Burn Center Referral Practice Evaluation and Treatment Outcomes Comparison Among Verified, Nonverified Burn Centers, and Nonburn Centers: A Statewide Perspective

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The American Burn Association (ABA) has developed comprehensive referral criteria to determine which burn-injured patient should be transferred to burn centers. This was a retrospective analysis of burn injuries using Illinois inpatient and outpatient hospital data from 2010 to 2015. Multivariable logistic and linear regression models were developed to evaluate ABA burn center referral criteria adherence and to compare treatment outcomes among those treated in verified burn center (VB), nonverified burn center (NVB), and other facilities (OF). In this study, 66% of those treated in facilities without specialized burn teams met the ABA referral criteria. Patients who were older than the age of 40 years, lived farther from burn units, and were originally treated in level I trauma center without burn units were less likely to be transferred to burn centers. Those transported and treated in burn centers had overall better treatment outcomes including fewer infection complications (VB vs OF: adjusted odds ratio [aOR]: 0.5, 95% confidence interval [CI]: 0.4–0.6; NVB vs OF: aOR: 0.5, 95% CI: 0.4–0.6), fewer patients requiring additional care in skilled nursing/rehabilitation facilities (VB vs OF: aOR: 0.5, 95% CI: 0.4–0.6; NVB vs OF: aOR: 0.7, 95% CI: 0.6–0.9), shorter length of hospitalization (VB vs OF: β: −0.4, $P < .001$; NVB vs OF: β: −0.8, $P < .001$), and comparable in-hospital mortality (VB vs OF: aOR: 1.3, 95% CI: 0.97–1.7; NVB vs OF: aOR: 1.01, 95% CI: 0.7–1.5). While verified and unverified burn centers demonstrated better treatment outcomes, the data demonstrated a need to understand the barriers of adhering to ABA criteria and an improved regional burn center referral guidelines education.

Based on Centers for Disease Control and Prevention injury statistics in 2017, it was estimated that 399,269 cases received medical treatment due to nonfatal fire and burn-related injuries in the United States, of which 18,959 (4.8%) were admitted as inpatients and 5830 resulted in deaths.[1] Approximately 60% of the hospitalized burn-injured patients were treated in one of the 128 U.S. burn units and 64 of them were American Burn Association (ABA) verified burn centers.[2] Verified burn centers, similar to certified trauma centers, must meet specific criteria to be certified.[3] However, it remains a subject of debate whether patients treated in these burn centers have better outcomes, and whether, in practice, hospital personnel do adhere to ABA burn center referral guidelines for transferring burn patients to specialized burn centers.[4,5]

Studies have demonstrated that level I trauma centers were associated with reduced mortality rates compared to nontrauma centers when evaluating general trauma patients.[6,7] However, the few studies exclusively evaluating burn injuries suggested that patients treated in burn centers were more likely to be discharged home and had fewer medical complications during the course of treatment, but the evidence was inconclusive regarding whether there was a reduction in mortality.[4,8]

The ABA has established burn center referral criteria to help guide medical professionals in the field and in hospitals regarding best practices for field transport and inter-hospital transfers. Similar to general trauma triage criteria, ABA burn center referral criteria consider the patients' age, burn severity/depth/etiology, comorbidities, and concurrent trauma.[9] However, the extent to which ABA referral criteria have been applied by medical professionals in practice is unclear. To date, only a few studies have investigated this question, and they showed that around 48% to 67% of patients suffering burns were treated in nonburn centers despite meeting the ABA criteria for transfer to a verified burn unit.[4,8,10,11] These studies also showed that Medicare and Medicaid patients,[10,11] patients suffering burns involving the hands/wrists and lower extremities,[8] older patients with comorbidities,[8] individuals suffering concomitant nonburn traumatic injuries,[8] and those living far from burn centers[11] were more likely to be treated in facilities without specialized burn care. However, these four studies either did not describe the characteristics of the nonreferrals at all or were based on analyses restricted to narrow geographic regions with only one or two burn centers and small sample sizes.[4,8,10] The current literature continues to lack sufficient information regarding adherence to ABA burn center referral criteria in the United States, and whether these specialized burn units effectively reduce adverse outcomes in burn patients.

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Illinois is a good test state, as it has three verified burn centers, as well as two nonverified burn units. In addition, Illinois has a comprehensive discharge database that captures more than 95% of all inpatient hospitalizations and outpatient emergency department (ED) visits in the state.[12] This study aimed to assess the differences in treatment outcomes among those treated in verified burn centers (VB), nonverified burn centers (NVB), and other facilities (OF) and to evaluate ABA burn center referral adherence, using current statewide inpatient and outpatient data.

METHODS

This is a retrospective analysis of all inpatient and outpatient burn injury cases treated in Illinois hospitals from 2010 to 2015. The databases were derived from billing records and represented a census of inpatient and outpatient cases treated in Illinois hospitals between January 1, 2010 and September 30, 2015. After the third quarter of 2015, all the hospitals converted from ICD-9-CM to the ICD-10-CM coding system. For continuity of coding, data after the third quarter of 2015 were excluded in this analysis. The outpatient database included all patients treated in EDs for less than 24 hours and who were not admitted to the hospital, while the inpatient database included all patients treated for 24 hours or longer in any Illinois hospital. Both datasets included information on patient demographics (age, race, and sex), exposure information, health outcomes (diagnoses, hospital procedures, and discharge status), and economic outcomes (hospital charges and payer source). The University of Illinois at Chicago IRB approved this work (# 2015-0971).

All burn cases treated in an Illinois hospital were included in this analysis. Burn cases were identified using ICD-9 diagnosis codes 940 to 949 across any of the 29 diagnosis code fields. Treating facility codes were used to identify the patients treated in the three hospitals with ABA-verified burn units (VB) or the two hospitals with nonverified burn units (NVB). The remainder of patients were considered to be treated in hospitals without burn units (OF).

The probabilistic matching method was used to identify duplicate entries and cases transferred between hospitals. Duplicate cases were defined as those with exact matches on all the variables, including hospital ID, date of birth, sex, race/ethnicity, patient residential ZIP code, and burn-related diagnosis codes. Of the 103,494 inpatient and outpatient burn injury cases in the dataset, 5720 (5.5%) were identified as duplicates and excluded from the analysis.

Transfers occurred when the same patient was treated in multiple hospitals on sequential dates. The following criteria were used to identify transfer cases: 1) exact matches on gender, date of birth, race/ethnicity, and patient residential zip code, 2) multiple different treatment facilities were involved, 3) the discharge date was equal or one day earlier than the admission date in the second facility, 4) and had the same burn injury ICD-9 diagnosis codes. Only the first transfer was investigated because of the small number of people who appeared to be transferred more than once. For those transferred between a nonburn unit and burn unit, patient data from the burn unit were used. For those transferred between two nonburn units, inpatient data were used for the analysis rather than the data from the outpatient visit. Otherwise, the earliest index record was used in the analysis among matched events.

The ICD-9 codes provide information regarding the body part affected, depth of the burn, that is, superficial (first degree), partial thickness (second degree), and full thickness (third degree), as well as the total body surface area affected (TBSA). The ICD-9-CM TBSA is restricted to 10% intervals (eg, patients with 15% TBSA are coded as 10–20% TBSA). If a patient suffered any full-thickness burn on any body part, or the ICD-9 code showed that the total percent TBSA of full-thickness burn was non-zero, then the patient was concluded suffering a full-thickness burn.

Table 1 presents the coding scheme for ABA burn center referral criteria. Patients who were with primary diagnosis as burn injury and who had medical disorders of diabetes, cardiovascular disease, or respiratory disease were identified as those who met the referral criteria of "Burn injury patients with preexisting medical disorders" (Table 1).[11] In addition, the referral criteria of "Any patient with burns and concomitant trauma" (Table 1) was coded as Any patient who was primary diagnosed as a burn, and had additional traumatic injuries with a cumulative New Injury Severity Score (NISS) score ≥ 4.[13] The ABA referral criterion "burns that involve the face, hands, feet, genitalia, perineum, or major joints" applied to 61% of the burn patients who met referral criteria and had hand burns as the greatest proportion of burn injuries (inpatient: 20% of all cases, outpatient: 35% of all cases). However, many of the hand injuries involved minor burns. Therefore, the ABA burn center referral criteria were modified and cases with only superficial and/or partial-thickness hand burns were defined as not met the referral criteria.

To evaluate the effectiveness of burn units in reducing adverse outcomes, the following outcomes were evaluated: length of hospitalization, infection complications during hospitalization, discharge to a skilled nursing or rehabilitation facility, and in-hospital mortality. Infection complications included *Clostridium difficile*, pseudomembranous colitis, septicemia, any pneumonia, infective myositis, severe sepsis, and post-surgery infection. Patients with a discharge status of "discharge/transferred to skilled nursing facility (SNF)" or "discharge/transfer to rehabilitation facility or hospital unit" were grouped together. Deaths included cases that were identified as expired at the time of discharge and patients discharged to hospice care. To avoid the influence of patients who arrived dead or died after failed resuscitation during the initial treatment, a stratified analysis that only included deaths occurring after the first 24 hours of hospitalization was performed. Those who left against medical advice (0.96%) were excluded from all outcome analyses.

Inpatient and outpatient cases were combined for the evaluation of transport and transfer practices. Distance to the nearest burn unit was determined by the lowest mileage from patients' residence to the five burn centers, which was calculated based on centroids between zip codes. New Injury Severity Score (NISS), a measure of injury severity, and Elixhauser comorbidity score were calculated based on ICD-9 diagnosis codes.[14,15]

As for the comparison of treatment outcomes between those treated in nonburn and burn units, only the inpatient

Table 1. ABA burn center referral criteria and study coding scheme

ABA Referral Criteria*	Study Coding Scheme
Burns that involve the face, hands, feet, genitalia, perineum, or major joints	ICD-9 codes show the burn involves the face, hands, feet, genitals, perineum, and major joints (knee, ankle, waist, elbows, shoulders)
Chemical burns	ICD-9 code = E924.1: Caustic and corrosive substances
Electrical burns, including lightning injury	ICD-9 code = E925: Accident caused by electric current and E907: Lightning
Inhalation injury	ICD-9 code = 506, 947.0, and 947.1: Respiratory conditions due to chemical fumes and vapors; burn of mouth and pharynx; burn of larynx, trachea, and lung
Burn injury patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality.	Primary diagnosis is burn and have preexisting medical disorders: diabetes (250) or respiratory system (460–519) or cardiovascular diseases (414)
Any patient with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses a greater immediate risk, the patient may be initially stabilized in a trauma center before being transferred to a burn unit. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.	Primary diagnosis is burn and have at least one other trauma (ICD-9 800–904) with New Injury Severity Score more than 4.
Burned children in hospitals without qualified personnel or equipment for the care of children.	Primary diagnosis is burn and age 0–10, but excluding those initially treated in children's hospitals (including Children's Memorial Hospital, La Rabida Children's Hospital, and Shriners Hospitals for Children—Chicago)
Burn injury in patients who will require special social, emotional, or rehabilitative intervention.	NA

*If a patient meets any of the above criteria, we said the patient meet the ABA referral criteria.

data were analyzed as most of the outcomes of interest pertain to inpatients. A three-way comparison was performed among inpatients: 1) burn patients hospitalized in VB, 2) patients hospitalized in NVB, and 3) patients hospitalized in OF. Pearson's chi-square tests were used for categorical variables. For continuous variables, analysis of variance was used. If a continuous variable was not normally distributed, Wilcoxon signed-rank test was used. In statistical assessments, a two-tailed *P* value lower than .05 was considered statistically significant.

Multivariable regression models were built to 1) identify factors associated with nonreferral to burn centers among those who met ABA burn center referral criteria; and 2) to compare treatment outcomes among patients treated in VB and NVB to those treated in facilities without burn units (OF, reference group). For the latter analysis, as the length of stay (LOS) had a nonparametric distribution, a median regression model was used to compare differences in median LOS among hospitalized patients. Logistic regression models were used to assess all other binary outcomes.

Statistical evaluation of covariates, as well as prior knowledge, was used to determine the inclusion of covariates in the final models. In the final multivariable models, at a minimum, the following covariates were assessed: patient age, race/ethnicity, male, TBSA greater than 10%, full-thickness burn (binary), NISS ≥16 (serious injury, binary), and the Elixhauser comorbidity score. For the model assessing predictors of nonreferrals, additional variables including payor type, distance to the nearest burn unit, and initial treatment facility (eg, level I trauma centers without burn units) were evaluated. Multi-collinearity among the independent variables was tested using tolerance and evaluating the standard errors. Stratified models restricting to patients meeting ABA burn center referral criteria were performed to better validate the main models.

RESULTS

Where Did Burn Patients Get Treated?

A total of 96,620 unique burn cases were included in the analysis (excluding 1154 transfers that counted twice). Of the 13,323 inpatient cases, 47.8% (6371 of 13,323) were treated in facilities with burn units compared to 7.3% of outpatient cases (6067 of 83,297). Among the inpatient cases, 90.1% of those treated in burn centers (5740 of 6371) met the ABA referral criteria compared to 66.4% of those treated in facilities without burn units (4619 of 6952). Among the outpatient cases, 77.5% (4701 of 6067) of those treated in burn centers met the ABA referral criteria compared to 74.2% (57,312 of 77,230) of those treated in facilities without burn units. Among the 1154 (1.1%) patients transferred between hospitals, most were initially treated in hospitals without burn units and then transferred to burn centers (63%), of which 91% met the ABA referral criteria.

Table 2 presents the characteristics of inpatient burn cases. After excluding patients who only suffered superficial and partial depth burns to the hands (modified ABA referral criteria),

Table 2. Comparison of inpatient burn injury cases by hospital type, Illinois, 2010–2015

Inpatient Characteristics	Ever Verified Burn Units (N = 5188)		Nonverified Burn Units (N = 1183)		Never Burn Units (N = 6952)	
	N	%	N	%	N	%
Age (mean/SD)	30.6	24.9	42.6	23.3	50.9	22.4
Male	3293	63.5	857	72.4	3918	56.4
White non-Hispanic	1677	32.3	994	84.0	4337	62.4
Black or African American	2072	39.9	104	8.8	1305	18.8
Hispanic or Latino	1041	20.1	39	3.3	693	10.0
Insurance						
Ever workers' compensation	72	1.4	43	3.6	99	1.4
Ever Medicaid	2308	44.5	382	32.3	2502	36.0
Ever Medicare	708	13.7	311	26.3	3138	45.1
Primary insurance self-pay	335	6.5	41	3.5	115	1.7
Proportion w/one or more comorbidities	2471	47.6	701	59.3	6168	88.7
Distance to the nearest burn unit						
Mean (miles, SD)	19	79	65	75	39	70
Median (miles, IQR)	7 (3–20)		63 (39–79)		20 (6–57)	
Total percent TBSA						
<10	3284	63.3	622	52.6	813	11.7
10–20	510	9.8	188	15.9	184	2.7
20–29	163	3.1	48	4.1	62	0.9
30–39	66	1.3	22	1.9	34	0.5
40–49	47	0.9	16	1.4	30	0.4
50–59	26	0.5	5	0.4	10	0.1
60–69	15	0.3	5	0.4	11	0.2
70–79	9	0.2	4	0.3	5	0.1
80–89	8	0.2	4	0.3	4	0.1
90+	21	0.4	3	0.3	51	0.7
Missing	1039	20.0	266	22.5	5748	82.7
New Injury Severity Score (NISS)						
Mean (SD)	5.0	5.4	6.7	7.0	2.9	4.6
Median (IQR)	3 (2–6)		5 (3–9)		1 (1–3)	
NISS ≥16 (serious injury)	295	5.7	122	10.3	213	3.1
Length of hospitalization (days)						
Mean (SD)	8.7	14.3	8.7	11.8	7.3	10.4
Median (IQR)	4	2–10	6	3–11	5	3–8
Discharge status						
Skilled nursing facility	198	3.8	96	8.1	1066	15.3
Rehab facility	146	2.8	59	5.0	225	3.2
Home healthcare service	937	18.1	419	35.4	1057	15.2
Routine discharge (to home or self-care)	3518	67.8	517	43.7	3772	54.3
Died	138	2.7	45	3.8	172	2.5
Die within 24 h (LOS = 0 or 1; no DOAs)	37	0.7	7	0.6	27	0.4
Die after 24 h (LOS ≥ 2; no DOAs)	101	2.0	38	3.2	145	2.1
Total hospital charges						
Mean (SD)	$82,146	$240,620	$74,335	$163,207	$45,309	$70,531
Median (IQR)	$28,565 (9610–72,070)		$33,581 (18,051–71,961)		$25,129 (12,911–50,962)	
Any infection complications	287	5.5	104	8.8	871	12.5
Pseudomembranous colitis	14	0.3	3	0.3	13	0.2
Septicemia	53	1.0	13	1.1	80	1.2
Infective myositis					1	0.0
Severe sepsis	123	2.4	47	4.0	475	6.8
All pneumonia	184	3.6	68	5.8	469	6.8
Post-surgery infection	33	0.6	6	0.5	44	0.6

Table 2. Continued

Inpatient Characteristics	Ever Verified Burn Units (N = 5188)		Nonverified Burn Units (N = 1183)		Never Burn Units (N = 6952)	
	N	%	N	%	N	%
Met ABA referral criteria (any of below)*	4660	89.8	1080	91.3	4619	66.4
Partial TBSA greater than 10%†	865	16.7	295	24.9	391	5.6
Third-degree burn‡	1537	29.6	529	44.7	725	10.4
Special body part burn	3458	66.7	841	71.1	3836	55.2
Chemical burn	193	3.7	46	3.9	146	2.1
Electrical burn	124	2.4	25	2.1	56	0.8
Inhalation burn	68	1.3	59	5.0	99	1.4
Have diabetes/CVD/respiratory	1136	21.9	326	27.6	581	8.4
Have another trauma	111	2.1	31	2.6	52	0.8
Criteria children	1651	31.8	128	10.8	129	1.9
Met modified referral criteria§	4420	85.2	1041	88.0	4120	59.3
Modified special body part burn§	2822	54.4	740	62.6	3234	46.5

IQR, interquartile range; *LOS*, length of stay; *ABA*, American Burn Association; *CVD*, cardiovascular disease; *DOA*, death on arrival.
*Coded ABA burn center referral criteria (Table 1).
†About 83% and 21% of inpatient cases were with missing percent TBSA in nonburn centers and burn centers. We assumed percent TBSA greater than 10% if it is missing.
‡About 27% and 4% of inpatient cases were with unspecified burn depth in nonburn centers and burn centers. We assumed the patient did not suffer full-thickness burn if the depth is missing.
§Excluding superficial and partial-thickness hand burn from referral criteria.

85% of inpatient cases treated in burn units met the ABA referral criteria compared to 59%, treated in facilities without burn units. For patients hospitalized in burn units, the median distance from the place of residence to the nearest burn unit was 11 miles (VB: 7 miles, NVB: 63 miles) compared to 20 miles among those never treated in a burn center.

Who Were More Likely Not to be Referred to a Burn Center?

Table 3 displays predictors of nonreferral to a burn unit among patients who met the ABA referral criteria. Among inpatient cases, none of the individual ABA burn center referral criteria was associated with elevated odds of being treated in a facility without burn units. For each 10-mile increase in the distance to the nearest burn unit the odds of being treated in a nonburn unit facility increased. Furthermore, older patients, persons with comorbidities, and those suffering concomitant serious nonburn trauma (NISS ≥16) were more likely to be treated in facilities without burn units. Moreover, patients initially treated in level I trauma centers without specialized burn units were substantially more likely not to be transferred to a burn unit.

Among outpatients, chemical and inhalation burns were related to increased odds of being treated in a facility without specialized burn teams, while most of the other ABA referral criteria, except third-degree burns, were not significantly associated with place of treatment.

Did Patients Treated in Burn Units Recover Better?

Based on the descriptive analysis, the mean length of hospitalization was higher among patients treated in burn centers ($P < .001$; Table 2). The in-hospital mortality rate was similar between patients treated in VB and those treated in OF (2.7% vs 2.5%); however, it was higher in NVB (3.8%, $P = .004$). Patients treated in either type of burn center had a lower percentage with reported infections and were less likely to be discharged to a skilled nursing facility (Table 2).

In the final adjusted median regression models (Table 4), patients treated in facilities with specialized burn teams had shorter median LOS compared to their counterparts treated in nonburn units. While the findings were statistically insignificant in some of the submodels, the direction of the parameter estimates was consistent across all the models (Table 4).

In the main model, the association between in-hospital mortality and treatment facility type was not statistically significant. When restricted to those meeting the ABA burn center referral criteria, admission to a VB was associated with higher in-hospital mortality compared to OF, although inconsistently across the submodels. For example, when excluding death occurred within 24 hours, the mortality was comparable across different facilities. It was worth noting that 23% (83 of 359) of the deaths did not meet ABA referral criteria and 71 of these 83 were treated in facilities without burn units. In other words, by restricting to those meeting ABA referral criteria, a much higher proportion of deaths reported by nonburn units was excluded. Finally, after adjusting for multiple covariates across all the models, patients treated in burn units were approximately 2-fold less likely to suffer infections or require further intensive treatment in an inpatient skilled nursing facility or rehabilitation center.

DISCUSSION

Burn injury remains a significant cause of morbidity and mortality in the United States and frequently requires specialized multidisciplinary care in burn units.[16,17] In the present study,

Table 3. Multivariable logistic regression: predictors of nonreferral to burn centers among patients meeting ABA burn referral criteria, Illinois, 2010–2015*

	Inpatients Meeting ABA Criteria (N = 10,554)					
	Original Referral Criteria (N = 10,359)			Modified Referral Criteria (N = 9581)**		
		95% CI			95% CI	
	OR	Lower	Upper	OR	Lower	Upper
Age 40–60 vs <40‡	2.3	2.0	2.6	2.7	2.4	3.1
Age >60 vs <40‡	2.8	2.4	3.3	3.5	3.0	4.1
Male vs Female	0.8	0.8	0.9	0.8	0.7	0.9
Black vs White	0.5	0.4	0.5	0.5	0.4	0.5
Hispanic vs White	0.6	0.5	0.7	0.7	0.6	0.8
Other races vs White	1.2	0.98	1.4	1.2	0.98	1.5
Ever worker's compensation	1.4	0.95	1.9	1.4	0.98	2.1
Ever Medicaid	1.2	1.07	1.3	1.2	1.04	1.3
Primary self-pay	0.5	0.4	0.6	0.5	0.3	0.6
Partial-thickness TBSA greater than 10%‡	0.5	0.4	0.6	0.5	0.5	0.6
Third-degree burn‡	0.3	0.3	0.4	0.3	0.3	0.4
Special body part burn‡	0.7	0.7	0.8	0.7	0.6	0.8
Chemical burn‡	0.9	0.7	1.1	0.9	0.7	1.2
Electrical burn‡	0.5	0.3	0.7	0.5	0.3	0.7
Inhalation burn‡	0.8	0.5	1.1	0.8	0.6	1.1
Have diabetes/CVD/respiratory‡,§	0.3	0.2	0.3	0.3	0.2	0.3
Have concomitant injury‡,§	1.0	0.7	1.5	1.0	0.7	1.5
NISS >16	1.6	1.3	2.1	1.6	1.3	2.1
Distance to nearest burn unit (per 10 miles)‖	1.02	1.01	1.03	1.02	1.01	1.03
Modified Elixhauser comorbidity index¶	1.8	1.7	1.8	1.7	1.6	1.8
Initially in level I trauma nonburn unit#	4.1	3.5	4.8	4.3	3.6	5.0

ABA, American Burn Association; *CVD*, cardiovascular disease; *OR*, odds ratio; *NISS*, New Injury Severity Score.
*Medicare was collinear with age and was therefore excluded. Both two models are with *C* statistic = 0.85.
†Based on descriptive analysis, the proportion of nonreferrals was changed after age older than 40, so categorical age groups were used.
‡Coded ABA burn center referral criteria (Table 1).
§Primary diagnosis is burn.
‖Adjusted OR scale in 10 miles.
¶Excluded diabetes/CVD/respiratory from Elixhauser score.
#Initially treated in level I trauma but without burn unit.
**Excluding superficial and partial-thickness hand burn from referral criteria.

less than half of the inpatients cases were treated in burn centers, which is consistent with a prior national study using data from 2001 to 2004.[11] Among the inpatient cases treated exclusively in facilities without specialized burn care, 66% met the ABA criteria for referral to a burn center. This is comparable to two prior studies from South Florida (54%; data from 2008) and North Carolina (67%; data from 2000 to 2007).[4,8]

The findings herein confirm that proximity to burn centers as well as the severity of the burn injury remain important drivers for treatment facility selection. Patients originally treated in level I trauma centers without burn units were less likely to be transferred to a burn center. This result has not been presented in other burn triage studies due to the lack of patient transfer information.[8,10,11] Around 5.7% of patients treated in facilities without burn units were with greater than 10% TBSA. The 5.7% of patients tended to have concomitant serious nonburn trauma (NISS ≥16; N = 107, 27.4%) and more than one comorbidities (N = 284, 72.6%), which were consistent with main nonreferral model results. The data analyses in this study demonstrated that patients treated in burn centers consistently showed fewer infection complications, were less likely to require additional care in skilled nursing/rehabilitation facilities, and had comparable in-hospital mortality.

Patient insurance status has been shown to affect transfer decisions.[4,8,11] Among those meeting ABA referral criteria, a larger proportion of patients with Medicare were treated in nonburn centers compared to their burn center counterparts (48% vs 16%), which was consistent with other inpatient studies.[8,11] However, this may be more of a function of disparities in referral of elderly patients in general, than specifically a function of Medicare coverage. When restricted to patients living within 10 miles away from a burn center, the elderly still had a higher odds of nonreferral to a burn unit. Although the crude proportion of Medicaid was comparable between nonreferred patients and patients treated in burn centers (36.0% vs 42.7%), Medicaid patients had increased odds of nonreferral in the final model (adjusted odds ratio:

Table 4. Multivariable regression models comparing treatment outcomes among burn patients treated in burn centers and in hospitals without burn units: length of hospitalization, discharge status, infection complication, and mortality, Illinois, 2010–2015

	Exposure (Reference: Facilities Without Burn Unit)					
	Verified Burn Center			Nonverified Burn Center		
Outcome Variables	***β***	***P***		***β***	***P***	
Length of hospitalization (median regression)*						
All cases	−0.4	<.001		−0.8	<.001	
Restricted to patients meet ABA referral criteria	−0.1	0.6		−0.6	<.001	
	OR	*95% CI*		*OR*	*95% CI*	
		Lower	*Upper*		*Lower*	*Upper*
Mortality						
Model A*						
All cases	1.3	0.97	1.7	1.01	0.7	1.5
Restricted to patients meet ABA referral criteria	1.4	1.003	1.9	1.01	0.7	1.6
Model B*: Restricted to deaths occurring after 24 h						
All cases	1.2	0.9	1.7	1.1	0.7	1.7
Restricted to patients meet ABA referral criteria	1.4	0.93	2.0	1.2	0.7	1.9
Model C†: Exclude covariate: partial TBSA greater than 10% and restricted to deaths occurring after 24 h						
All cases	1.3	0.97	1.8	1.2	0.8	1.9
Restricted to patients meet ABA referral criteria	1.5	1.1	2.2	1.4	0.9	2.2
Infections during hospitalization*						
All cases	0.5	0.4	0.6	0.5	0.4	0.6
Restricted to patients meet ABA referral criteria	0.5	0.4	0.5	0.5	0.4	0.6
Discharge to a nursing or rehabilitation facility*						
All cases	0.5	0.4	0.6	0.7	0.6	0.9
Restricted to patients meet ABA referral criteria	0.5	0.4	0.6	0.6	0.5	0.8

ABA, American Burn Association; *OR*, odds ratio; *CVD*, cardiovascular disease; *NISS*, New Injury Severity Score.
*Control for age (continuous), male, race/ethnicity (white as reference), partial TBSA more than 10% (dichotomous), full-thickness burn (dichotomous), burn to face, hand, feet, genitalia, perineum, or major joints (dichotomous), chemical burn (dichotomous), electrical burn (dichotomous), inhalation burn (dichotomous), have concomitant trauma and primary diagnosis is burn (dichotomous), with diabetes/CVD/respiratory and primary diagnosis is burn (dichotomous) and NISS more than 16 (dichotomous). Elixhauser comorbidity was excluded due to collinearity with age (VIF more than 1.7).
†Because 83% and 21% inpatients were with missing percent TBSA among nonburn centers and burn centers, respectively, we assumed TBSA was lower than 10% when it was missing. Due to the concern of bias caused by this assumption, we also run models without partial TBSA more than 10% (binary).

1.2), and it was consistent with past research.[11] In contrast, patients without insurance coverage (ie, self-pay cases) were more likely to be treated in a burn center.

Studies using the National Inpatient Sample concluded that higher-volume centers (assumed as burn centers) had better outcomes than lower volume centers (assumed to be nonburn centers).[18] Another study showed that despite the burn center treating more severe burn injuries than facilities without burn units, those treated in burn centers had better functional outcomes.[5] When considering modern injury outcomes, mortality alone is no longer sufficient. It can often confound the results, as the trauma centers and burn units receive a disproportionate number of the most severe cases who are dead on arrival or die shortly after arriving. Acute and long-term functioning must be considered as additional outcome measures in order to evaluate quality of care.[19,20] This study showed that patients treated in verified and nonverified burn centers were less likely to have reported infection complications during their hospital stay (primarily a lower proportion of severe sepsis and pneumonia) and were less likely to be discharged to a skilled nursing/rehabilitation facility. The findings on length of hospitalization were inconsistent in the submodels but were significantly lower in the main models after adjusting for important covariates. The longer LOS observed in other studies was likely due to the small sample sizes and using descriptive statistics alone.[4,8]

The in-hospital fatality rate was comparable between burn center and nonburn center patients after excluding patients who were dead on arrival or failed resuscitation cases (<24 hours), but the result was sensitive to the inclusion of percent TBSA in the models (Table 4). The results could also be influenced by differential reporting of burn injuries in hospitals with and without specialized burn units. A large number of deaths that did not meet the ABA referral criteria was observed, of which the vast majority were reported by hospitals without burn units. Coding of burn information has

been shown to be problematic[4,21,22] and it may be worse in facilities without specialized burn teams, especially if deaths occurring early in the intake process were inadequately coded. More studies with higher quality capture of percent TBSA, as reported in the National Burn Repository, are needed.

This study has several limitations. Firstly, regional disparities in access to specialized trauma teams have been reported in the peer-reviewed literature in other U.S. states as well as internationally.[23–25] Generally, rural communities have lower levels of trauma service and are less likely to receive specialized trauma care. This study did show that proximity to burn centers played an important role in level of burn care received in Illinois. Secondly, even though this study was able to identify transfers between facilities, a probabilistic matching strategy was used which included an element of potential error. However, as any two matched patients must meet very strict conditions across numerous matching variables to be determined as transfer cases, the false-positive rate should be rather low. Thirdly, the data in the study only included information from the receiving facilities. The lack of data regarding the transport decisions made in the field and the communication between facilities prior to transfer limited the ability to identify barriers to adhering to ABA referral guidelines.

In this study, the determination of TBSA relied entirely on coded diagnoses abstracted from patient records, and coding of diagnoses between facilities may not be consistent. As an example, 21% of burn inpatients treated in facilities with specialized burn teams lacked sufficient ICD-9 coding details to determine percent TBSA, compared to 83% of nonburn center inpatients, while the body part injured, and depth of burn was well captured by the ICD-9 codes across all facilities. To further complicate matters, TBSA overestimation was a well-established problem. Nonburn physicians have been found to overestimate small burns (TBSA <20%) and underestimate severe burns with percent TBSA more than 20%.[4,21,22] However, in this study, only 191 (1.8%) inpatients were identified as meeting referral criteria solely based on "partial TBSA more than 10%." Thus, the missing percent TBSA should not bias the estimates of nonreferrals. Additionally, 4162 (40.2%) patients exclusively met the referral criterion "burns that involve the face, hands, feet, genitalia, perineum, or major joints." To address this concern, a subanalysis was conducted by excluding superficial and partial hand burns (modified criteria), which reduced the percentage to 32.7%. However, the conclusions did not change regardless of which criterion was used (original or modified) in the nonreferral models (Table 3).

Moreover, the data system did not capture all outpatient visits. It only included patients seeking emergent care in the ED or those with referrals to clinics that required registration in the ED. The "outpatient" ED data in this study will capture all acute treatment cases that passed through an ED but not those treated as "outpatient" in physician offices, private clinics, or urgent care facilities that were not attached to an ED. The system will neither capture follow-up visits to one of these non-ED facilities. However, this analysis was focused on acute care decisions, so the loss of follow-up care cases was not directly pertinent to this analysis. In addition, for many of these follow-up visits, their initial hospital treatments were captured in the analysis. The acute care cases treated outside of the ED setting will almost entirely involve minor initial burn injuries. There was no point to capture all the minor burn cases that had limited to no long-term impacts on individuals. Those initial minor burn injuries would most likely not be recommended to be triaged to a burn unit by the ABA. The focus of this study was on ABA referral criteria adherence in emergent cases and the outcomes that resulted from regional referral practices. The ABA referral criteria are principally designed for the cases analyzed in this study, not for nonemergent follow-up cases.

This study demonstrated a limited ABA referral criteria adherence in Illinois and better functional outcomes among those treated in burn centers. Increased education for first responders and emergency room staff with respect to regional burn center referral guidelines may be helpful in increasing transports and transfers to facilities with specialized burn care teams, but more information is needed on personnel, institutional, and system-wide barriers to adhering to the ABA referral guidelines.

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