Hospital-based trauma quality improvement initiatives: First step toward improving trauma outcomes in the developing world

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BACKGROUND: Injuries remain a leading cause of death in the developing world. Whereas new investments are welcome, quality improvement (QI) at the currently available trauma care facilities is essential. The objective of this study was to determine the effect and long-term sustainability of trauma QI initiatives on in-hospital mortality and complications at a large tertiary hospital in a developing country.

METHODS: In 2002, a specialized trauma team was formed (members trained using advanced trauma life support), and a western style trauma program established including a registry and quality assurance program. Patients from 1998 onward were entered in to this registry, enabling a preimplementation and postimplementation study. Adults (>15 years) with blunt or penetrating trauma were analyzed. The main outcomes of interest were (1) in-hospital mortality and (2) occurrence of any complication. Multiple logistic regression was performed to assess the impact of formalized trauma care on outcomes, controlling for covariates reaching significance in the bivariate analyses.

RESULTS: A total of 1,227 patient records were analyzed. Patient demographics and injury characteristics are described in Table 1. Overall in-hospital mortality rate was 6.4%, and the complication rate was 11.1%. On multivariate analysis, patients admitted during the trauma service years were 4.9 times less likely to die (95% confidence interval, 1.77–13.57) and 2.60 times (odds ratio; 95% confidence interval, 1.29–5.21) less likely to have a complication compared with those treated in the pretrauma service years.

CONCLUSION: Despite significant delays in hospital transit and lack of prehospital trauma care, hospital level implementation of trauma QI program greatly decreases mortality and complication rates in the developing world. (*J Trauma Acute Care Surg*. 2013;75: 60–68. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Care management study, level IV.

KEY WORDS: Trauma; quality improvement; developing world.

Trauma is a growing global public health concern; with nearly 6 million deaths each year, the World Health Organization estimates that injuries account for one sixth of the global adult disease burden. A disproportionate, 90% of all trauma deaths occur in lower middle–income countries (LMICs), where resources to deal with this crisis are limited.[1] According to a recent estimate, approximately 2 million lives could be saved each year if these countries were to have the same level of trauma care as the developed world.[2]

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One of the methods to decrease the burden of mortality from trauma in developed countries has been the implementation of trauma quality improvement (TQI) programs. DiRusso et al.[3] reported a reduction in trauma mortality from 44% to 27% for severely injured patients following hospital-based TQI implementation. Similarly, McDermott et al.[4] demonstrated a 22% reduction in preventable or potentially preventable deaths following the introduction of citywide TQI measures. A recent systematic review concluded that TQI programs "have been consistently shown to improve the process of care, decrease mortality, and decrease costs."[5] One of the criteria for the American College of Surgeons trauma center verification is the presence of a QI program.[6,7]

Almost all literature regarding TQI initiatives comes from high-income countries where ensuring sustained delivery of high-quality trauma care through QI efforts has now become the standard.[8,9] There is very little evidence suggesting improved patient outcomes following TQI program implementation in LMICs. A review of trauma care systems in 100 facilities from four LMICs (Ghana, India, Mexico, and Vietnam) found TQI measures to be virtually nonexistent.[10] Empirical evidence from successful TQI programs in the developed world as well as from nontrauma QI efforts in the LMICs (such as an obstetrical QI program) seems to suggest that similar

programs might improve trauma care globally.[11] However, more direct evidence to support widespread TQI implementation in resource-strained environments is urgently warranted. The objective of the present study was to determine the clinical efficacy and long-term durability of a hospital-based TQI program in a LMIC. We hypothesized that such a program would lead to a reduction in in-hospital morbidity and mortality among trauma patients.

PATIENTS AND METHODS

Data Source and Study Population

The study population includes patients entered into the Aga Khan University Hospital Trauma Database (AKUH-TD) between the years 1998 and 2010. This hospital database collects information on trauma patients satisfying the institution's trauma call activation criteria (Supplemental Figure 1, http://links.lww.com/TA/A287),[12] which is similar to the criteria used in the developed world.[13,14] Patients older than 15 years with blunt or penetrating injuries were included. Those who were dead on arrival or sustained burn injuries were excluded.

AKUH is located in Karachi, Pakistan's providing services to 50,000 inpatients and 600,000 outpatients annually.[15,16] It serves as a primary and referral trauma center, equipped with trauma resuscitation room, diagnostic radiology, dedicated emergency operating room, and a multidisciplinary trauma team.[17] Although the city has a substantial trauma burden, most injured patients receive little or no prehospital care or any prearrival notification in cases of interfacility transfers.

In this study, we divided patients entered into the AKUH-TD into two groups; pre-TQI implementation group (years 1998–2001) and post-TQI implementation group (years 2002–2010). Our main outcome variables were occurrence of in-hospital complication and mortality. A complication was defined as the development of any one of the following during the course of the hospital stay: acute renal failure, cardiac arrest, myocardial infarction, coagulopathy, pulmonary embolism, wound infection, urinary tract infection, pneumonia, abdominal abscess, any other abscess, and sepsis. Mortality

1. Organizational improvements

- Establishment of a multidisciplinary trauma team.
- Training of residents and faculty using adapted American College of Surgeons (ACS) Advanced Trauma Life Support (ATLS) protocols.
- Mandatory resident rotations with the trauma service.
- Establishment of the AKUH Trauma Database (AKUH-TD) as part of a trauma outcomes feedback program.

2. Improvements in patient care

- Establishment of an Emergency Room trauma rush call generation protocol.
- 24-hour availibility of dedicated trauma resuscitation and operating rooms.
- 24-hours availibility of computed tomography scanning.
- Performance of Selective Non-Operative Management (SNOM) with support from Interventional Radiology to perform angio-embolization.
- Availibility of modern intraoperative surgical devices e.g. harmonic scalpels, bowel staplers, vessel fusion devices.
- Performance of Damage Control Surgery with support from the Anesthesiology and Intensive Care.
- Use of the low-cost "poor-man's VAC" for vacuum-assisted abdominal closure in the critically ill.
- Collaboration with Hematology to setup a massive blood transfusion protocol.
- Improved post-operative care with dedicated trauma care nurses.

3. Clinical Trauma Fellowship

- A 2 year post-residency program designed to give extensive exposure to trauma surgery and surgical critical care.

4. Resident-centered trauma education

- Trauma care included as core curriculum topic for residents.
- Initiation of Primary Trauma Care and adapted ATLS courses.
- Initiation of adapted Advanced Trauma Operative Management (ATOM) courses for residents .
- Weekly trauma grand rounds and trauma morbitiy and mortality meetings.
- Trauma journal clubs to keep uptodate with current trauma literature.
- Trauma presentations at the Surgical Grand Rounds.
- Regular attendance and presentations at the online International Trauma Grand Rounds hosted by Baylor College of Medicine, Houston, TX.

5. Trauma Outcomes Research

- Establishment of a trauma quality improvement evaluations program in collaboration with the Johns Hopkins Hospital (JHH), Baltimore, MD
- Initiation of the AKUH-JHH Trauma Outcomes Research Fellowship

6. Experiential learning through active participation in mass casualty incidents

- Anticipation, organization, triage and management of violent, intentionally injured.
- Active on-site disaster relief activities following natural calamities e.g. earthquakes

Figure 1. Structured TQI initiatives undertaken at the AKUH starting in the year 2002.

TABLE 1. Comparison of Baseline Patient Demographics and Injury Severity Characteristics Between Pre-TQI Years (1998–2001) and Post-TQI Years (2002–2010)

Variables	Pre-TQI (1998–2001) n = 421 n (%)	Post-TQI (2002–2010) n = 806 n (%)	*p*
Age			
16–25	142 (33.7)	238 (29.5)	0.13
26–35	125 (29.7)	245 (30.4)	0.79
36–45	68 (16.2)	156 (19.4)	0.17
46–55	54 (12.8)	94 (11.7)	0.56
56–65	18 (4.3)	41 (5.1)	0.53
66–75	13 (3.1)	20 (2.5)	0.53
≥76	1 (0.2)	11 (1.4)	0.07
Missing	0 (0.0)	1 (0.1)	—
Sex			
Male	356 (84.6)	698 (86.6)	0.33
Female	65 (15.4)	108 (13.4)	
Mechanism of injury			
Motor vehicle collision	277 (65.8)	473 (58.7)	<0.01
Firearm	88 (20.9)	136 (16.9)	0.09
Blast	4 (1.0)	73 (9.1)	<0.01
Others	22 (5.2)	52 (6.5)	0.38
Fall	20 (4.8)	45 (5.6)	0.52
Stab	10 (2.4)	22 (2.7)	0.70
Missing	0 (0.0)	5 (0.6)	—
Type of injury			
Blunt	317 (75.3)	509 (63.2)	<0.01
Penetrating	104 (24.7)	296 (36.7)	
Missing	0 (0.0)	1 (0.1)	—
Intent of injury			
Unintentional	325 (77.2)	560 (69.5)	<0.01
Intentional	93 (22.1)	227 (28.2)	0.02
Missing	3 (0.7)	19 (2.4)	0.04
Transferred from another facility			
Yes	66 (15.7)	341 (42.3)	<0.01
No	212 (50.4)	301 (37.3)	<0.01
Missing	143 (34.0)	164 (20.4)	<0.01
Transport			
Ambulance	23 (5.5)	513 (63.7)	<0.01
Private vehicle/walk in	101 (24.0)	143 (17.7)	<0.01
Others	5 (1.2)	3 (0.4)	0.13
Missing	292 (69.4)	147 (18.2)	<0.01
Time from injury to presentation			
<1 h	144 (34.2)	197 (24.4)	<0.01
1–6 h	172 (40.9)	395 (49.0)	<0.01
>6 h	84 (20.0)	162 (20.1)	0.95
Missing	21 (5.0)	52 (6.5)	0.30
Hypotensive			
Yes	28 (6.7)	42 (5.2)	0.30
No	388 (92.2)	759 (94.2)	0.18
Missing	5 (1.2)	5 (0.6)	0.33
GCS score			
3–8	164 (39.0)	33 (4.1)	<0.01
9–12	30 (7.1)	20 (2.5)	<0.01
13–15	227 (53.9)	753 (93.4)	<0.01
RTS			
0–3.9	27 (6.4)	20 (2.5)	<0.01
4–6.9	179 (42.5)	57 (7.1)	<0.01
7–7.8	215 (51.1)	728 (90.3)	<0.01
Missing	0 (0.0)	1 (0.1)	—
ISS			
0–8	111 (26.4)	338 (41.9)	<0.01
9–15	87 (20.7)	123 (15.3)	0.02
16–24	64 (15.2)	68 (8.4)	<0.01
25–75	158 (37.5)	257 (31.9)	0.05
Missing	1 (0.2)	20 (2.5)	<0.01
Injuries by body region			
Head and neck	209 (49.6)	230 (28.5)	<0.01
Thorax	101 (24.0)	214 (26.6)	0.33
Abdomen	72 (17.1)	202 (25.1)	<0.01
Need for operative intervention			
Yes	65 (15.4)	405 (50.3)	<0.01
No	356 (84.6)	401 (49.8)	
Admission to the ICU			
Yes	86 (20.4)	231 (28.7)	<0.01
No	280 (66.5)	442 (54.8)	<0.01
Missing	55 (13.1)	133 (16.5)	0.11
Need for ventilator support			
Yes	40 (9.5)	121 (15.0)	<0.01
No	371 (88.1)	679 (84.2)	0.07
Missing	10 (2.4)	6 (0.7)	0.03

was defined as death during the index hospitalization. Patient demographics included age and sex. Prehospital characteristics included transfer status, mode of transport, and time from injury to presentation (<1 hour, 1–6 hours, >6 hours). Injury characteristics included work-related injury, mechanism of injury, type of injury, intent of injury, presence of shock at admission (initial systolic blood pressure < 90 mm Hg), Glasgow Coma Scale (GCS) score (3–8, 9–12, 13–15), Revised Trauma Score (RTS) (0.0–3.9, 4.0–6.9, 7.0–7.8), Injury Severity Score (ISS) (0–8, 9–15, 16–24, 25–75), and the presence of injuries by body region. Process of care measures included need for operative intervention, admission to the intensive care unit (ICU) and need for ventilator support.

TQI initiatives

Starting in the year 2002, a number of structured TQI initiatives (Fig. 1) were undertaken as follows.

Organizational Improvements

Two crucial organizational measures were instituted. The first step was development of a multidisciplinary trauma team centered around a dedicated surgeon. Staff from anesthesiology, emergency medicine, and surgical subspecialties

(general, orthopedic, and neurosurgery) were trained in western style trauma care using adapted advanced trauma life support protocols. This mandatory 2-day course was held as adjunct to the previously instituted basic life support and advanced cardiac life support training.[12] In addition, residents from the aforementioned specialties were required to rotate with trauma team.

Second, to provide critical performance evaluations, a trauma outcomes feedback program was established. A prospective trauma database (AKUH-TD) was formulated in the year 2002 with the goal of understanding indigenous trauma perspectives and assessing in-hospital trauma morbidity and mortality. It contains important patient demographics, injury severity (e.g., ISS, RTS, GCS) and processes of care variables (e.g., admission to the ICU) that have widely been used to benchmark western trauma centers.[17,18] To measure the baseline quality of trauma care, 4 years of retrospective data (for the years 1998–2001) were included in this database using medical chart review.

Improvements in Patient Care

To streamline emergency department trauma triage and management, a trauma rush call activation protocol was devised (Supplemental Figure 1, http://links.lww.com/TA/A287). Around-the-clock availability of trauma resuscitation and operating rooms was ensured. Further improvements included 24-hour availability of a computed tomography scanning, focused ultrasonography for abdominal trauma and use of several modern intraoperative surgical devices, for example, harmonic scalpels, bowel staplers, and enhanced postoperative care via dedicated trauma care nurses.

In addition, three extremely important technical advances were initiated. First, a massive blood transfusion protocol was established. Second, damage-control surgery was made possible for the critically injured with support of intensive care. Third, with the availability of angioembolization, a selective nonoperative management was initiated to manage blunt solid visceral injuries.

Clinical Trauma Fellowship

A 2-year postresidency trauma fellowship program was started in 2006. This is one of the first formal trauma fellowship programs in Pakistan and is designed to give extensive exposure to trauma surgery.

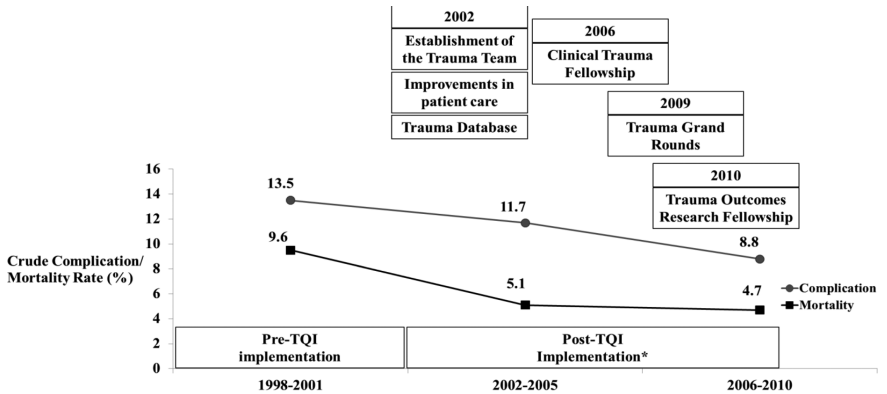
Resident-Centered Trauma Education

Resident curriculum was modified to include a combination of skills-based learning and didactics. Residents were trained in trauma care using adapted advanced trauma life support protocols. This course is now being conducted by the College of Physicians and Surgeons of Pakistan and is available to residents of all teaching hospitals. In addition, courses similar to the advanced trauma operative management were initiated in collaboration with the government run Civil Hospital Karachi featuring cadaveric dissection and simulations laboratories to enhance operative skills.

A number of forums were established to engage residents in academic discussions including a regular trauma journal club, weekly trauma grand rounds, as well as morbidity and mortality meetings. Recently, AKUH joined the online International Trauma Grand Rounds, initiated and hosted by Baylor College of Medicine. This unique forum provides a truly global perspective on trauma care with contributions from centers in the developing world (Pakistan, Iraq, Ecuador, and Columbia) as well as established Level 1 trauma centers from the United States (Baylor College of Medicine, Houston, Texas, and Broward General Medical Center, Fort Lauderdale, Florida).

Trauma Outcomes Research

As part of the TQI evaluations, a trauma outcomes research program was envisioned to train dedicated trauma outcomes research fellows in modern trauma epidemiology, benchmarking, and quality evaluations, who could use indigenous data to undertake performance assessments. In 2010, a program was set-up in collaboration with Johns Hopkins Center for Surgical Trials and Outcomes Research in Baltimore, Maryland. Three fellows have gone through this program, and active transfer of knowledge and program monitoring continues throughout the year via biweekly AKUH-JHH Trauma Outcomes Research Group meetings held through video conferencing.



*Crude complication and mortality rate for aggregate post-TQI years (2002-2010) was 9.8% and 4.9% respectively.

Figure 2. Crude complication and mortality rate for pre-TQI and post-TQI implementation years. *Crude complication and mortality rate for aggregate post-TQI years (2002–2010) was 9.8% and 4.9%, respectively.

Experiential Learning Through Active Participation in Mass Casualty Incidents

Since 2002, AKUH trauma team has actively participated in multiple disaster relief efforts. This has included in-hospital anticipation, organization, triage, and management of injury victims as well as in-field medical relief camps following devastating natural calamities such as the 2005 earthquake and the 2010 floods in northern Pakistan.[19] This experiential learning has proven to be invaluable in providing a rapid, efficient, and sustained response in times of need.

Data Analysis

We assessed pre-TQI and post-TQI performance in terms of adjusted odds of complications and mortality using multivariate logistic regression with pre-TQI years as the reference group. Factors significantly associated with complications and mortality on univariate analyses (with $p < 0.1$) as well as clinically relevant variables (age, sex, type of injury, time from injury to presentation), chosen a priori, were included in this multivariate model.[20] For physiologic injury risk adjustment in the final multivariate models, GCS score and presence of

TABLE 2. Univariate Analysis: Factors Associated With Complications and Mortality Among All Trauma Patients Admitted During the Years 1998–2010

	Complications	Mortality
	OR (95% CI)	OR (95% CI)
Post-TQI years (2002–2010) (reference, pre-TQI [1998–2001])	0.69 (0.48–0.99)**	0.49 (0.31–0.77)**
Age > 65 y (reference, 16–65 y)	1.00 (0.39–2.58)	2.89 (1.24–6.71)**
Male sex (reference, female sex)	1.62 (0.90–2.95)	1.02 (0.53–1.97)
Mechanism of injury (reference, motor vehicle collision)		
Stab	0.77 (0.18–3.29)	—
Fall	1.85 (0.87–3.92)	2.40 (1.08–5.40)**
Firearm	2.89 (1.90–4.40)**	1.69 (0.97–2.94)
Blast	1.72 (0.84–3.51)	1.95 (0.88–4.32)
Others	1.59 (0.76–3.36)	—
Penetrating injury (reference, blunt injury)	1.99 (1.39–2.86)**	1.30 (0.81–2.09)
Intentional injury (reference, unintentional injury)	2.19 (1.52–3.18)**	1.53 (0.94–2.49)*
Transferred from another facility (reference, nontransfers)	1.74 (1.12–2.70)**	1.10 (0.63–1.91)
Transport (reference, ambulance)		
Private vehicle/walk-in	1.13 (0.70–1.83)	0.85 (0.42–1.68)
Others	2.91 (0.57–14.80)	2.32 (0.28–19.48)
Time from injury to presentation (reference, <1 h)		
1–6 h	1.61 (0.99–2.61)*	1.15 (0.64–2.07)
>6 h	2.38 (1.40–4.05)**	1.51 (0.78–2.95)
Hypotensive (reference, systolic blood pressure > 90 mm Hg)	5.34 (3.15–9.06)**	10.65 (6.00–18.91)**
GCS (reference, 3–8)		
9–12	1.51 (0.78–2.96)	0.92 (0.42–1.98)
13–15	0.22 (0.15–0.33)	0.10 (0.06–0.18)**
RTS (reference, 0–3.9)		
4–6.9	0.56 (0.29–1.09)*	0.16 (0.08–0.32)**
7–7.8	0.12 (0.06–0.24)**	0.02 (0.01–0.04)**
ISS (reference, 0–8)		
9–15	2.85 (1.44–5.62)**	5.84 (2.05–16.60)**
16–24	6.64 (3.44–12.82)**	20.56 (7.69–54.96)**
25–75	5.58 (3.19–9.78)**	8.15 (3.16–21.01)**
Injuries by body region†		
Head and neck	1.14 (1.03–2.13)**	2.51 (1.58–3.98)**
Thorax	1.68 (1.15–2.46)**	2.11 (1.32–3.37)**
Abdomen	2.34 (1.60–3.40)**	2.16 (1.34–3.49)**
Need for operative intervention	2.84 (1.98–4.11)**	1.71 (1.08–2.70)**
Admission to the ICU	7.25 (4.82–10.89)**	6.58 (3.89–11.13)**
Need for ventilator support	5.39 (3.61–8.05)**	12.76 (7.81–20.84)**
Complications	—	21.09 (12.7–35.03)**

*$p < 0.1$.
**$p < 0.05$.
†With no injury as the reference group for each injury by body region.
Clinically relevant variables (age, sex, type of injury, time from injury to presentation), chosen a priori, and those with $p < 0.1$ on univariate analyses were included in the multivariate analyses.

TABLE 3. Multivariate Analyses: Independent Factors Associated With Complications and Mortality Comparing Pre-TQI Years (1998–2001) to Post-TQI Years (2002–2010)

	Complications	Mortality
	OR (95% CI)	OR (95% CI)
Post-TQI years (2002–2010) (reference, pre-TQI [1998–2001])	0.38 (0.19–0.77)*	0.20 (0.07–0.57)*
Age > 65 y (reference, 16–65 y)	0.24 (0.04–1.53)	9.34 (1.80–48.38)*
Male sex (reference, female sex)	1.34 (0.58–3.12)	0.63 (0.21–1.85)
Time from injury to presentation (reference, <1 h)		
1–6 h	1.35 (0.72–2.56)	0.64 (0.26–1.59)
>6 h	1.72 (0.86–3.44)	0.80 (0.29–2.18)
Intentional injury (reference, unintentional injury)	1.31 (0.55–3.15)	1.70 (0.48–5.94)
Penetrating injury (reference, blunt injury)	1.27 (0.52–3.11)	0.70 (0.19–2.55)
Hypotensive (reference, systolic blood pressure > 90 mm Hg)	1.25 (0.56–2.83)	5.26 (2.09–13.23)*
GCS (reference, 3–8)		
9–12	1.20 (0.48–3.01)	0.86 (0.27–2.70)
13–15	0.40 (0.20–0.79)*	0.30 (0.12–0.76)*
ISS (reference, 0–8)		
9–15	1.63 (0.63–4.22)	1.37 (0.31–6.06)
16–24	1.58 (0.59–4.21)	2.90 (0.70–12.01)
25–75	3.01 (1.35–6.71)*	1.03 (0.27–3.90)
Injuries by body region		
Head	0.84 (0.44–1.57)	1.06 (0.41–2.73)
Thorax	1.06 (0.62–1.81)	1.32 (0.61–2.86)
Abdomen	1.04 (0.57–1.89)	1.50 (0.61–3.65)
Need for operative intervention	2.76 (1.46–5.23)*	3.49 (1.36–8.97)*
Admission to the ICU	3.97 (2.23–7.08)*	2.73 (1.16–6.40)*
Need for ventilator support	2.32 (1.24–4.36)*	5.94 (2.57–13.69)*
Presence of any complication	—	7.61 (3.52–16.44)*

*$p < 0.05$.

hypotension were included as separate variables rather than the RTS because the former demonstrated a higher discriminative ability when predicting a complication or mortality (assessed using area under the receiver operating characteristics curve). The final multivariate logistic regression model for complication as an outcome included age, sex, time from injury to presentation, intent of injury, type of injury, presence of hypotension, GCS, ISS, injuries by body region (head and neck, thorax and abdomen), need for operative intervention, admission to the ICU, and the need for ventilator support. The final model for mortality additionally adjusted for the presence of any complication. The adjusted odds ratio (OR) for complication and mortality was recorded following this risk adjustment. To determine the long-term durability of the program, patients admitted during the post-TQI years were split into first 4 years (2002–2005) and subsequent 5 years (2006–2010). Adjusted odds for both mortality and complications were then calculated, controlling for the covariates mentioned previously for each post-TQI year group with pre-TQI years as the reference. All analyses were performed using Stata/IC version 12 (Stata, College Station, TX). Significance was set at $p < 0.05$ throughout, unless specified otherwise.

RESULTS

A total of 1,227 patient records were analyzed. Table 1 describes the comparison of baseline patient demographic and injury severity characteristics of patients treated in the pre-TQI years versus those treated in the post-TQI years. For the pre-TQI implementation years, the unadjusted complication rate was 13.5% versus 9.8% for postimplementation years ($p < 0.05$). Similarly the unadjusted mortality rate was almost half compared with preimplementation (9.6% vs. 4.9%, $p < 0.05$). Figure 2 demonstrates the maintenance of this downward trend through the first four and subsequent five post-TQI implementation years. On univariate analyses, several factors predicted increased odds of complications including

TABLE 4. Multivariate Analyses: Long-Term Durability of the TQI Program Comparing Pre-TQI Years (1998–2001) to Two Post-TQI Year Groups (2002–2005 and 2006–2010)

		Complications*	Mortality**
		OR (95% CI)	OR (95% CI)
Pre-TQI	1998–2001	1	1
Post-TQI	2002–2005	0.45 (0.20–1.02)	0.13 (0.03–0.48)
	2006–2010	0.35 (0.16–0.74)	0.28 (0.08–0.85)

*Model adjusted for age, sex, time from injury to presentation, intent of injury, type of injury, presence of hypotension, GCS score, ISS, Abbreviated Injury Scale (AIS) score by body region (head, thorax, and abdomen), need for operative intervention, admission to the ICU, need for ventilator support, and in-hospital mortality, **Model additionally adjusted for presence of any complication.

mechanism of injury, physiologic injury severity, transfer delays, and site of injury along with the need for operative intervention, admission to the ICU, and need for ventilator support (Table 2). Factors predicting increased odds of mortality included age; injuries from fall; presence of hypotension; low GCS score; low RTS; high ISS; head and neck, thoracic and abdominal injuries; need for operative intervention; admission to the ICU; need for ventilator support; and presence of any complication.

Table 3 demonstrates that the adjusted odds of complications (OR, 0.38; 95% confidence interval [CI], 0.19–0.77) and mortality (OR, 0.20; 95% CI, 0.07–0.57) both decreased significantly after the implementation of the TQI program. Independent factors associated with the development of a complication included lower GCS score, higher ISS, need for operative intervention, admission to the ICU, and need for ventilator support. Factors that were found to be associated with mortality included age greater than 65 years, presence of hypotension, lower GCS score, need for operative intervention, admission to the ICU, need for ventilator support, and presence of any complication.

Table 4 explores the long-term durability of QI measures. The adjusted odds of both complication and mortality declined for the first 4 years (2002–2005) after the implementation of the program and remained low for the next 5 years (2006–2010) compared with the pre-TQI years.

DISCUSSION

This analysis of more than 1,200 patients demonstrates the successful implementation and maintenance of an almost decade-long hospital-based TQI program in the developing world. Patients admitted after TQI implementation were nearly 5 times less likely to die and 2.6 times less likely to have a complication after adjusting for potential confounders. The reduction in adverse outcomes seen in the first 4 years after program implementation was maintained in the subsequent 5 years, suggesting that not only were the QI measures effective but also were durable. Given that many "outside-the-hospital" issues such as poverty, political instability, violence, and even prehospital care are unfortunately out of the hands of trauma surgeons and hospital administrators, sustained and dedicated hospital-based TQI initiatives may well be the first step toward improving trauma outcomes in the developing world.

High-income countries have successfully demonstrated that hospital-based TQI programs save lives, decrease complications, improve processes of care measures, and are cost-effective.[5,21–23] DiRusso et al.[3] demonstrated cost savings of more than $4,000 per patient after a TQI intervention with net savings of more than 10:1 against investments. Similarly, Ruchholtz et al.[24] reported a reduction in time to diagnostic/therapeutic interventions and in overall mortality from 17% to 10%. A UK study reported a decrease in mortality from 40% to 35% in blunt trauma patients with ISS greater than 15 after TQI initiation.[25] Further studies demonstrate that even simple measures such as proper patient care documentation improve quality of trauma care.[26–28]

Few studies have been conducted to directly evaluate the performance and feasibility of such programs in LMICs. In a recent systematic review by the World Health Organization–IATSIC, only 2 of 36 articles evaluating TQI initiatives were from the developing world, both from the same institution in Thailand reporting improvements in trauma mortality after program implementation.[5,29,30] Studies have focused on resuscitation training in developing countries,[30,31] but few evaluate hospital-based TQI.

A number of factors contributed toward the success of TQI measures at our center. Foremost was a pivotal shift in hospital policy to support an integrated TQI program. Before its initiation, trauma patients were managed by individual surgical subspecialties with little cross-talk between them. The TQI program brought together all surgical subspecialties as well as emergency medicine, anesthesiology, and radiology in an attempt to make trauma care a robust, interdisciplinary undertaking. Second, we used a tailored, multifaceted approach in designing our TQI program with simultaneous focus on trauma education (training of residents and fellows), patient care (dedicated trauma diagnostic/therapeutic services including initiating damage-control surgery and massive blood transfusion protocol for the critically injured, low-cost solutions such as an improvised VAC device), and experiential disaster management exposure. Third, we placed great emphasis on establishing a strong trauma outcomes research program in collaboration with leading experts on injury prevention and management research. The resultant transfer of knowledge regarding trauma epidemiology and analytic skills enabled us to evaluate trauma outcomes. We believe that these concerted, wide-ranging efforts undertaken during the last decade have enabled us to improve trauma outcomes at our hospital.

Training fellows and staff with low trauma volumes poses significant challenges. Affordability and patient access are the major reasons for low yearly volumes. AKUH is a private institution where most patients have to pay out-of-pocket for treatment. Consequently, patients are taken either to one of city's three large tertiary care government-run hospitals, where treatment is free, or to other private institutions based on their capacity to pay. Second, most patients are transported by any "scoop-and-run" means (private vehicles, taxi cabs) to the nearest hospital, which may not be the best equipped facility to care for that particular patient. AKUH is also located in a less violent part of the city and hence experiences less trauma in its proximity. Several factors help overcome this challenge. Being better equipped with modern trauma care facilities enables us to care for increasingly complex cases, with high proportions of penetrating and operative trauma. Fellow is on call 5 days a week, ensuring involvement in most cases. Moreover, we have recently increased our focus on trauma academics through regional and international collaborations. All of these factors enable our trainees to have a truly enriching educational experience. Our study has several important limitations. This was a single-institution, retrospective trauma database analysis, from a medical center with less than 100 patients per year and hence may suffer from a potential selection bias and may not be entirely generalizable. Moreover, we were only able to follow up patient outcomes till discharge and hence cannot accurately comment on

long-term outcomes. However, several factors help mitigate these concerns. Our center is located in the multiethnic city of Karachi and is accessed by patients from all socioeconomic backgrounds. In addition, as a large referral center, we often receive and treat some of the sickest patients in the city. These factors make these results relevant to the context of urban trauma care of most LMICs, especially those in South Asia. To overcome the issue with small annual sample size, we used data from over 12 years to evaluate patient outcomes. Another important limitation was posed by more than 10% missing data for some patient variables (hospital transfer, transport, time from injury to presentation and admission to ICU). While we acknowledge this as an area for future improvement, data collection by trained personnel has resulted in near-complete data for most variables of interest. In addition, our analyses identified the same predictors of trauma morbidity and mortality as that found in the literature, rendering our analyses internally valid.

Widespread trauma systems implementation has resulted in dramatic improvements in quality of trauma care in the developed world. Such systems implementation is costly and requires a shift in national health policies, both of which are extremely challenging in the resource limited circumstances of most LMICs. However, indigenous trauma research, like the one presented here, does provide evidence in support of an integrated hospital-based TQI program, tailored according to the available resources. Such measures may well constitute the first step toward improving trauma outcomes in the developing world.

AUTHORSHIP

Z.G.H., S.N.Z., A.H.H., A.M., A.P., and H.Z. contributed in the study concept and design. A.M., F.S., S.N.Z., Z.G.H., A.P., and H.Z. performed the acquisition of data. Z.G.H., S.N.Z., M.K., A.H.H., A.P., A.L., and H.Z. performed the analysis and interpretation of data. Z.G.H., A.H.H., S.N.Z., M.K., A.P., A.L., and H.Z. provided critical revision of the manuscript for important intellectual content. Z.G.H. and S.N.Z. provided statistical analysis. A.H.H. obtained funding.

DISCLOSURE

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EDITORIAL CRITIQUE

Despite major resource limitations in Pakistan, the development and implementation of this multifaceted trauma quality improvement (TQI) program have led to sustainable reductions in morbidity and mortality.

Review of this well-written article does raise several questions. The authors state that prehospital care is limited. While minimal prehospital intervention has merit in specific circumstances, with 40% to 50% of patients arriving 1 hour to 6 hours after injury and 20% presenting more than 6 hours after injury, would outcomes improve if prehospital care improved? Prehospital care seems to be a logical next step.

Study definitions can be troublesome. The authors list "complications" but never provide study definitions. Their complication list is extensive (renal failure, myocardial infarction, coagulopathy, pulmonary embolus, surgical site infection, urinary tract infection, and sepsis), yet the reported overall complication rates are strikingly low when mortality rates are considered. In the pre-TQI years, 13.5% of patients sustained any complication, while 9.6% died during their hospitalization. Did the authors fully analyze 1,227 complete charts for each complication to assess their primary study end point? Inclusion/exclusion criteria may offer another explanation. Were all patients with a trauma activation included or only those admitted?

Data analysis reveals an interesting finding. When comparing the pre-TQI and post-TQI periods, patients after the initiation of TQI programs had greater Glasgow Coma Scale (GCS) scores, Revised Trauma Scores (RTSs), and lower Injury Severity Scores (ISSs) yet more often required operative intervention. These statements seem contradictory, and we must be further assured that outcome improvements were not simply because patients were less severely injured after TQI implementation to truly evaluate the effectiveness of the program.

Perhaps, the most important question raised however is the one we ask ourselves, "If it can be done in Pakistan, what can I do in my own hospital to improve care?" I would like to thank the authors for their inspiring work.

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