

A preliminary analysis of Level IV trauma centers within an organized trauma system

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BACKGROUND:	The effect of Level IV trauma center (TC) accreditation within an existing trauma network remains understudied. This study compared preaccreditation to postaccreditation data from Level IV TCs within a mature trauma system in Pennsylvania to determine whether TC designation affected time to and/or rate of transfer to definitive care. Level IV TCs were hypothesized to have a decreased time to transfer following accreditation and improved mortality.
METHODS:	The Pennsylvania Trauma Systems Foundation collects predesignation and postdesignation data from hospitals pursuing accreditation. Data from Pennsylvania Trauma Systems Foundation between 2012 and 2017 were analyzed. Variables of interest included patient demographics, injury severity, mortality, and incidence of surgical interventions precredentialing to postcredentialing. A multilevel mixed-effects logistic regression model assessed the adjusted impact of Level IV TC accreditation on transfer rate. ArcGIS Desktop was used for geospatial mapping of lives and geographic area covered by the addition of Level IV TCs in Pennsylvania.
RESULTS:	Five hospitals underwent Level IV credentialing from 2012 to 2017, providing data on 5,076 cases (pre, 2,395 [47.2%]; post, 2,681 [52.8%]). No significant difference in age, admission Glasgow Coma Scale score, or shock index was observed preaccreditation to postaccreditation. A difference in transfer rate was observed after credentialing in unadjusted (62.7% vs. 63.3%; $p < 0.014$) and adjusted analyses (adjusted odds ratios, 1.13, $p = 0.389$). There was a trend toward reduced odds of mortality postcredentialing (adjusted odds ratios, 0.59, $p = 0.261$). Major surgical intervention decreased (Pre, 0.42%; Post, 0.04%; $p = 0.004$).
CONCLUSION:	Level IV TC accreditation has beneficial effects on increased transfer rates and may improve mortality. It is important to continue to observe the impact of Level IV TCs on patient outcomes within a mature trauma system. (<i>J Trauma Acute Care Surg.</i> 2019;87:666–671. Copyright © 2019 Wolters Kluwer Health, Inc. All rights reserved.)
LEVEL OF EVIDENCE:	Prognostic and epidemiological, level III.
KEY WORDS:	Level IV trauma center; outcomes; transfer time; nontertiary hospital.

In the United States, trauma is the leading cause of death in the first 44 years of life.¹ In an effort to improve survival among injured patients, the American College Surgeons (ACS) Committee on Trauma released the Optimal Hospital Resources for the Injured Patient in 1976. There are currently five trauma center (TC) levels in the United States that are managed at the state and regional level, and follow the ACS guidelines.²

Legislation in the Commonwealth of Pennsylvania established the Pennsylvania Trauma System Foundation (PTSF) and since 1985 it has served as the designating authority of the State's TCs.^{3–5} Level I and II accredited centers act as definitive care hospitals, accepting transfers from Level III and IV centers and treating the most severely injured patients. Historically, Level I and II TCs have been located in more populated urban areas. In an effort to expand the high quality, specialized care offered at TCs and reduce the disparity of care available in rural areas, PTSF released the accreditation standards for Level III and Level IV centers in 2004 and 2009, respectively.⁶ More recently, to address the national concern of this discrepancy of access to quality care, the ACS has joined forces with various federal agencies to develop a plan for a National Trauma System.²

The effect of Level IV TC accreditation within an existing trauma network remains largely understudied. This study compares time to and frequency of transfer to definitive care among hospitals in Pennsylvania before and after accreditation to test the hypothesis that injured patients would be transferred to higher care sooner, more often and demonstrate improved mortality following accreditation.

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METHODS

Study Design and Population

The Pennsylvania Trauma Outcome Study (PTOS) dataset was queried for trauma admissions from 2012 to 2018. The PTOS is a database that contains statewide trauma registry data for all hospitals accredited by PTSF. It contains detailed information on all trauma patients meeting at least one of the following inclusion criteria: death secondary to trauma, intensive care unit/step-down unit admissions, hospital stay longer than 48 hours or hospital stay between 36 and 48 hours with Injury Severity Score (ISS) of 9 or higher and admitted transfers in and/or out of the hospital.

Since its establishment in 1985 as part of the Emergency Medical Services Act, PTSF has served as the accrediting body for all TCs in the state of Pennsylvania.³ The PTSF is tasked with accrediting adult and pediatric centers alike, in accordance with the American College of Surgeon standards set forth in the Resources for Optimal Care of the Injured Patient, at a minimum.⁷ Between 2012 and 2018, a total of seven Level IV accredited TCs submitted data to this registry, but only five were included in the analysis because the additional TCs had limited data due to their recent accreditation. The PTSF collects both prepursuit and postaccreditation data from hospital undergoing the TC accreditation process. In addition to the postaccreditation data included in PTOS, 2 years of preaccreditation data from PTSF were utilized in this study.

To evaluate the effect of Level IV TC accreditation on patient outcomes, the study population was divided into two groups: preaccreditation and postaccreditation. No changes in the dataset definitions for transfer rates, time to transfer or other variables of interest were noted over the study period.

Inclusion and Exclusion Criteria

All trauma patients with blunt, penetrating and burn mechanism of injury who were admitted to a Level IV TC in Pennsylvania were our population of interest. Patients dead on arrival were excluded from this analysis.

Data Points

Variables of interest include: patient demographics (age, gender); injury classification (injury type, ISS); primary physiological parameters upon admission (heart rate, systolic blood pressure, Glasgow Coma Scale [GCS]); length of stay [LOS] (emergency department [ED LOS], hospital LOS); discharge status (mortality); scene departure time; and, ED admission time.

Outcome Measures

The primary outcome of interest was the transfer rate between sites preaccreditation and postaccreditation. The secondary outcomes of interest were mortality, time to transfer, and LOS preaccreditation and postaccreditation. The PTSF works closely with candidate hospitals pursuing Level IV accreditation. There was a rollout period during which time hospitals were tracking their data and putting forth action plans that gradually impact time to transfer out over time. In Pennsylvania, the PTSF staff is highly involved in educating a hospital from the time it submits a formal letter expressing its desire to pursue accreditation up until the time the hospital is approved for level IV accreditation. An important feature of the education is developing quality improvement processes through data monitoring, including the amount of time required to transfer patients to higher levels of care. An additional requirement for accreditation is the staff of the candidate hospital must be mentored by an established, higher-level TC.

Statistical Analysis

Univariate analysis using Wilcoxon rank-sum and Fisher's exact tests were performed on continuous (age, ISS, GCS, LOS, vent days) and categorical variables (gender, mortality, post-ED destination), respectively, to compare patient demographic and clinical profiles before and after accreditation. A multilevel mixed-effects regression model was fit to determine the effect of accreditation on time to transfer and mortality conditioned on age, gender, ISS, and GCS score. The area under the receiver operating characteristic curve (AUROC) was calculated for the transfer models to determine their discriminant capacity. All data manipulation and statistical analyses were completed with Stata/MP, version 15.0 (Stata Corp, College Station, TX). For the purpose of this study the alpha was set at 5% with a statistical significance of $p < 0.05$.

To generate a map and assess the TC coverage in PA, the Network Analyst extension of ArcGIS 10.5.1 desktop was used to generate 60 minute travel times based upon speed limits, to each TC using a road network layer provided by PA Department of Transportation. US Census Bureau 2016 American Community Survey 5-year census data were used to estimate the population coverage for each TC at the centroid of the census tract.

RESULTS

In PA, the time from initiation of pursuit to the time of accreditation for hospitals in a health system that has a Level I TC was shortest at 2 years. In contrast, critical access hospitals took the longest with one hospital taking 5 years and another hospital 7 years. Hospitals not fitting these categories took on average 3–4 years. Seven PTSF hospitals underwent Level IV credentialing between 2012 and 2018. Of those seven hospitals, only five

had completed more than 12 months of reporting following accreditation. Thus, 5,076 cases from five TCs were included in the study. Following accreditation the Level IV hospitals overall saw an 11.9% increase in the number of patients treated at their facilities from 2395 (preaccreditation) to 2681 (postaccreditation). No significant difference in age, ISS, GCS score, shock index or gender was observed between the preaccreditation and postaccreditation patient population (see Table 1). An increase in transfer rate was observed precredentialing to postcredentialing in unadjusted analysis (62.7% vs. 63.3%; $p = 0.014$) and adjusted analysis (adjusted odds ratios [AOR], 1.125; 95% confidence interval [CI], 0.861–1.469; $p < 0.389$; AUROC, 0.756) (see Table 2). There was also a decline in mortality postcredentialing (AOR, 0.59; 95% CI, 0.234–1.484; $p = 0.261$; AUROC, 0.944) (Table 3). Major surgical intervention decreased substantially (Pre, 10; Post, 1; $p = 0.004$). Interestingly, patients are more likely to present to Level IV TCs in private vehicles vs. Level I–III TCs in the state (32.0% vs. 21.2%; $p < 0.001$).

The total area covered by Pennsylvania Trauma System Foundation's centers within a 60 minute drive time was approximately 26,488 square miles of the state's 45,301 square miles. The Level IV TCs added 4,563 square miles of area covered, which represents approximately 10.1% of the entire state, bringing the total area covered by the existing network to 68.5% (Fig. 1). The Commonwealth's population is 12,783,977 and the Level IV TCs cover an additional 265,225 lives bringing the total to 12,498,200 only an additional 2.1% of the total population.

DISCUSSION

In 1966 the National Academy of Sciences and the National Research Council published "Accidental Death and Disability: the Neglected Disease of Modern Society."⁸ This white paper highlighted trauma as a major health problem and was the impetus of major trauma system development in the United States. As much of the development centered around major academic medical centers in large urban areas, many rural areas were left lacking the advances in trauma care that were realized in the 50 years since the 1966 white paper. This growing disparity in rural versus urban access to trauma care is highlighted by the disproportionate fatality from motor vehicle crashes in rural areas (56.9%) where less than a third of the U.S. population lives.⁹ While the high profile violence in urban areas has received much focus in both the lay and scientific press, there is a quiet carnage occurring in our rural areas.

The difficulties of providing adequate trauma care in a rural setting have been well documented and include: discovery issues, rudimentary prehospital care, long transport times and low volume leading to skill degradation of rural trauma providers.¹⁰ In an effort to address the growing disparity between urban and rural trauma outcomes the American College of Surgeons Committee on Trauma formed the Rural Trauma Subcommittee, consisting of experts in trauma care from across the nation to address the needs of the rural trauma victim. The result was to devise and promulgate standards for rural hospitals to participate in an organized system of trauma care (Level IV TCs). A guiding principle for rural community hospitals is to be able to identify the major trauma victim, stabilize his/her life

TABLE 1. Preaccreditation and Postaccreditation Patient Profile

Variables	PTSF Preaccreditation (n = 2,395)	PTSF Postaccreditation (n = 2,681)	p value
Age in years, mean (SD)	57.7 (27.3)	59.1 (26.5)	0.049
Gender (male), n (%)	1,162 (46.5)	1,337 (53.5)	0.296
ISS, median (IQR)	5 (5)	5 (5)	<0.001
GCS score, median (IQR)	15 (0)	15 (0)	0.123
ICU LOS, days,* median (IQR)	0 (0)	0 (0)	0.985
Hospital LOS, days, median (IQR)	1 (2)	1 (2)	0.734
Mortality, n (%)	54 (2.25)	50 (1.86)	<0.001
Transfer Rate, n (%)	1,501 (62.7)	1,673 (63.3)	0.014

SD, standard deviation; ICU, intensive care unit.

*Patients with ICU LOS > 0 days.

threatening injuries and transfer the patient to a higher level TC for definitive care.

Since 1986, Pennsylvania has maintained an organized voluntary trauma system. PTSF is a private organization, not associated with any governmental agency, in charge of accrediting TCs within the state. At a minimum, it relies on the ACSCOT Resources for Optimal Care of the Injured Patient criteria for its accreditation standards that TCs must comply with. In 2009, the PTSF began its Level IV program to bridge the gap in coverage of large areas of Pennsylvania, especially the rural regions. The results presented herein are a preliminary analysis of the Level IV TCs that have been accredited in the state. We are encouraged by the results that show a significantly increased rate of transfer to a higher level of care. This may reflect the ability of these community hospitals to properly identify the major trauma victim. There was essentially no difference in time to transfer preaccreditation and postaccreditation (invalidating our original hypothesis). This could be accounted for due to two factors. First, the preparation for a community hospital to become a Level IV TC, in many cases, involved several years. The preaccreditation data was collected in the immediate two years prior to accreditation. As such, many of these hospitals were functioning as de facto Level IVs with all of the expedited transfer processes already in place. Second, the exigencies of rural community hospital trauma care are as such that transfer to definitive care is many times hampered by transportation issues. Emergency medical services care in rural communities is a mile wide and an inch deep. That is, almost all communities may have an ambulance, but only one ambulance, and if that ambulance is out on a call or another transfer then that hospital is left without transportation. Aeromedical

transport in rural communities is limited many times by weather or geographic constraints.¹⁰ As such, a decision by the physician to transfer may be made expeditiously, only to have the patient in limbo as they await for transportation to arrive.

Less surgery is being performed at Level IV TCs post-accreditation again speaks to the fact that the hospitals are not holding onto the patients unnecessarily but are getting them out to a higher level of trauma is promising.

More patients arrived at Level IV TCs by private vehicle following accreditation. In Level I to III TCs, there is more frequently the security of advanced prehospital notification, allowing for advanced preparation of the major trauma victim, the level of alert ascertained, and provide a seamless transition from the prehospital setting to the resuscitation bay. In the Level IV TC, more frequently the patient is dropped off at the door by private vehicle. In this situation, the level IV provider must simultaneously triage and mobilize limited resources. This adds to the complexity of rural trauma care.

The addition of Level IV TCs within Pennsylvania resulted in an increase of 10.1% of the state landmass yet only 2.1% of the state population covered within a 60 minute travel time to a TC (Fig. 1). It is disappointing, from a trauma system perspective that Herculean effort is made on the part of many community hospitals to become Level IV TCs, only to cover a small percentage of the population. Conversely, the Level IV TC is an invaluable resource to local communities. It should be noted that as of this writing there are a number of hospitals applying for Level IV accreditation. This would undoubtedly fill in more of the gaps of the underserved population and landmass within the state of Pennsylvania.

TABLE 2. AOR for Transfer Postaccreditation

Transfer		
Variables	AOR (95% CI)	p
Postaccreditation	1.125 (0.857–1.476)	<0.389
Age	0.963 (0.959–0.966)	<0.001
Male sex	1.441 (1.220–1.703)	<0.001
ISS	1.063 (1.045–1.081)	<0.001
GCS score	1.091 (1.051–1.133)	<0.001
Injury year	1.085 (0.979–1.202)	0.118
AUROC, 0.756		

TABLE 3. AOR of Mortality Postaccreditation

Mortality		
Variable	AOR (95% CI)	p
Postaccreditation	0.589 (0.234–1.484)	0.261
Age	1.018 (1.005–1.032)	0.008
Male sex	0.998 (0.544–1.833)	0.996
ISS	1.028 (0.999–1.057)	0.055
GCS score	0.604 (0.567–0.644)	<0.001
Injury year	1.004 (0.718–1.405)	0.980
AUROC, 0.944		

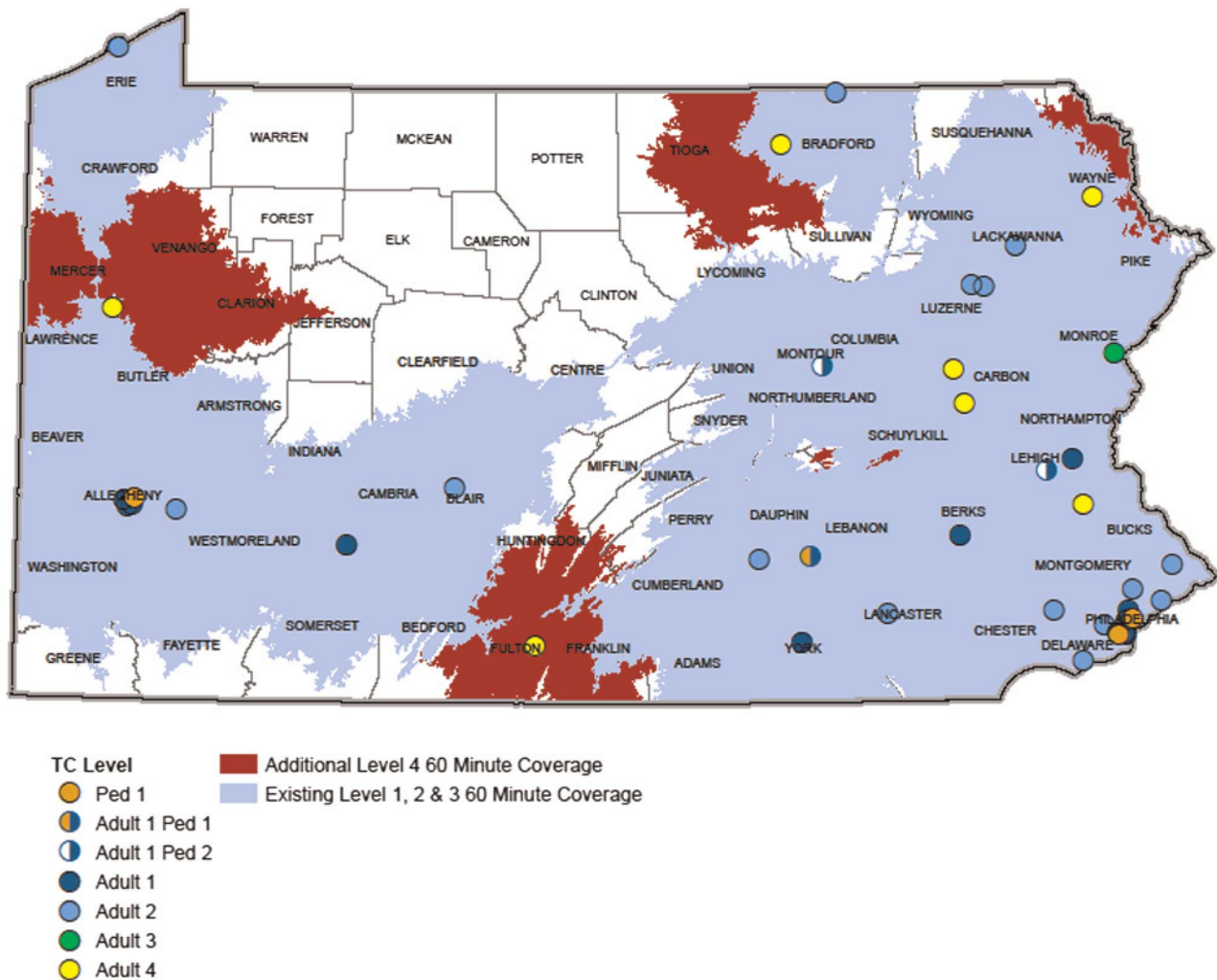


Figure 1. Trauma system coverage including Level IV TCs.

While the ACS does not have accreditation standards for Level V TCs, they can be found in the most isolated areas of the country and are accredited by state or regional designating authorities. These isolated regions are formally recognized by the US Census Bureau as frontier areas. Here there are fewer than seven people per square mile.¹¹ In Montana, they are commonly referred to as “Trauma Receiving Facilities” where an initial evaluation is performed, and both an established transfer protocol and agreement exists with a Level I to III TC to ensure timely care.¹²

The ACS has renewed promotion of a national trauma care system in an effort to translate the lessons learned on the battlefield to civilian care in an effort to address the discrepancy in care received between rural and urban patients.² Urban dwellers have access to a Level I or II TC within 1 hour 95% of the time, while their rural counterpart only do 24% of the time. Further, as Mock et al.¹³ concluded, there are significant differences in mortality between rural and urban residents (ISS, < 8: no significant difference; ISS, 9–24: 10% rural, 3% urban; ISS, ≥ 25: 73% rural, 41% urban). The ACS recognizes these gaps and is seeking to improve care and achieve the goal of zero preventable deaths and disability. It seeks to create a system where there is a system

of accountability, with common standards for both prehospital care and TCs, to limit variability in care received and ultimately patient outcomes in a proactive learning environment supported at a Federal level. Level IV centers will play a major part in realizing this goal. In a single-state trauma system, the additional lives and square miles in a 60 minute drive time to the a TC is apparent (Fig. 1).

This study is not without inherent threats to validity. This study reflects the experience of only five TCs in a well-established state-wide trauma system and thus our inferences may not be widely applicable in other settings. Due to the nature of the database, we were unable to study patient outcome once they were transferred. Additionally, only patients treated at TCs were evaluated; therefore, trauma patients admitted to and managed at nontrauma hospitals were excluded. The preaccreditation data was collected in the immediate 2 years prior to accreditations, as such, many of these hospitals were functioning as de facto Level IV TCs with all the expedited transfer processes already in place. The limited number of deaths both preaccreditation and postaccreditation in this preliminary analysis, 54 and 50, respectively, may have influenced a type II error with regard to mortality as the *p* value is very sensitive to sample size. In our

stateside database, we have no way of tracking what happens to patients once they are transferred from the Level IV facility to a higher level of care. As a result, this study may have underestimated the number of deaths that occurred and the impact of Level IVs on the overall mortality.

The addition of Level IV TCs to a mature trauma system may have a significant impact on the management and care of critically injured patients. The ACS has recognized the vast difference in care available in rural centers, and the addition of Level IV centers to a robust trauma system could be the way of the future. The impact of Level IV TCs appears promising, but additional studies should be conducted to evaluate their influence on patient outcome and how to best utilize this potential resource.

CONCLUSION

Level IV TC accreditation results in increased transfer rates and may improve overall mortality. While a preliminary analysis of Level IV TCs in Pennsylvania, these results suggests a potential benefit, the overall usefulness in terms of percentage of lives covered is small.

AUTHORSHIP

T.M.V. participated in the study design, data analysis, data interpretation, article preparation, editorial oversight. A.D.C. participated in the data interpretation, article preparation. M.A.H. participated in the data interpretation, article preparation. B.W.G. participated in the study design, data analysis. E.H.B. participated in the study design, data interpretation. S.J. participated in the study design, data analysis. J.A. participated in the data interpretation, article preparation. D.B. participated in the data analysis, data interpretation, editorial oversight.

The opinions and views expressed in this article are solely those of the author(s) and do not represent an endorsement by or position of the Pennsylvania Trauma Systems Foundation.

DISCLOSURE

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