blood cells.

lated the transfer of 95% of moderately to severely injured patients from the NTC to a TC. Specifically, we used the empirical information regarding secondary undertriage and overtriage by NTCs to calculate the resulting number of patients with minor injuries who would also be transferred to the regional TC. We then used published estimates of mortality reduction to estimate the number needed to transfer (NNT) to save 1 life: 1.9% mortality risk reduction for patients with moderate to severe injuries treated at TCs, and 3.5% mortality risk reduction for patients with severe injuries treated at TCs.[2]

We conducted all analyses and data management with Stata version 11/IC statistical software (StataCorp LP, College Station, Texas). The University of Pittsburgh Institutional Review Board reviewed the study and approved it as exempt from the requirement of written informed consent.

RESULTS

HOSPITALS

Between April 1, 2001, and March 31, 2005, 197 acute care facilities in Pennsylvania evaluated trauma patients in their EDs. We excluded 4 facilities in hospital referral regions that extended outside the state and 17 federal or specialty hospitals. Of the remaining 176 hospitals, 24 were adult TCs and 152 were NTCs.

PATIENTS

A total of 221 726 patients were admitted to these 176 hospitals. We excluded 61 250 patients (28%) evaluated initially in a TC, 63 340 patients (28%) whose injury complex did not meet our inclusion criteria, and 3256 patients (2%) initially evaluated at an NTC who did not meet our inclusion criteria. Of the remaining cohort, 22 177 patients (24%) had a moderate to severe injury and 71 703 patients (76%) had a minor injury.

TRIAGE RATES

Secondary undertriage occurred for 69% of patients with moderate to severe injuries initially evaluated at NTCs. Secondary overtriage occurred for 53% of patients transferred to TCs (**Figure 1**).

In univariate analyses, hospitals more likely to transfer moderately to severely injured patients had fewer beds ($P<.001$), had fewer average admissions ($P<.001$), were less likely to have residents ($P<.001$), were less likely to belong to a health care system with a TC ($P<.001$), and were more likely to have lower treatment intensity ($P<.001$).

©2011 American Medical Association. All rights reserved.
Downloaded From: http://archsurg.jamanetwork.com/ on 10/30/2014

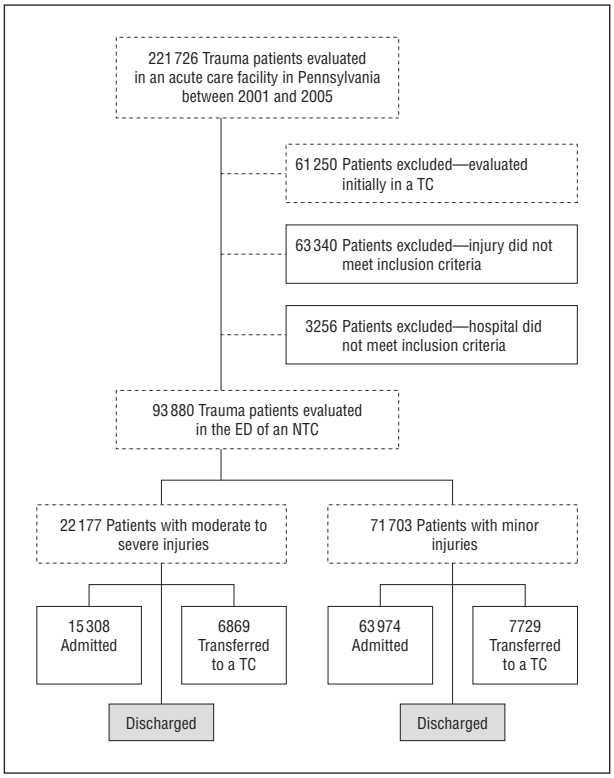

Figure 1. Disposition of trauma patients evaluated at an acute care facility in Pennsylvania between April 1, 2001, and March 31, 2005. The Pennsylvania Health Care Cost Containment Council and the Pennsylvania Trauma Systems Foundation did not include information on patients discharged home from the emergency department (ED) (dark gray boxes), making our estimates of the total numbers of patients (dashed boxes) inexact. TC indicates trauma center; NTC, nontrauma center.

Compared with patients with moderate to severe injuries who were undertriaged, patients who were appropriately transferred to TCs from NTCs were younger and more likely to be men. They were more likely to have either commercial insurance or no insurance, as expected for a younger population, and more likely to have been transferred during off-peak hours. They also had more comorbidities and higher ISSs. Patients with major vascular injuries, open skull fractures, and spinal cord injuries were more likely to be transferred to a regional TC. Patients with pulmonary injuries, spinal column fractures, and torso injuries were more likely to be admitted to the NTC (**Table 2**).

In multivariate hierarchical models, hospitals with more beds (odds ratio [OR] = 0.95; 95% confidence interval [CI], 0.94-0.98; $P < .001$) and a higher number of average trauma admissions per year (OR = 0.65; 95% CI, 0.55-0.76; $P < .001$) were less likely to transfer patients. Older patients (OR = 0.96; 95% CI, 0.95-0.96; $P < .001$) and women (OR = 0.73; 95% CI, 0.67-0.79; $P < .001$) were less likely to be transferred to a TC. Patients who had no insurance (OR = 1.41; 95% CI, 1.15-1.73; $P < .001$), presented at an off-peak time (OR = 1.61; 95% CI, 1.48-1.75; $P < .001$), had more comorbidities (OR = 2.45; 95% CI, 2.34-2.56; $P < .001$), and had greater injury severity (OR = 1.14; 95% CI, 1.14-1.15; $P < .001$) were more likely to be transferred to a TC.

Table 2. Characteristics of Patients With Moderate to Severe Injuries Admitted to Nontrauma Centers and Transferred to Trauma Centers

	Patients With Moderate to Severe Injuries Initially Evaluated at an NTC		
Characteristic	Admissions to NTC (n = 15 308)	Transfers to TC (n = 6869)	*P* Value
Age, mean (SEM), y	71 (0.16)	54.8 (0.27)	<.001
Female, No. (%)	8807 (58)	2469 (36)	<.001
Insurance, No. (%)			<.001
Commercial	3020 (20)	3279 (48)	
Medicare only	2959 (19)	886 (13)	
Medicare and Medicaid	849 (6)	134 (2)	
Medicare and commercial	7309 (48)	1438 (21)	
Medicaid only	883 (6)	700 (10)	
Uninsured	287 (2)	377 (5)	
Time of transfer, No. (%)			<.001
Peak	8794 (57)	2986 (44)	
Off peak	6514 (43)	3867 (56)	
Comorbidities, mean (SEM), No.	0.68 (0.01)	1.34 (0.02)	<.001
ISS, mean (SEM)	10.3 (0.05)	18.1 (0.11)	<.001
Injuries, No. (%)			
Aortic	47 (0.3)	111 (2)	<.001
Cardiac	212 (1)	71 (1)	.03
Rib fractures or pulmonary contusions	3182 (21)	1261 (18)	<.001
Great vessel injury	29 (0.2)	70 (1)	<.001
Open skull fracture	35 (0.2)	116 (2)	<.001
Open extremity fracture	25 (0.2)	19 (0.3)	.08
Spinal column fracture	8018 (52)	2644 (38)	<.001
Spinal cord injury	161 (1)	143 (2)	<.001
CNS injury	120 (1)	126 (2)	<.001
Significant torso injury with comorbid condition	1218 (8)	613 (9)	.02

Abbreviations: CNS, central nervous system; ISS, Injury Severity Score; NTC, nontrauma center; TC, trauma center.

SIMULATION

The distributions of injury severity for patients with minor and moderate to severe injuries overlap (**Figure 2**). Therefore, physician discrimination (ie, the identification of patients who do and do not require transfer) necessarily results in errors. Currently, 3650 transfers occur annually (1717 with moderate to severe injuries and 1932 with minor injuries). Using published mortality risk reduction estimates for patients with moderate to severe injuries treated at a TC,[2] we estimate that current practice saves 32 lives and that the NNT to save 1 life is 114.

Meeting the ACS-COT benchmark of 5% undertriage for patients with moderate to severe injuries would result in the transfer of 18 945 patients per year: 5267 with moderate to severe injuries and 13 678 with minor injuries. This represents a 5-fold increase in transfers; the largest TC would have to admit 4649 transfers per year instead of 896 transfers per year, and the smallest TC would have to admit 27 transfers per year instead of 5

©2011 American Medical Association. All rights reserved.
Downloaded From: http://archsurg.jamanetwork.com/ on 10/30/2014

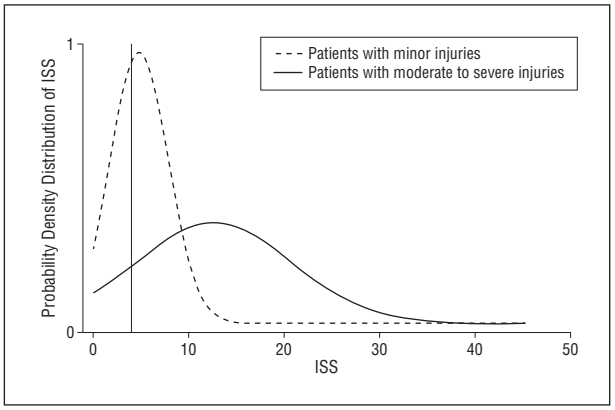

Figure 2. Probability density distribution of Injury Severity Score (ISS) for patients with minor and moderate to severe injuries who presented initially to a nontrauma center. Overlap in the probability densities of minor and moderate to severe injuries implies that physician discrimination between the 2 populations is imperfect. Achieving less than 5% undertriage would require an ISS threshold of 4 (vertical line), resulting in the transfer of 18 945 patients per year.

transfers per year. This transfer pattern, provided the volume could be absorbed, would save 99 potential lives, or 67 more than current practice. The incremental NNT would be 228 and the total NNT would be 191.

One possible strategy to improve physician discrimination would be to amend the transfer criteria. Currently, transfer criteria include an amalgam of moderate to severe injuries (AIS ≥2). If the ACS-COT mandated only the regionalization of treatment for patients with severe injuries (AIS ≥4), there would be less overlap in the severity distributions of patients who did or did not require transfer. Meeting the ACS-COT benchmark for 5% undertriage for patients with severe injuries would then result in the transfer of 2285 patients per year: 949 with severe injuries and 1336 with moderate injuries. This represents 1368 (40%) fewer transfers; the largest TC would admit 560 transfers per year and the smallest TC would admit 3 transfers per year. Of the 1717 patients currently transferred with moderate to severe injuries, 590 would remain at the NTC. These modified criteria would save 58 potential lives per year but lose 11 lives per year. Consequently, adopting modified criteria would result in 47 potential lives saved per year, or 15 more than current practice. The total NNT would be 48 (**Figure 3**).

COMMENT

In this retrospective cohort analysis of trauma patients initially evaluated at NTCs in Pennsylvania between 2001 and 2005, we demonstrated that current rates of secondary undertriage and overtriage do not begin to approach ACS-COT recommendations. In the context of current practice patterns, full implementation of ACS-COT guidelines would require a 5-fold increase in annual transfers from NTCs to TCs. Hospitals currently lack the capacity to absorb this volume, making the 67 incremental potential lives saved by implementation impossible to achieve. Changing the population targeted for an undertriage rate of less than 5% to those patients with severe injuries only increases the feasibility of achieving the target but would compromise quality and safety.

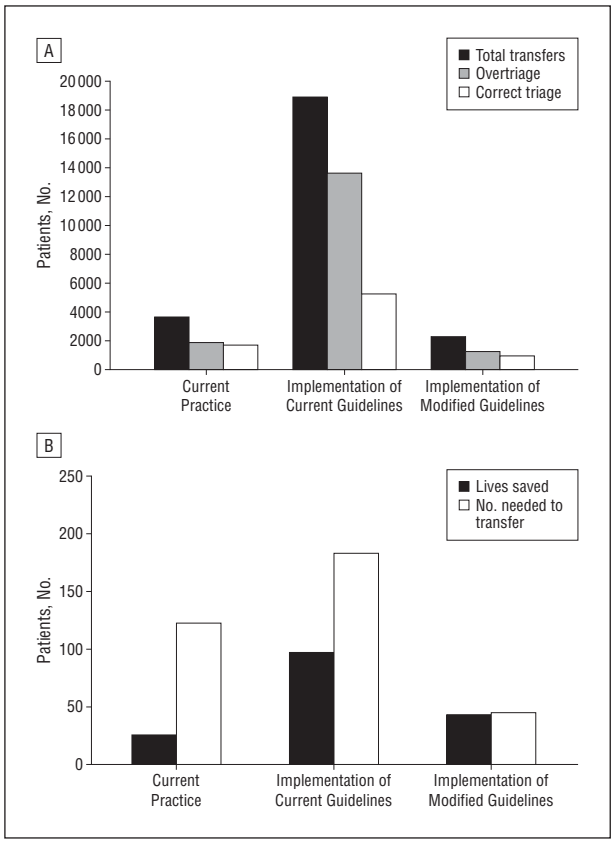

Figure 3. Comparison of patient volume shifts and lives saved under current practice patterns, implementation of current guidelines, and implementation of modified guidelines. A, Distribution of transfers from nontrauma centers to trauma centers. B, Number of lives saved (transferred patients with moderate to severe injuries divided by the reciprocal of the absolute mortality risk reduction) compared with the number needed to transfer (transferred patients divided by number of lives saved).

Previous studies have described rates of 30% overall undertriage among patients with moderate to severe injuries.[18-20] They have implicitly assumed that physicians can realistically accomplish 5% undertriage and have attributed failures to regionalize patients either to bias[20] or to unacceptable variations in care.[18,19] Our analysis of secondary triage patterns brings into question the validity of these conclusions. Primary triage decisions made in the field reflect considerations of physiological stability, injury severity, and proximity to a TC. Secondary triage decisions made in the ED of an NTC should reflect physicians' best efforts to match patient needs with institutional resources. Our finding of 70% secondary undertriage suggests that physician discrimination between patients with minor and moderate to severe injuries may play a significant role in ongoing failures to accomplish complete regionalization. Given the existing ability of physicians to discriminate among patients with minor and moderate to severe injuries under conditions of uncertainty, the appropriate transfer of 95% of the moderately to severely injured patients would require transfer of a far higher proportion of patients with minor injuries than previously supposed. Quality improvement initiatives that raise the number of transfers without reallocating resources would significantly burden TCs. Moreover, higher occupancy rates correlate with a risk

©2011 American Medical Association. All rights reserved.
Downloaded From: http://archsurg.jamanetwork.com/ on 10/30/2014

of in-hospital mortality,[21] so safely increasing the number of transfers 5-fold would require substantial changes in personnel and infrastructure.

Instead, the ACS-COT might consider new educational strategies for helping physicians to discriminate between patients with minor and moderate to severe injuries beyond Advanced Trauma Life Support, the predominant method by which the ACS-COT disseminates its guidelines. Educational techniques that modify heuristics, such as those described in the threat detection literature, might have better success at helping physicians to navigate the uncertainty of clinical diagnosis.[22] Finally, the ACS-COT could amend how it defines criteria for transfer to a TC. Management of certain injuries categorized by the ACS-COT as life threatening, such as spinal column fractures (AIS of 2), may not require the specialized services available in a TC. Limiting transfer criteria to injuries known to influence immediate and early mortality, such as a transected aorta (AIS of 4), might improve discrimination and ensure that those transferred are most likely to benefit.

Regionalization has become the paradigm for allocation of resources in critical illness, including mechanical ventilation,[23] cardiac catheterization,[24] and stroke.[25] Indeed, the Institute of Medicine uses trauma as an exemplar for these efforts.[1] The safety of changing trauma regionalization guidelines remains unclear. Current practice may not achieve optimal results; however, simply increasing the volume of transfers without effecting system changes may have unintended consequences. Alternatively, reducing the total number of transfers by making transfer criteria more stringent may result in worsened outcomes for patients remaining at NTCs. Changing triage criteria might also have safety implications other than those considered here. Our estimates include only mortality benefits and do not account for the morbidity reduction resulting from care at a high-volume center.

Our study has several limitations. First, we combine single-state administrative data with state registry information to identify triage patterns for trauma. Privacy restrictions prevented us from linking data records to confirm that we identify the same patients in both data sets. However, the degree of overlap between the 2 cohorts (99.7%) suggests that our inclusion criteria have allowed us to identify the same population of patients in both data sets. Second, we were unable to identify patients evaluated and then discharged from the ED of NTCs. However, exclusion of these patients should bias our results toward the null. Physicians who discharged patients home with moderate to severe injuries did not recognize the need to transfer these patients to a TC. Had they admitted them to an acute care facility at all, we assume they most likely would have chosen their own hospital, thereby increasing rates of undertriage. Third, we used ISS as a surrogate for the clinical cues that might inform physicians' decisions about whether a patient had a minor or moderate to severe injury. Our *ICD-9-CM* diagnostic code to ISS conversion tool attempted to mimic the calculations of trauma registrars. Their assessments are widely accepted as the best means of quantifying injury severity retrospectively. Nonetheless, ISS may not capture the degree of uncertainty experienced by physicians. Our findings of 70% undertriage suggest that ISS inflates injury severity compared with that perceived by the clinician. Patients with moderate to severe injuries may appear even more similar to patients with minor injuries than our analysis would suggest, biasing our calculations of the NNT to save additional lives toward the null.

In conclusion, our findings bring into question the feasibility of fully implementing the model of regionalization currently advocated by the ACS-COT given current practice patterns. Triaging all moderately to severely injured patients to TCs may require the transfer of so many patients with minor injuries that it would overwhelm the existing system. In the context of existing infrastructure, alternatives for feasibly achieving a regionalized trauma system require either that physicians at NTCs increase their capacity to discriminate between moderate to severe and other injuries or that ACS-COT guidelines and targets for undertriage be modified to reflect current limitations in discrimination.

Accepted for Publication: November 24, 2010.
Published Online: March 21, 2011. doi:10.1001/archsurg.2011.43
Correspondence: Deepika Mohan, MD, MPH, Department of Critical Care Medicine, University of Pittsburgh, 637 Scaife Hall, 3550 Terrace St, Pittsburgh, PA 15261 (mohand@upmc.edu).
Author Contributions: Dr Mohan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Mohan, Rosengart, Farris, Angus, and Barnato. *Acquisition of data:* Mohan. *Analysis and interpretation of data:* Mohan, Rosengart, Farris, Cohen, Angus, and Barnato. *Drafting of the manuscript:* Mohan and Barnato. *Critical revision of the manuscript for important intellectual content:* Mohan, Rosengart, Farris, Cohen, Angus, and Barnato. *Statistical analysis:* Mohan, Rosengart, Farris, Cohen, and Angus. *Obtained funding:* Mohan and Barnato. *Administrative, technical, and material support:* Barnato. *Study supervision:* Rosengart, Farris, Angus, and Barnato.
Financial Disclosure: None reported.
Funding/Support: This work was supported by grant 1KL2RR024154 from the National Center for Research Resources, a component of the National Institutes of Health and the National Institutes of Health Roadmap for Medical Research (Dr Mohan). This work was also funded in part by a seed grant from the Department of Critical Care Medicine, University of Pittsburgh.
Role of the Sponsors: The funding agencies had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; or preparation, review, or approval of the manuscript.
Disclaimer: The contents are solely the responsibility of the authors and do not necessarily represent the official view of the National Center for Research Resources or the National Institutes of Health. The Pennsylvania Health Care Cost Containment Council is an independent state agency and has provided data to this entity in an effort to further PHC4's missions of educating the public and containing health care costs in Pennsylvania. The Penn-

©2011 American Medical Association. All rights reserved.
Downloaded From: http://archsurg.jamanetwork.com/ on 10/30/2014

sylvania Health Care Cost Containment Council, its agents, and staff have made no representation, guarantee, or warranty (express or implied) that the data provided to this entity are error free or that the use of the data will avoid difference of opinion or interpretation. This analysis was not prepared by PHC4. It was prepared by the authors of this article. The Pennsylvania Health Care Cost Containment Council, its agents, and staff bear no responsibility or liability for the results of this analysis, which are solely the opinion of the authors. Data were provided by the PTSF, Mechanicsburg. The PTSF specifically disclaims responsibility for any analyses, interpretations, or conclusions.

Online-Only Material: The eAppendix, eReferences, and eFigures are available at http://www.archsurg.com.

Additional Information: Information on the National Center for Research Resources is available at http://www.ncrr.nih.gov/. Information on Reengineering the Clinical Research Enterprise can be obtained from http://commonfund.nih.gov/clinicalresearch/overview-translational.aspx.

Additional Contributions: Joyce Chang, PhD, University of Pittsburgh, provided statistical support and Nathan McWilliams, MPA, PTSF, helped in acquiring the PTSF registry data. Neither received compensation beyond their normal salaries.

REFERENCES

1. US Department of Health and Human Services. Model trauma system planning and evaluation. https://www.socialtext.net/acs-demo-wiki/index.cgi?regional_trauma_systems_optimal_elements_integration_and_assessment_systems_consultation_guide. Accessed November 21, 2010.
2. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med*. 2006;354(4):366-378.
3. Celso B, Tepas J, Langland-Orban B, et al. A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centers following the establishment of trauma systems. *J Trauma*. 2006;60(2):371-378.
4. Demetriades D, Martin M, Salim A, Rhee P, Brown C, Chan L. The effect of trauma center designation and trauma volume on outcome in specific severe injuries. *Ann Surg*. 2005;242(4):512-51519.
5. Mann NC. Assessing the effectiveness and optimal structure of trauma systems: a consensus among experts. *J Trauma*. 1999;47(3)(suppl):S69-S74.
6. Mullins RJ, Mann NC. Population-based research assessing the effectiveness of trauma systems. *J Trauma*. 1999;47(3)(suppl):S59-S66.
7. Mackenzie EJ, Rivara FP, Jurkovich GJ, et al. The impact of trauma-center care on functional outcomes following major lower-limb trauma. *J Bone Joint Surg Am*. 2008;90(1):101-109.
8. Committee on Trauma, American College of Surgeons. *Resources for Optimal Care of the Injured Patient 2006*. Chicago, IL: American College of Surgeons; 2006.
9. US Census Bureau. State and county quickfacts. http://quickfacts.census.gov/qfd/states/42000.html. Accessed July 1, 2010.
10. Pennsylvania Trauma Systems Foundation. Trauma center accreditation status October 2000. http://www.ptsf.org. Accessed May 14, 2010.
11. Pennsylvania Trauma Systems Foundation. Trauma center accreditation status October 2001. http://www.ptsf.org. Accessed May 14, 2010.
12. Pennsylvania Trauma Systems Foundation. Trauma center accreditation status October 2002. http://www.ptsf.org. Accessed May 14, 2010.
13. Pennsylvania Trauma Systems Foundation. Trauma center accreditation status October 2003. http://www.ptsf.org. Accessed May 14, 2010.
14. Pennsylvania Trauma Systems Foundation. Trauma center accreditation status October 2004. http://www.ptsf.org. Accessed May 14, 2010.
15. Barnato AE, Farrell MH, Chang CC, Lave JR, Roberts MS, Angus DC. Development and validation of hospital "end-of-life" treatment intensity measures. *Med Care*. 2009;47(10):1098-1105.
16. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998;36(1):8-27.
17. MacKenzie EJ, Steinwachs DM, Shankar B. Classifying trauma severity based on hospital discharge diagnoses: validation of an ICD-9CM to AIS-85 conversion table. *Med Care*. 1989;27(4):412-422.
18. Macias CA, Rosengart MR, Puyana JC, et al. The effects of trauma center care, admission volume, and surgical volume on paralysis after traumatic spinal cord injury. *Ann Surg*. 2009;249(1):10-17.
19. Nathens AB, Jurkovich GJ, MacKenzie EJ, Rivara FP. A resource-based assessment of trauma care in the United States. *J Trauma*. 2004;56(1):173-178.
20. Schilling PL, Campbell DA Jr, Englesbe MJ, Davis MM. A comparison of in-hospital mortality risk conferred by high hospital occupancy, differences in nurse staffing levels, weekend admission, and seasonal influenza. *Med Care*. 2010;48(3):224-232.
21. Chang DC, Bass RR, Cornwell EE, Mackenzie EJ. Undertriage of elderly trauma patients to state-designated trauma centers. *Arch Surg*. 2008;143(8):776-782.
22. Wolfe JM, Horowitz TS, Van Wert MJ, Kenner NM, Place SS, Kibbi N. Low target prevalence is a stubborn source of errors in visual search tasks. *J Exp Psychol Gen*. 2007;136(4):623-638.
23. Kahn JM, Linde-Zwirble WT, Wunsch H, et al. Potential value of regionalized intensive care for mechanically ventilated medical patients. *Am J Respir Crit Care Med*. 2008;177(3):285-291.
24. Le May MR, So DY, Dionne R, et al. A citywide protocol for primary PCI in ST-segment elevation myocardial infarction. *N Engl J Med*. 2008;358(3):231-240.
25. Gropen T, Magdon-Ismail Z, Day D, Melluzzo S, Schwamm LH; NECC Advisory Group. Regional implementation of the stroke systems of care model: recommendations of the northeast cerebrovascular consortium. *Stroke*. 2009;40(5):1793-1802.

INVITED CRITIQUE

ONLINE FIRST

Inclusive Trauma Systems Must Embody Appropriate Triage Guidelines

The premise that the American College of Surgeons' advocacy for the development of trauma systems may not be feasible is both provocative and, I would argue, possibly self-defeating. However, feasibility is realized only when issues such as those raised here are addressed and there is the surgical leadership and political will to create such a system.

Such trauma systems must be inclusive, meaning that the resources of all committed facilities are used. Only the most seriously injured patients require the resources of level I and II TCs.

Mohan and colleagues are to be commended for addressing the fundamental triage issue that is relevant to the development of any trauma system and the regionalization of trauma care and for demonstrating the need for more intuitive and accurate triage instruments.

Inclusive trauma systems take on importance in that the trauma model, including triage guidelines, is an in-

©2011 American Medical Association. All rights reserved.
Downloaded From: http://archsurg.jamanetwork.com/ on 10/30/2014